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Pedestrian Reaction to Crossing Signal Delay

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Pedestrians with experience at a certain intersection learn the length of signal cycle, the phase change pattern of the signal, and the order in which traffic flow is released. These pedestrians have a higher chance of noncompliance with traffic signals. Most of the noncomplying pedestrians save a small amount of time, less than 18 seconds, by crossing the road shortly before the onset of the WALK signal indication. The study agrees with other studies done in the past that pedestrians ignore the traffic signals. They do so in order to reduce their own time delays.

by Deogratias Eustace

One of the elements requiring the attention of traffic engineers and planners is the pedestrian. Pedestrian signal delay is usually modeled by assuming that pedestrians arrive at the signal randomly throughout the cycle and proceed only when a WALK signal is given to provide the right of way. There are times when some pedestrians ignore the indicated pedestrian signal to minimize their delay (Virkler, 1998).

Considerable research has been done on pedestrian behavior in urban streets in the past and more in recent years. Most of these research efforts have been centered on the needs of young school children, and recently much interest has been directed on elderly pedestrians. Also a good amount of research has been conducted concerning pedestrian traffic, mostly in central business district (CBD) areas of large cities where there is a considerable mix of young, middle-aged and elderly pedestrians. However, little has been documented on a special category of pedestrians—college students—who routinely cross some very busy streets adjacent to their college campuses. There is an interest in getting information on this specific group of pedestrians, because this normally involves a collection of young people of almost equal age, who most likely walk in small groups and in a hurry. This age group may be in the forefront of signal violation, since they may be rushing in the morning to meet their class schedules.

The general pedestrians (noncollege students) may have different values of time and thus possible different rates of signal violation in order to reduce their own delay. Furthermore, unlike the general pedestrians in the city center, students are likely to be much more familiar with the crosswalk and its signal timings, which may increase their noncompliance behaviors.

This paper focuses on the compliance of a special group of pedestrians (college students) with traffic signals, their reaction to the delay caused by these signals, and how

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much time is saved by those who do not comply. In other words, is there enough time saved to make them risk crossing a roadway illegally? With increasing parking problems in most cities, the issue of pedestrian planning and safety has become of paramount importance. Due to this problem, a driver may be forced to park his/her car several blocks away from the intended final destination. The person may pass through several crosswalks in this process. So a pedestrian is not necessarily a person who starts and ends their journey on foot. It is obvious that all of us, in one way or another, have been pedestrians at some time.

Pedestrian Traffic Signals

Pedestrian Signal Indications and Their Meaning

According to the *Manual on Uniform Traffic Control Devices* (MUTCD; Federal Highway Administration, 1988), the following are pedestrian signal indications and their meaning:

- Steady DON'T WALK (SDW) indication—means that a pedestrian shall not enter the roadway in the direction of the indication.
- Flashing DON'T WALK (FDW) indication—means that a pedestrian shall not start to cross the roadway in the direction of the indication, but that any pedestrian who has partly completed his/her crossing during the WALK indication can proceed to a sidewalk, or to a safety island.
- WALK indication—means that a pedestrian facing the signal indication may proceed across the roadway in the direction of the indication. The WALK indication means that *there may or may not be a possible conflict of pedestrians with turning vehicles.*

Operation of a Pedestrian Signal

There are two types of pedestrian signal controls that are in use in the United States, namely, the pretimed pedestrian signals and the pedestrian actuated signals. The pretimed pedestrian signals are normally designed to work together with the vehicle signals, whereby both will continue to cycle regardless of whether there are pedestrians on the crosswalk or vehicles in the intersection. In the case of the pedestrian actuated signal type, the vehicle signals are pretimed and keep on changing according to the cycle, while the pedestrian signal remains on the SDW phase until a pedestrian comes and presses a button to actuate the signal. However, the pedestrian WALK signal phase does not come immediately after the button is pressed, it depends on which vehicle lane has the right-of-way. So the waiting time is variable in this case. The pretimed pedestrian signals are the only ones analyzed in this study.

