The Safety, Operational, and Cost Impacts of Pedestrian Indications at Signalized Intersections

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ABSTRACT

Pedestrian signals have been used in the United States since the 1920s. Although these signals are viewed by many as a safety improvement, studies to date have not entirely sustained this premise. Other studies have centered on improving operational efficiency of pedestrian signals through timing, phasing, and uniformity of displays. In addition to these safety and operational considerations, energy conservation and reduced operation and maintenance revenues are added justification for optimal and judicious use of pedestrian signals. The effects that pedestrian signal indications have on safety, operations, and cost are examined. Information is drawn from the literature and analyses of accidents, delay, and benefits versus cost. The study concludes that there is evidence indicating that pedestrian signals are overused and thus contribute to unnecessary costs and delays and possibly reduced safety. A need exists for the more judicious use of pedestrian indications at signalized intersections.

Approximately 130,000 motor vehicle accidents involving pedestrians occurred in 1981, which resulted in 9,000 pedestrian fatalities and 100,000 injuries. A majority of these accidents (84 percent) occurred in urban areas. Approximately 25 percent of the pedestrians killed or injured (26,700) were crossing or entering intersections (1, pp. 45-47, 55, 61).

The competition for space between pedestrians and vehicles is increasing, particularly in densely populated regions. 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.

Pedestrian signals have been used in the United States since the 1920s. Although they are viewed by many engineers as a safety improvement, studies to date have not entirely sustained this premise. In some instances the correlation between pedestrian signal installations and public pressure is far greater than the correlation between pedestrian signals and accident reduction or improved operations.

In addition to the safety and operational considerations just mentioned, energy conservation and reduced operation and maintenance funds are added justification for optimal and judicious use of pedestrian signals. At this time traffic engineers have insufficient information and data to determine where pedestrian signals are needed most and in what manner they should be operated to best meet all requirements.

The safety, operational, and cost impacts of using pedestrian signal indications at signalized intersections are examined in this paper. Four sources of information are used: existing literature, a pedestrian accident analysis, a delay analysis, and a benefit/cost analysis.

LITERATURE REVIEW

The information that appears to be most useful to pedestrians is a clear indication of when to walk without interference from traffic. In evaluating the effect of pedestrian signals versus no pedestrian signals at intersections, Mortimer (2) found that the pedestrian signal aided pedestrians in estimating the safe crossing time remaining. As a result, a significantly greater number of pedestrians crossed during the WALK interval compared with the green interval of the traffic signal. At the traffic signal without pedestrian indications, the highest pedestrian flow occurred during the amber interval, a potentially hazardous situation.

Forsythe and Berger (3) presented the results of interviews with pedestrians crossing unsafely (without a WALK or a green indication). The overriding factor was clearly time related. A need to hurry or a desire to keep moving was the prime motivation behind disobeying pedestrian (or traffic) signals. The implication for intersection safety appeared to be that, as with vehicles, the pedestrian stream must be kept flowing.

A study by Orne (4) developed some interesting findings. Data were collected on pedestrian violations, pedestrian volume, and vehicle volume at intersections with and without pedestrian signals in two cities. The data analysis showed that pedestrian violations were positively correlated with both pedestrian and vehicle volumes even though a regional difference in pedestrian characteristics was shown to exist between the two cities. The correlation was higher at the intersections with pedestrian signals than at those without.

A particular aspect of the pedestrian signal has been of concern. As Sleight (5, pp. 224-253) noted, the meaning of pedestrian signals is not always clear. In certain installations, WALK means that the pedestrian has exclusive use of the crosswalk and no traffic will interfere; however, in the majority of situations traffic is permitted to turn through a crosswalk during the WALK indication. A pedestrian really has no way of knowing which type of control is in effect at a particular intersection. Obviously the pedestrian who frequents semiexclusive, controlled crosswalks builds a different set of expectancies than the pedestrian who has to watch for turning traffic regardless of signal message.