Literature Review on Pedestrian Compliance to Traffic Signals

The logic behind the pedestrian signals is that all pedestrians who arrive during the pedestrian clearance (FDW) and pedestrian red (SDW) signals will wait until the beginning of the next pedestrian green (WALK) signal and then immediately enter the crosswalk (FHWA, 1988). However, this is not always the case. Unlike motorists, who expect to be stopped by the police if seen violating the signals, pedestrian compliance with traffic signals is rarely enforced unless there is an accident. This may be one of the reasons why some pedestrians violate the traffic signals in order to reduce their delay.

The degree to which a traffic control device is properly applied is usually demonstrated by how well it is observed. Smith (1978) cites the pedestrian signals as an example of those traffic control devices which are not properly observed. He further notes that, although these signals are intended to provide helpful information to the pedestrian, they are virtually ignored in many locations.

Smith studied the pedestrian compliance with the flashing DON'T WALK interval at intersections in Washington, D.C., Phoenix, Arizona, and Buffalo, New York. He suggests that the longer the flashing DON'T WALK interval, the greater the possibility of increased noncomplying pedestrians. He concludes that pedestrians generally comply with the clearance interval up to a certain interval length (specifically, an interval timed close to minimum clearance) and that longer clearance times encourage noncompliance.

The reason for the significant decrease in compliance for clearance intervals longer than the minimum appears to be that most pedestrians are not fooled into thinking that they have less time to cross the street before vehicles in the cross street are released. Pedestrians who regularly use the same crosswalk know quite accurately how much time they will require to safely complete their crossing. Consequently, if they know that there is a long clearance interval, they will not hesitate to begin their crossing during that interval.

Pedestrians' action of disregarding the traffic signal may be partly due to the great attention which engineers give to motorists. Signals are designed and programmed to reduce vehicular delay and this is the major criterion for evaluating the level of service of a signalized intersection (Smith, 1978). For pedestrians, engineers consider safety only when installing the signals. The aim is to increase the safety of crossing pedestrians, not to decrease their delay. Bruce (1965) says "... in urban and central business district (CBD) locations, the pedestrian presents an element of sharp conflict with vehicular traffic, resulting in high accident and traffic delay." Pignataro (1973) also says, "... pedestrian movements and characteristics must be studied for the purpose of providing a design that minimizes pedestrian—vehicle conflict, *increases pedestrian safety, and minimizes vehicle delay.*" Thus one can see that many engineers do not consider pedestrian delay. That is why pedestrians are ready to risk their lives and cross the street illegally. Delay may be a more important consideration to a pedestrian than safety issues. Pedestrian delay must be considered in the evaluation of the level of service of the traffic control device serving pedestrians.

Seneviratne and Frase (1987), when investigating issues related to planning for pedestrians needs in the CBD, found that the primary objective of pedestrians is movement between points by the shortest path (minimum delay) and that protection from weather, congestion free sidewalks, and safety are only secondary concerns.

Hulbert (1982), citing a 1976 study by Robertson carried out in seven U.S. cities, found that pedestrian compliance varies widely: only 42% complied in Buffalo, New York, whereas in Tempe, Arizona, compliance was 84%. So, many factors may affect pedestrian noncompliance with signals.

Virkler (1998), who collected data in the CBD area of Brisbane, Australia, concludes that a significant number of pedestrians had small delay savings, averaging 7.9 seconds by entering the crosswalk before the WALK indication is on.

Zegeer and Deen (1973) say that research indicates that about two out of every three pedestrians killed in traffic accidents violated a traffic law or committed an unsafe act. In their pedestrian accidents study in Kentucky, Zegeer and Deen found that most pedestrian fatalities were the fault of the pedestrian (69%).

Field Study Procedure and Experimental Design

Subjects and Their Tasks

Subjects in this study were the crossing pedestrians at the crosswalk under study.

The subjects were not aware that they were being monitored, and were expected to cross the roadway in their usual manner. Therefore, there was no direct communication between the investigators and the subjects.

Conditions for the Study

The study was performed during good, dry weather conditions. It was decided that those days when the weather was poor (not conducive for walking) should not be included. Bad weather may have an influence on the subjects and hence they might not behave at the crosswalk as they normally do. The study was conducted during morning rush hours (peak hours), i.e., between 8-9:00 A.M., and during lunch time, i.e., between 12 and 1:00 P.M. in the month of November.[1] Surveys were conducted during weekdays only, and data were collected for two consecutive weeks.