One way of providing more information is to use a flashing signal. However, a similar problem exists in that the WALK or DONT WALK indication may flash with the intent of conveying two different messages. The flashing WALK is intended to warn pedestrians of turning vehicles. The flashing DONT WALK indicates the clearance interval; that is, the signal is about to change. Again pedestrians build expectancies that may be incorrect for other intersections, or if they face different uses of the flashing signal and cannot build an expectancy, they will tend to ignore that signal.

In a study of pedestrians' understanding of the meaning of signal indications, Robertson (6) found that of 400 pedestrians surveyed in two cities, only 2.5 percent understood the intended meanings of flashing WALK and steady WALK. Less than half of the pedestrians in both cities said that they would expect vehicles to be turning into the crosswalk during the WALK interval even though turning vehicles in both cities made up one-fourth of the total traffic passing through the intersections and all turns were permitted.

Overall the pedestrian signal appears to have limited effectiveness. The major limitation is the uncertainty of information provided. However, it may not be practical to expect all of the desirable information features to be included in every pedestrian signal system. As Welke (7) pointed out, the practical aspects of complicated signal systems (i.e., cost and maintenance) limit their use to heavily traveled intersections. Even if a complete information set cannot be provided in every signal application, considerable gain can result by standardizing the meaning of the information presented. If different amounts of information need to be given at various sites, provisions must be made for the pedestrian to identify or be aware of the difference.

It is apparent from the literature that researchers have some degree of understanding of the needs and expectations of pedestrians crossing at signalized intersections; however, there is much evidence to indicate that these needs and expectations are not being fully accommodated. Low compliance with the signal; lack of understanding of the meaning of pedestrian indications; and inadequate accommodations for special pedestrians, such as the elderly and the handicapped, are examples of needs and expectations not being met.

ACCIDENT DATA ANALYSIS

Accidents and accident rates have traditionally been accepted as the ultimate measures of safety because they represent the ultimate failure of safety provisions. Although numerous from an overall viewpoint, pedestrian accidents are rare events that often occur under various circumstances. It is therefore quite difficult to use pedestrian accident statistics to determine accident causation factors or to ascertain which countermeasures are effective or show a potential benefit. The difficulty could be reduced if there were a way to measure, or express, pedestrian exposure and thus indicate some measure of risk. Because vehicle traffic is somewhat homogeneous, exposure may be calculated in terms of measures such as vehicle miles of travel. Pedestrian traffic is for the most part heterogeneous and meaningful exposure relationships have not yet been fully developed.

Three existing data bases containing more than 5,100 accidents and representing 20 different urban areas were obtained and examined. These included the following:

1. District of Columbia pedestrian intersection accidents from 1971 through 1973 (2,685),
2. Pedestrian intersection accidents from 13 cities collected during the Snyder and Knoblauch (8) study of pedestrian behavior (973), and
3. Pedestrian intersection accidents from 7 cities collected during the Knoblauch (9) study of urban pedestrians (1,443).

For convenience, these data bases will hereafter be referred to as the D.C., PED, and URPED data bases, respectively. The D.C. data base contained only information from police accident reports. The other data bases contained behavioral data from in-depth investigations in addition to police report information.

Table 1 gives the frequency and percentage of pedestrian accidents by type of control for each of the three data bases analyzed. The percentages of control type from the PED and URPED data bases reflect the average for several cities and are in close agreement with one another. The D.C. data base, which represents a single city, has different percentages but shows the same trend between control types as reflected in the average data from 20 cities. Overall, at intersections with pedestrian accident histories, 44 percent of the accidents occurred at signalized intersections.

TABLE 1 Pedestrian Intersection Accidents by Data Base and Type of Control

	Type of Control						
	Signal		None[a]		Stop or Yield		
Data Base	Frequency	Percent	Frequency	Percent	Frequency	Percent	Total
D.C.	1,043	39	1,378	51	264	10	2,685
PED	477	49	359	37	137	14	973
URPED	700	48	506	35	237	17	1,443
Total	2,220	44	2,243	44	638	12	5,101

[a]This category includes accidents that occurred on the major street of a nonsignalized intersection.

An analysis was conducted of 47 intersections (23 with pedestrian signals, 19 with traffic signals only, and 5 with no signals) in Washington, D.C., where pedestrian and vehicle volumes as well as pedestrian accident data were available. Pedestrian accident rates were calculated for each intersection by dividing the number of pedestrian accidents in 3 years during a 10-hr period by a sample of the pedestrian volume during the same 10-hr period. Mean pedestrian accident rates were then calculated for each type of control. Tests of significance (Student's t) revealed that the intersections with vehicular or pedestrian signals or both had a significantly lower accident rate than nonsignalized intersections. There was no significant difference in mean accident rates between intersections with pedestrian signals and intersections with traffic signals only. These results imply that signalized intersections are safer than nonsignalized intersections and that pedestrian signals are no safer than traffic signals alone. Caution should be exercised when these findings are used because the small samples may not be representative.

More substantial evidence may be found in a recent study by Zegeer et al. (10) in which it was concluded that there was no significant difference in pedestrian accidents between signalized intersections with standard timed pedestrian signals and those with no pedestrian signal indications. The study was based on data from 1,100 intersections in 15 U.S. cities, and the analysis controlled for both pedestrian and vehicle volumes as well as one-way and two-way operation. The study did not examine nonsignalized intersections but does offer strong evidence that, in general, pedestrian signal indications are no safer than traffic signals alone.

Approximately one of every five accidents in the data base involved a turning vehicle hitting a pedestrian. Left turns accounted for about 62 percent of the turning accidents [60 percent in the data by Zegeer et al. (10)]. Before these statistics could be used as indicators of a safety problem, however, it was necessary to examine them in light of some measure of exposure. The first step was to determine whether accidents between turning vehicles and pedestrians occurred at a greater rate than the rate of turning vehicles. Sixty-two intersections were sampled from the D.C. accident data base. The only sampling criterion was that pedestrian volumes, vehicle counts by movement, and accident histories be available for each intersection. The pedestrian and vehicle volumes were based on 10-hr counts. The 3-year accident histories ranged from zero to seven accidents per intersection. Of the 62 intersections in the sample, 8 had no signals, 29 had traffic signals only, and 25 had both traffic and pedestrian signals.

This sample data base revealed the following:

1. Of the 202 pedestrian accidents that occurred, 29 percent involved turning vehicles;
2. The average ratio of turning vehicles to total vehicles entering the intersection was 17 percent;
3. Left-turning accidents accounted for 59 percent of the total turning accidents; and
4. Left turns represented 44 percent of the total turns.

On the basis of these data, turning vehicles, and in particular left-turning vehicles, were overrepresented in these pedestrian intersection accidents. This analysis assumed that the vehicle counts were representative of the vehicle volumes over the period in which the accident data were collected.

Some interesting trends were reflected by the pedestrian accident rates in Table 2. Left turns had a higher rate than right turns at signalized intersections. The through-movement rate was higher than the turning-movement rate at nonsignalized intersections but lower at signalized intersections. Overall, left turns were almost three times more hazardous to pedestrians than through movements. This corresponded to research by Habib (11), who found the left-turning maneuver to be about four times as hazardous as the through movement with regard to pedestrian accidents when turning volumes were considered.

TABLE 2 Pedestrian Accident Rates by Type of Control

	Type of Control			
Type of Rate[a,b]	No Signal	Signal Only	Pedestrian Signal	All
Left turn	—[c]	5.99	3.69	4.33
Right turn	2.24	1.85	2.59	2.34
Total turn	1.22	3.78	3.06	3.22
Through	5.95	1.54	1.17	1.51
Total vehicle	5.52	1.95	1.60	1.90
Pedestrian volume	3.16	1.41	0.81	1.10

[a]Accident rates based on vehicles = number of pedestrian accidents divided by total 10-hr vehicle volume times 10,000.
[b]Accident rates based on pedestrians = number of pedestrian accidents divided by total 10-hr pedestrian volume times 1,000.
[c]No left-turn accidents occurred at unsignalized intersections. Left turns made up 45 percent of the total turns.