Site Locations

The study was conducted in Manhattan, Kansas, which is the location of Kansas State University (KSU). Crosswalks at busy signalized intersections adjacent to KSU were selected for this study. The following intersections were included:

- Anderson Avenue/Manhattan Avenue intersection
- Anderson Avenue/17th Street intersection

Both intersections are pretimed, signalized intersections and serve a good number of student pedestrians who cross the roadway to/from their nearby residences. The Anderson Avenue/Manhattan Avenue intersection crosswalk serves a good number of pedestrians during the afternoon lunch hour. A business district near the intersection provides a number of activities, which attract pedestrian traffic like bookshops, fast-food restaurants, etc.

Phase Timings

The traffic signal phase durations at the two intersections are shown in Table 1 below. There is a gap of two and four seconds between the end of the FDW phase indication and the start of the opposing vehicular GREEN phase indication at Anderson Avenue/17th Street and Anderson Avenue/ Manhattan Avenue intersections, respectively.

Figures 1 and 2 show phase durations for pedestrian and opposing vehicular signals for both study sites.

Measurements

Two types of measurements were conducted in this study: (1) the pedestrian counts for all crossing pedestrians, (2) the pedestrian delay (for complying pedestrian traffic) and time saved (for noncomplying pedestrian traffic). The pedestrian count was carried out by the tallying method while the time delay/ saved was measured by use of a stopwatch.

The pedestrian traffic counts were recorded separately, according to the following three categories:

- the number of pedestrians who entered the crosswalk during the WALK signal indication.
- the number of pedestrians who entered the crosswalk during the clearance interval (flashing, DON'T WALK indication).
- the number of pedestrians who entered the crosswalk during the solid DON'T WALK indication.

The time delayed/time saved was recorded as follows:

- time saved—the number of seconds left in the clearance interval for the pedestrian who entered the crosswalk during the FDW interval plus the SDW phase interval. Also the number of seconds left before the next WALK interval for the

Table 1: Traffic Signal Phase Durations

Intersection	Pedestrian signal duration (sec)			Vehicular signal duration (sec)			Cycle length	No. of Phases
	WALK	FDW	SDW	GREEN	YELLOW	RED		
Anderson/17th St.	10	10	58	35	4	39	78	2
Anderson/Manhattan	8	12	56	20	4	52	76	3

Figure 1: Traffic Signal Partitions at Anderson Avenue/17th Street Intersection

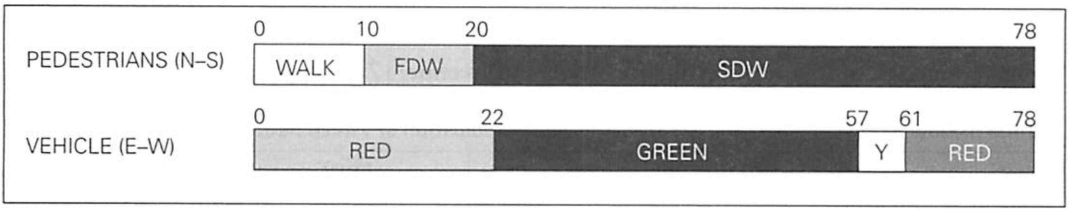
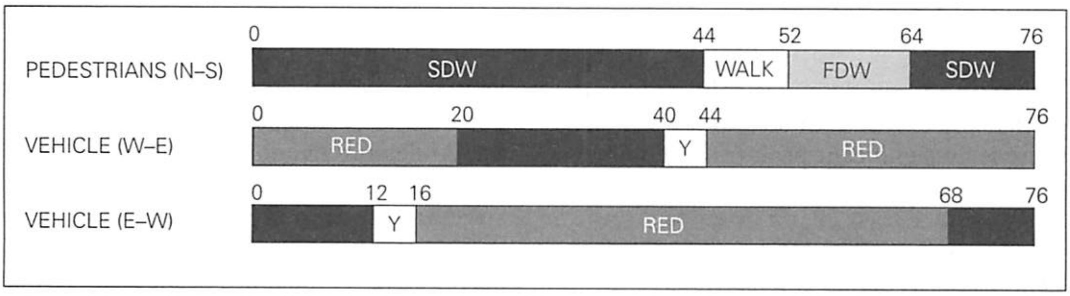


Figure 2: Traffic Signal Partitions at Anderson Avenue/Manhattan Avenue Intersection



pedestrian who proceeded and crossed during the SDW interval.