On the basis of the data reflected in Table 2, signalized intersections had lower pedestrian accident rates than nonsignalized intersections when either vehicle or pedestrian volumes were considered. Standard tests of differences in mean accidents, pedestrian volume, vehicle volume, and number of turns per intersection between each type of control showed no significant difference in mean accidents per intersection and significant differences (0.1 level) in all of the other means. As one might expect, the mean volumes (pedestrians, vehicles, and turns) were higher at the signal-only intersections and highest at the pedestrian signal intersections. Caution should be exercised when interpreting the findings in Table 2, because the sample of 62 intersections from which the data were drawn may not be representative of each of the types of control.

In conclusion there was evidence to support the contention that turning movements, and in particular left-turning movements, present a safety problem for pedestrians crossing at intersections and that it appears that the problem may be more acute at signalized intersections.

In addition, Zegeer et al. (10) concluded that the presence of pedestrian indications may tend to create a false sense of security in that pedestrians may think that they are fully protected and do not need to be cautious. The absence of pedestrian indications makes pedestrians feel that they must rely on their own senses and judgment and thus exercise more caution, particularly with regard to turning vehicles.

Age appears to have a significant effect on pedestrian behavior. The data were analyzed to determine what age groups of pedestrians crossing at intersections were overinvolved or at risk when exposure was taken into account. Age data were available on 2,397 pedestrians in the total data base. Almost 40 percent of the pedestrians involved were under the age of 15.

Risk for each age group was calculated by dividing the percentage of pedestrians involved in accidents by the corresponding percentage of the population. Risk was then plotted by age and is shown in Figure 1. Risk values greater than 1 represented age ranges that were overinvolved in pedestrian intersection accidents given the proportion of those age ranges found in the general population. These data tended to confirm the results of other studies that the young (between 5 and 15 years) and the elderly (more than 64 years) are overrepresented in pedestrian intersection accidents.

The accident factors discussed thus far have all related to the incidence of the accident. In other words these factors related to the occurrence of the accident and to whether that occurrence could be expected given the situation with regard to exposure. The following factors characterized those accidents that occurred (and were reported). The salient factors included pedestrian injury severity, pedestrian actions, driver actions, and blocked vision.

The data on 2,371 pedestrians indicated that injuries occurred most frequently at signalized intersections and least frequently on approaches with stop or yield control. Fatalities were particularly high at signalized intersections when compared with nonsignalized intersections. The number of pedestrians with no injuries was low; that is, 4 percent of those struck were not injured. This indicates that when struck by a vehicle, the pedestrian seldom escapes injury. It is also possible that many no-injury accidents go unreported. Except for the trends already noted, the other injury categories reflected few differences.

With respect to causal factors, inattention was cited for pedestrians over drivers by almost three to one. Blocked vision was also frequently cited as a causal factor by both pedestrians and drivers. The blocking objects were almost identically reported: parked cars, 39 percent; standing traffic, 23 per-

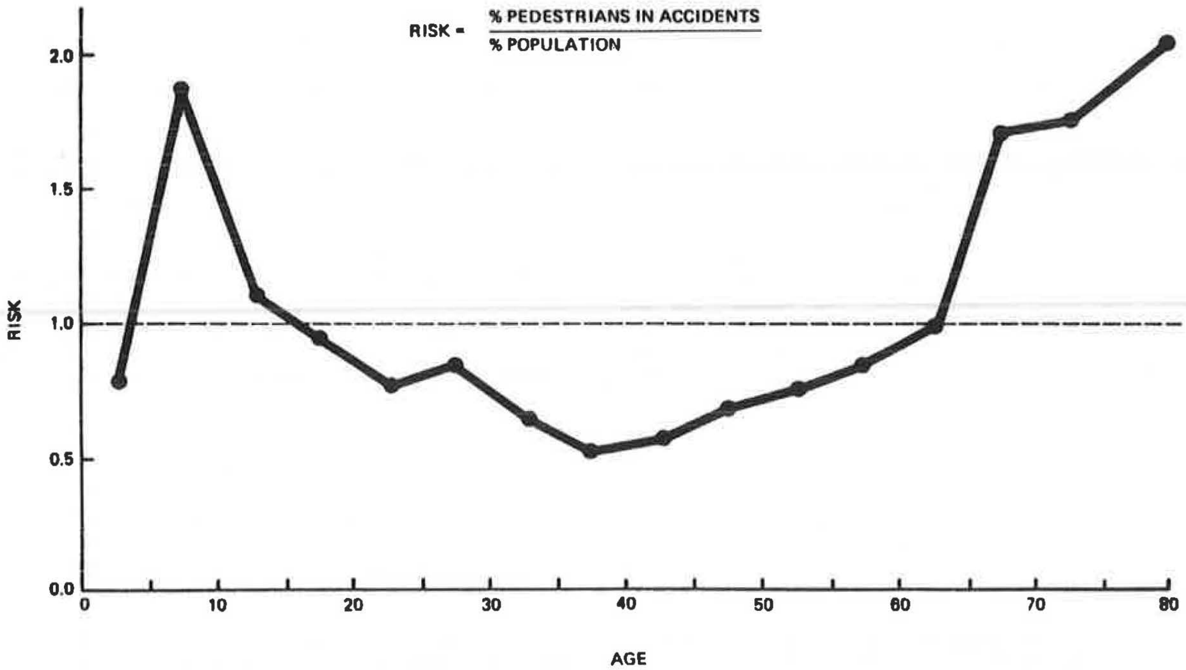

FIGURE 1 Pedestrian intersection accident risk by age based on exposure.

cent; moving traffic, 22 percent; and other, 16 percent.

To drivers, pedestrians appeared suddenly in their path in one-third of the accidents coded. The pedestrians did not recognize the need for evasive action in two-thirds of the accidents coded.

The major violations coded were failure by drivers to yield the right-of-way to pedestrians, crossing against the signal by pedestrians, speeding, and hit and run. The pedestrian was charged in approximately one-half of the accidents, the driver in approximately one-third.

By comparison, the study by Zegeer et al. (10) concluded that approximately one-half of the intersection pedestrian accidents were caused by pedestrians violating the traffic or pedestrian signal or both. In the other half of the pedestrian accidents, the pedestrians were following the instructions of traffic or pedestrian signals, but were struck by motorists who failed to observe or yield to pedestrians in time.

DELAY ANALYSIS

The purpose of the delay analysis was to assess the impact of pedestrians on intersection performance as reflected by vehicle and pedestrian delay. The analysis included signalized intersections with and without pedestrian signals.

Pedestrian delay at signalized intersections has been shown to be a function of signal timing, pedestrian and vehicle volume, and roadway width. It is also a function of one other major factor, which is often overlooked or assumed away. Pedestrian compliance with the signal can have a significant impact on pedestrian delay, particularly at intersections with moderate to low vehicle volumes. Pedestrians who are willing to trust their own judgment of gaps in traffic incur less delay than those who comply with the signal. A number of factors appear to influence a pedestrian's willingness to obey the signal. The strongest motivation for high pedestrian compliance with pedestrian signals is the pedestrian's perceived need for assistance in crossing the street. This motivation is reflected by the relationship between the percentage of violators (those crossing when vehicles have the right-of-way) and vehicle volume, which has been established in several studies and confirmed in this study. As vehicle volume increases, pedestrian violations decrease.

Signal timing was found to influence compliance. When too much green time was given to vehicle traffic with respect to its volume, pedestrian violations increased. Increasing pedestrian clearance time was also accompanied by an increase in pedestrian violations. Other factors such as age, sex, width of street, sight distance, and weather affect compliance in varying degrees. Because of the number of factors that influence pedestrian compliance, there is a large variance from site to site and city to city.

With respect to type of control, an examination of the proportion of the cycle where the pedestrian must wait (assuming he complies) shows that one would anticipate the least pedestrian delay under pedestrian-actuated control and the most delay under fixed-time, exclusive-pedestrian-phase (scramble) control, all else being equal.

Traditionally vehicle delay has often been the controlling factor when trade-offs were made with pedestrian delay and to a large extent safety. This is not unexpected given the magnitude of difference between pedestrian and vehicle volumes.

In general, vehicles are delayed by pedestrians in one of the following ways:

1. Direct conflict with left- and right-turning vehicles when pedestrians are given the right-of-way concurrently with vehicles on the street parallel to the crosswalks,
2. Control of vehicle green time by the minimum walk time requirement,
3. The use of an exclusive pedestrian phase (scramble) or prohibition of turns, or
4. Pedestrian-actuated control at intersections

of high-volume major streets and low-volume minor streets.