- time delay—the number of seconds taken for a pedestrian who arrived either during the FDW or SDW intervals and the next WALK interval (time waited).

Results

Results of Pedestrian Traffic Count (Signal Observance)

Table 2 and Table 3 show the signal compliance results of pedestrian traffic counts and the percentage of pedestrians that crossed the road during the three signal indication categories.

Table 2: Signal Compliance Results for Anderson Avenue/Manhattan Avenue Intersection Crosswalk

Time of Day		Signal Indication at Which Pedestrian Crossed		
		WALK	FDW	SDW
Afternoon	Number	396	67	100
	Percentage (%)	70.3	11.9	17.8
Morning	Number	142	21	38
	Percentage (%)	70.6	10.4	18.9

Table 3: Signal Compliance Results for Anderson Avenue/17th Street Intersection Crosswalk

Time of Day		Signal Indication at Which Pedestrian Crossed		
		WALK	FDW	SDW
Morning	Number	150	90	534
	Percentage (%)	19.4	11.6	69

No afternoon data was collected for the Anderson Avenue/17th Street intersection as there is no significant peak traffic volume in the afternoon at this crosswalk.

Time Saved and Time Delayed for Pedestrians at Signal Intersections

Results of measured time delay for pedestrians at signal intersections and time saved for pedestrians who ignore the signals are summarized in Tables 4-7 below.

Discussion of Results

Pedestrian Compliance With Traffic Signals

The pedestrian compliance with traffic signals summarized in Tables 2 and 3 shows quite different behaviors among pedestrians crossing at the two crosswalks. The data for Anderson Avenue/Manhattan Avenue crosswalk show that about 70% of the pedestrians observed the traffic signals while only about 20% observed the signals at the Anderson Avenue/17th Street crosswalk. Figures 3 and 4 show clearly the differences of pedestrian compliance to traffic signals at the Anderson Avenue/Manhattan Avenue intersection and Anderson Avenue/17th Street intersection. The figure of one intersection seems as if it is a laterally inverted mirror image of the other, i.e., it seems as one figure was rotated 180 degrees with the point at FDW being the pivot in order to obtain the other figure.

Pedestrian Delay and Time Saving Strategies

It is assumed that 30 seconds is an acceptable level of mean pedestrian delay and 60 seconds is the maximum (95th percentile) delay (King, 1977). It is believed that, when the delay exceeds 60 seconds, pedestrians try risk-taking maneuvers in order to reduce their delay. It can be observed from Tables 4 and 5 that most of the pedestrians who arrived during the flashing don't walk (FDW) phase either saved or were delayed by

Table 4: Results of Time Saved/Delayed at Anderson Avenue/Manhattan Avenue Intersection

	During FDW		During SDW		Total Number of Pedestrians
	Stopped	Walked	Stopped	Walked	
Time delayed if *stopped* or time saved if *walked* in seconds	60	64	33	24	
Number of pedestrians recorded	16	70	213	90	389

Table 5: Results of Time Saved/Delayed at Anderson Avenue/17th Street Intersection

	During FDW		During SDW		Total Number of Pedestrians
	Stopped	Walked	Stopped	Walked	
Time delayed if *stopped* or time saved if *walked* in seconds	65	62	25	16	
Number of pedestrians recorded	1	46	22	319	388

Table 6: Percentage of Compliers vs. Noncompliers Who Arrived During FDW and SDW Signal
Indications at Anderson Avenue/Manhattan Avenue Intersection Crosswalk

Percentage	Flashing DON'T WALK	Solid DON'T WALK
Stopped	18.6	70.3
Walked	81.4	29.7