In assessing the impact of various pedestrian signal phasing and timing alternatives on vehicle delay, Abrams and Smith (12) dealt exclusively with delay to right-turning vehicles. They assumed that the delay incurred when right-turning vehicles must yield to pedestrians in the crosswalk was the only significant delay to vehicles beyond that normally introduced by the signal. They found that street width (length of crosswalk) had a significant effect on right-turn delay. With crosswalks less than 60 ft (18.3 m) long, right-turning vehicles had to wait until pedestrians crossing from both curbs had cleared the street. With longer crosswalks, one or more vehicles could turn right between the time that the near-side curb pedestrians had cleared and the time that the far-side curb pedestrians reached the lane into which the vehicles were turning.

Pedestrian-induced left-turn delay is generally less severe than right-turn delay. This is primarily because heavy left-turn movements are usually accommodated by a separate left-turn phase during which pedestrians are not permitted to enter the crosswalk where conflicts may occur. When left turns are permitted without a separate left-turn phase, the turning vehicles must first yield to opposing through traffic before they turn. This usually gives pedestrians an opportunity to clear the crosswalk before the left-turning vehicle reaches it. As indicated in the accident analysis portion of this paper, the conflict between left turn and the pedestrian is one of the most hazardous. A left-turning driver who is seeking a gap in opposing traffic may be sufficiently distracted not to see the pedestrian in the crosswalk through which he is turning.

During the early 1950s the exclusive pedestrian phase, or scramble, was introduced in several U.S. cities. It met with mixed success. Installed as a safety measure (pedestrians and vehicles were separated from conflict), it was found to significantly increase both pedestrian and vehicle delay (13). The application of scramble is somewhat limited today. It is found in some of the larger cities in downtown sections and has also enjoyed a wider application at intersections where safety is paramount, such as at school crossings.

BENEFIT/COST ANALYSIS

Pedestrian indications could conceivably benefit users in two ways: reduced delay and improved safety. As discussed previously, delay to pedestrians and vehicles at signalized intersections is primarily a function of signal timing and, to a lesser extent, compliance with the signal indications. Signal timing is a function of vehicle and pedestrian demand (usually expressed in terms of volumes). Vehicular signals are generally timed to accommodate vehicles and pedestrians regardless of whether pedestrian indications are present. Therefore, pedestrian indications have no significant effect on that portion of delay that is affected by signal timing.

The remaining question is whether pedestrian indications have an impact on pedestrian compliance. The evidence is somewhat mixed on this issue. Some studies have reported increases in compliance after pedestrian indications were installed, whereas others have found no change. Even where increases in compliance have occurred, the overall noncompliance rate has remained relatively high except at intersections with high vehicular volumes.

From another point of view, the delay to motorists caused by pedestrians who do not comply with the signal is generally offset by the reduction in pedestrian delay resulting from the noncompliance. Thus the conclusion is that, in general, pedestrian indications do not significantly affect either pedestrian or vehicle delay.

With respect to safety, data from a sample of 47 intersections in this study revealed no significant difference in mean pedestrian accident rates between signalized intersections with and without pedestrian indications. More conclusively, the study by Zegeer et al. (10) found concurrently timed pedestrian signals to have no significant effect on pedestrian accident distributions or frequencies for a sample of more than 1,100 locations representing these two groups. This finding was also true for the five largest cities in the sample, both individually and collectively.

On the basis of this evidence, one could conclude that pedestrian signal indications, as predominantly applied (i.e., concurrent timing), offer no safety benefit over that provided by vehicular signals alone. However, it is clear from the literature that safety did improve at some locations. The safety benefit then had to be a function of proper application. In other words, the pedestrian indications had to meet specific pedestrian needs that could not be met by the vehicular signals alone. For example, the indications may serve to reduce the hazards posed by poor sight distance; to clarify confusing traffic signal phasing; or to aid young, old, and handicapped pedestrians.