Table 7: Percent of Compliers vs. Noncompliers Who Arrived During FDW and SDW Signal
Indications at Anderson Avenue/17th Street Intersection Crosswalk

Percentage	Flashing DON'T WALK	Solid DON'T WALK
Stopped	2.1	6.5
Walked	97.9	93.5

Figure 3: Average Crossing Pedestrians for Different Signal Phases at Anderson Avenue/ 17th Street Intersection

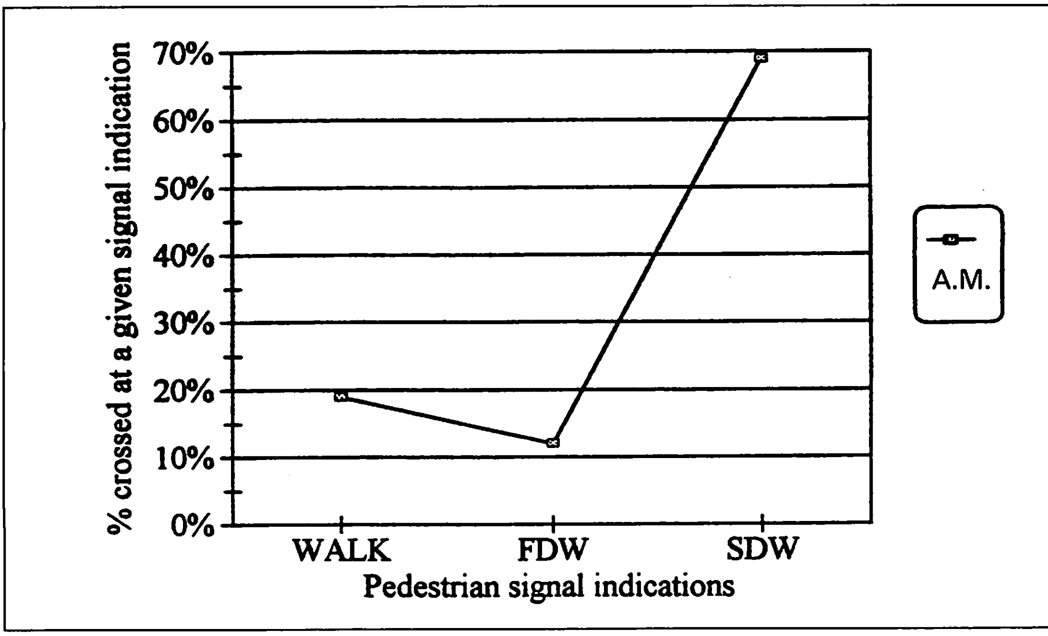
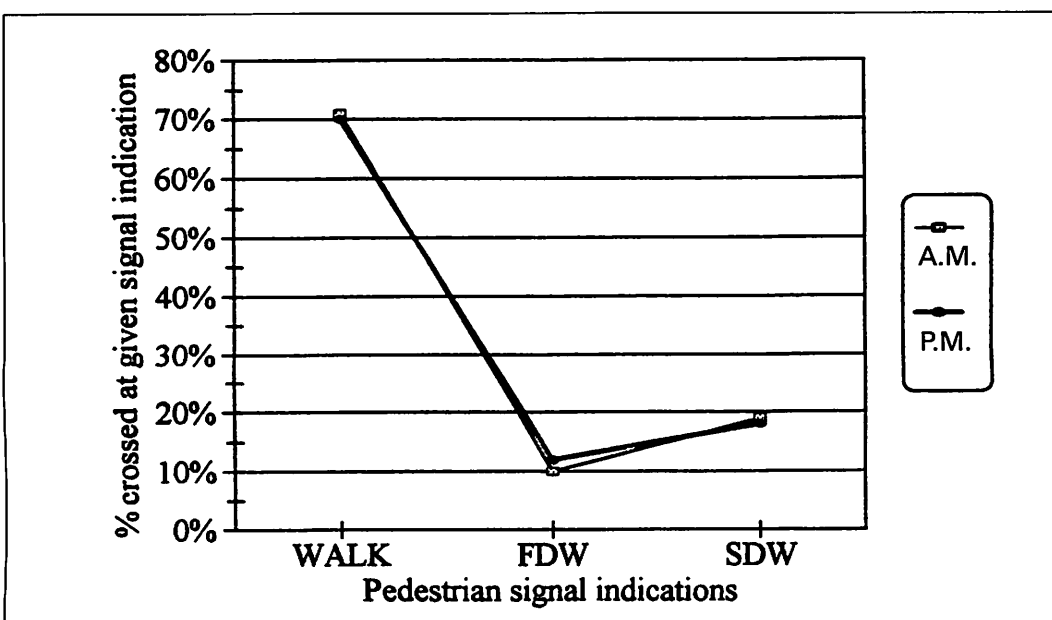


Figure 4: Average Crossing Pedestrians for Different Signal Phases at Anderson Avenue/ Manhattan Avenue Intersection



60 or more seconds. This may explain why most of the pedestrians who arrive during this phase interval decide to proceed and cross the roadway.

Pedestrians Saving Time Between 1-18 Seconds

At the Anderson Avenue/17th Street intersection there is a high percentage of pedestrians crossing during the SDW phase. It was found that most of them cross shortly before the WALK signal was on. From the signal indications shown in Figure 1, there is a 17-second gap after the vehicles have stopped (start of vehicle RED phase) on the main road (which is being crossed), and the onset of the pedestrian WALK phase. So, pedestrians who are familiar with this intersection have knowledge of this gap, which influences the timing of their crossing the road. An effort has been taken to sort out the number of pedestrians who cross the road and save time between 1-18 seconds. Data show that at the Anderson Avenue/17th Street intersection, 76% of the pedestrians who cross during the SDW phase, do so within 18 seconds before the WALK signal is on. As opposed to the Anderson Avenue/Manhattan Avenue intersection, only 38% do so. Tables 8 and 9 show these percentages clearly. During the study, it was also observed that there are a good number of pedestrians (who seem to be experienced with the location) who watch the vehicle signal indications rather than the pedestrian signal. These pedestrians know the signal cycle changes and when the gap will be available in the vehicle stream, at which time they cross the road.

WALK Phase vs. FDW Phase Durations

Since most of the FDW phases have a similar duration to the WALK phase, this will continue to tempt pedestrians to use the FDW phase for crossing. Likewise, if the vehicle YELLOW phase has a time duration similar to the GREEN phase, motorists would not stop when the YELLOW indication is on. They would continue on, being sure of clearing the intersection before meeting a conflicting traffic steam from another direction.

If we don't want to make the FDW interval as a WALK interval, then the FDW interval should be made short, like the vehicles' YELLOW interval; otherwise, pedestrians will continue to use the FDW interval as a WALK phase. However, there is no additional danger for pedestrians using the FDW phase to cross the road because both pedestrians crossing during the WALK and FDW phases face the same situation—right turn on red (RTOR) vehicles are allowed to conflict with the pedestrians. Also, some FDW phases are longer than the WALK phases (such as the Anderson Avenue/Manhattan Avenue intersection). If the SDW was shortened for

Table 8: Pedestrians Saving Time Between 1-18 Seconds at Anderson Avenue/Manhattan Avenue Intersection

Walked During Solid Don't Walk Phase (SDW)	
Total number of pedestrians crossed	90
Number of pedestrians who saved time ≤18 seconds	34
Percent of total pedestrians who saved ≤18 seconds	38%

Table 9: Pedestrians Saving Time Between 1-18 Seconds at Anderson Avenue/17th Street Intersection

Walked During Solid Don't Walk Phase (SDW)	
Total number of pedestrians crossed	319
Number of pedestrians who saved time ≤18 seconds	244
Percent of total pedestrians who saved ≤18 seconds	76%

the safety of pedestrians, it means the WALK phase has to be made longer. In the long run the WALK + SDW interval will remain almost the same; as a result, no benefits would be obtained from this change.