The following analysis included the costs to equip and operate pedestrian indications at a typical four-leg intersection with crosswalks on all approaches. It was assumed that traffic signals were in place and that the existing fixed-time controller would accommodate the operation of the pedestrian indications. A signal life of 10 years and a discount rate of 8 percent were assumed; signal equipment costs were based on prices in various sources (14;15, p. 6). The annual costs, expressed in 1981 dollars, are summarized in Table 3. The most expensive (incandescent) and least expensive (fiber optics) signal types were chosen to establish the cost ranges shown. Power consumption was the largest single item and represented between 30 and 68 percent of the total annual cost.

TABLE 3 Annualized Cost of Pedestrian Indications (Incandescent and Fiber Optics)

	Annual Cost ($1981)	
Item	Per Signal[a]	Per Intersection[b]
Equipment cost ($225-353)	33.53- 52.61	268.24-420.88
Power consumption[c] (based on $0.06/kW · hr)	70.96- 23.65	567.65-189.22
Installation (1 hr at $20/hr)	2.98	23.84
Maintenance per signal per year (includes parts and labor)	16.88- 29.81	135.08-238.45
Total	124.35-109.05	994.81-872.39

[a]Assume 10-year signal life with a discount rate of 8 percent.
[b]Includes eight signals.
[c]Watts per signal x 24 hr x 365 x $0.05.

The total annual cost of pedestrian indications was not easily compared with the total annual costs of the intersection traffic signals because of the wide variance in different types of controllers and signal equipment. A comparison was made, however, between the power consumption costs of traffic signals versus pedestrian indications. The power consumed by the controller was not included. It was assumed that the same typical four-leg intersection had two 3-section, 12-in. traffic signals on each approach for a total of 24 signal heads rated at 150 W per head. It must be remembered that only eight heads are lit at any given time. The annual power consumption for each head (at $0.06/kW•hr) would cost $78.84 and for the intersection $630.72. If incandescent pedestrian indications were used in conjunction with the traffic signals, they would consume 47 percent of the power needed to operate this intersection. Fiber-optic indications would consume 23 percent of the total power to operate the intersection.

With the methodology suggested by AASHTO (16, pp. 11-34 and 63-65), the estimated benefits and costs were compared for alternative improvements at a typical signalized intersection. Two cases were examined. Case 1 was the installation of pedestrian signal indications, and case 2 was the removal of the pedestrian indications. The criterion for economic feasibility was that the equivalent uniform annual benefits exceed the equivalent uniform annual costs.

For case 1 it was assumed that the pedestrian indications were being installed to meet specific pedestrian needs; thus the benefit was in terms of the prevention of pedestrian accidents. For this hypothetical example it was assumed that the pedestrian indications would prevent an average of one pedestrian accident every 2 years (or 0.5 accident per year). The cost of a pedestrian accident was calculated by multiplying the proportions of fatalities and injuries by the representative costs for fatal and injury accidents (16), respectively, and summing the products. Performing this calculation resulted in a cost of $22,953 per pedestrian accident (in 1981 dollars). The annual benefit (cost savings) of installing pedestrian indications was found by multiplying the number of accidents prevented annually (0.5) by the cost per accident ($22,953). Thus, the equivalent uniform annual benefit for case 1 was $11,477.

The equivalent uniform annual costs to purchase, install, operate, and maintain incandescent pedestrian signals at the intersection were taken from Table 3 and amounted to $995. The equivalent uniform annual benefits exceeded the equivalent uniform annual costs by $10,482, which indicated that the installation of pedestrian indications at this intersection was economically desirable.

In case 2 the alternative improvement was the removal of pedestrian indications at a signalized intersection where there were no specific pedestrian needs being met beyond those provided by the vehicular signal. Based on the findings of both this and the study by Zegeer et al. (10), there would be no difference in safety with or without the pedestrian indications; therefore, the equivalent uniform annual benefit was zero. The equivalent uniform annual costs were the same as those in case 1 ($995), but because the pedestrian indications had been removed, these costs were in reality negative costs or savings. Therefore the costs actually represented an economic benefit of $995 [0 - (-$995)], thus indicating that the removal of pedestrian indications was economically desirable.