Differences in Pedestrian Behaviors at These Two Intersections

Since these intersections are not far from each other, and they serve almost the same type of pedestrians, one would expect similar results at both intersections. However, there are large differences in pedestrian behavior at the two intersections. The following are possible contributing factors to the observed differences:

Street width and number of lanes being crossed. At the Anderson Avenue/Manhattan Avenue intersection, the street crossing is 57 feet (17.4 m) wide and it is a four-lane undivided road at the crosswalk location. At the Anderson Avenue/17th Street intersection, the street crossing is 37.5 feet (9.6 m) wide, and it is a two-lane road. Studies (Zaidel and Hocherman, 1987) have shown that pedestrians feel unsafe as the roadway to be crossed becomes wider—fewer pedestrians violate the traffic signals.

Intersection width. Studies (Zaidel and Hocherman, 1987) have shown also that the wider the intersection, the higher the speed it invites from right-turning vehicles; this increases conflict between the crossing pedestrian and the right turn on red (RTOR) vehicles. It should also be noted that the pedestrian WALK signal is normally concurrent with the right turn from the intersecting road. At the Anderson Avenue/Manhattan Avenue intersection, there is a real threat to crossing pedestrians from vehicles making a right turn from Manhattan Avenue toward Anderson Avenue.

Vehicle traffic volume. There is higher vehicle traffic volume at the Anderson Avenue/Manhattan Avenue intersection than at the Anderson Avenue/17th Street intersection. Pedestrians can rarely obtain enough time to cross the road during the FDW phase because of higher vehicle traffic at the former intersection. Studies (Zaidel and Hocherman, 1987; Harrell, 1994) have shown that the higher the traffic volume, the higher the influence on pedestrian safety at pedestrian crosswalks.

It can be hypothesized that increases in street width, intersection width, and vehicle traffic volume would decrease the number of pedestrians who violate traffic signals. Unfortunately an empirical test of these propositions is beyond the scope of this study. The number of high volume pedestrian crossings in Manhattan is not large enough to produce a sufficient sample size for a reliable statistical test of the above hypothesis.

Conclusions and Recommendations

Conclusions

Pedestrians with experience crossing a road at a certain intersection will know the length of the signal cycle, the phase change pattern, and the order in which the traffic flow is released. Generally, these pedestrians will have only one side of the intersection to watch (while crossing before the WALK signal is on), because they know which traffic stream they may conflict with as they cross the road before the WALK signal is on. These experienced pedestrians have a higher chance of noncompliance with the traffic signal since they are familiar with the traffic stream and signal change pattern at the intersection. The majority of these pedestrians watch the vehicle signal instead of the pedestrian signal. Most of the noncomplying pedestrians save a small amount of time, less than 18 seconds, by crossing the road shortly before the onset of the WALK signal indication.

Pedestrians who are not familiar with the intersection are most likely to comply with the traffic signals because they will be watching all directions. Additionally, these pedestrians are uncertain since they are not sure which vehicle traffic stream will be released at any given time. This may reduce their willingness to take increased risk by violating the traffic signal.

In this study, 81-98% of the pedestrians who arrive during the FDW phase use the FDW interval as if it is a WALK interval; therefore, very few pedestrians stop during the FDW phase. The study agrees with other previous studies done in the past that pedestrians ignore the traffic signals. They do so with the main aim of reducing their own delays. Since the pedestrians in this study have a good knowledge of the traffic pattern and signal cycles, their potential cost of injury is very low relative to the time costs of waiting.

Pedestrian compliance with traffic signals may be greatly affected by the traffic volume, number of conflicting points with vehicles, and roadway and intersection width.

Recommendations

Further studies should be done on the behavior of special groups of pedestrians, e.g., college students who are familiar with certain crosswalks compared with other crosswalks serving general public (mix) pedestrians. Much more data needs to be collected and other pedestrian behaviors analyzed. Further studies should be done on "pedestrian actuated" signals at nearby intersections and the results compared to this study that analyzed only pretimed signals. Further studies should be performed during different seasons of the year and during different weather conditions to determine if these variables affect pedestrian compliance with traffic signals. Also, pedestrian behavior during off-peak, vehicular traffic periods needs to be analyzed.

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Endnotes

1. The study analyzes pedestrian behavior when both vehicular traffic and number of pedestrians are at a peak. Although beyond the scope of this study, a useful research extension is to compare the results of this study to pedestrian behavior observed during off-peak vehicular periods.

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