These hypothetical examples demonstrate that both the installation and the removal of pedestrian indications may be economically feasible if they are installed where they are needed and removed from where they are not needed.

CONCLUSIONS

There is no doubt that pedestrian intersection accidents pose a safety problem. In 1981 alone, 26,700 pedestrians were killed or injured at intersections (1). Evidence indicates that traffic signals offer an improvement to pedestrian safety. Pedestrian indications, when properly applied to meet specific pedestrian needs, are thought to provide an additional safety improvement. The magnitude or extent of that added improvement has not been established. In short, pedestrian indications appear to contribute to the reduction of accidents or accident potential at some intersections, have little or no effect at others, and even increase accidents at still others. There is clearly a need to determine the conditions under which the safety afforded by pedestrian indications is realized, or in other words, when pedestrian indications are effective in enhancing safety.

The presence of pedestrian signal indications does not appear to significantly affect the performance of the intersection as measured by pedestrian and vehicle delay. The operation of those indications in conjunction with the vehicular signals (in terms of phasing and timing), however, has a profound effect on delay. When traffic signals are employed, care must be taken to ensure that they are properly timed.

Until recent years, the cost of providing and operating traffic and pedestrian signals has not been a major problem to most jurisdictions. During the 1950s, 1960s, and early 1970s, intersection signalization experienced tremendous growth. In the absence of more definitive information and armed with generally worded warrants and guidelines in the Manual on Uniform Traffic Control Devices (MUTCD), many jurisdictions undertook use of pedestrian indications. For example, Los Angeles had pedestrian indications at 89 percent of its signalized intersections in 1974.

Since 1974 the economic situation has changed significantly. Inflation has reduced buying power and in turn the ability of government budgets to sustain the growth of signal control. Operating budgets have, in effect, been reduced by the rising cost of energy. The luxury of signal control that does not produce a reasonable and necessary benefit can no longer be afforded. As the analysis demonstrated, the cost of pedestrian signals is substantial.

With no relief to the economic and energy problems in sight, ways must be found to reduce costs. Pedestrian indications offer a cost-reduction target; therefore, it is critical that the conditions for the effective use of these indications be determined so that the safety benefits afforded by these devices will not be lost in an arbitrary move to cut costs.

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Evaluation of Innovative Pedestrian Signalization Alternatives

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ABSTRACT

The purpose of this study was to develop and evaluate innovative pedestrian sign and signal alternatives, particularly those that indicate the clearance interval (in place of the flashing DONT WALK message) and those that warn pedestrians of possible turning vehicles (instead of the flashing WALK message). A total of 41 alternatives were developed, and the 8 judged most promising were evaluated at several sites within 5 U.S. cities. The alternatives were evaluated using before-and-after studies of pedestrian violations and various types of pedestrian-vehicle conflicts. Based on the results of the Z-test analyses of observations at the study sites, several alternatives were recommended for inclusion in the Manual on Uniform Traffic Control Devices for application at intersections with pedestrian safety problems. These included the WALK WITH CARE signal indication, a sign for motorists stating YIELD TO PEDESTRIANS WHEN TURNING (regulatory sign), a pedestrian warning sign stating PEDESTRIANS WATCH FOR TURNING VEHICLES, and a pedestrian signal explanation sign (word and symbolic). A three-section pedestrian signal using DONT START to indicate the clearance interval was recommended for additional testing, but little or no benefit was found for the use of the steady DONT WALK indication for the clearance interval or the flashing WALK indication (to warn pedestrians of turning vehicles).

One of the major pedestrian safety problems in the United States today is the ineffectiveness and confusion associated with pedestrian signal indications. Pedestrians in many cities often do not comply with pedestrian signal indications because of a lack of understanding or respect for the devices. In fact, violations of the DONT WALK message have been found to be higher than 50 percent in many cities (1).

There could be several reasons for the lack of effectiveness of pedestrian signal indications in commanding respect, improving compliance, or reducing pedestrian accidents. This study addressed the misunderstanding and confusion on the part of pedestrians regarding the meaning of the steady or flashing DONT WALK indication and the steady and flashing WALK indication.

A steady, illuminated DONT WALK message means that a pedestrian shall not enter the intersection