Pedestrian Walking Speeds and Conflicts at Urban Median Locations

BRIAN L. BOWMAN AND ROBERT L. VECELLIO

Results are presented of an analysis of pedestrian walking speeds and conflicts for a project sponsored by the Federal Highway Administration. The project included analysis of urban and suburban medians located on unlimited-access arterials. Pedestrian walking times were measured in Atlanta, Phoenix, and Los Angeles–Pasadena on three types of arterial cross sections: raised median, two-way left turn (TWLT), and undivided. Pedestrian speeds were computed for three age categories of pedestrians. Statistical tests were applied to determine the effect on walking speeds of median type, crossing location (midblock versus signalized intersection), and pedestrian age. Pedestrian-vehicle conflict data and accident data were collected and conflict rates were calculated. Statistical tests were applied to determine the effect of crossing location, median type, and accident rate on conflict type. The results indicate that pedestrian walking speeds are a function of age and crossing location. The type of median did not affect pedestrian-vehicle conflicts. It was found that through and right-turn conflicts were related to the accident data.

Pedestrian accidents annually account for approximately 16 percent of total traffic fatalities in the United States, with 7,400 pedestrian fatalities occurring during 1990 (*1*). The pedestrian safety problem is largely an urban one. Each year nearly 60 percent of all pedestrian fatalities occur in urban areas. In some large urban areas 40 to 50 percent of those killed in traffic accidents are pedestrians (*2*).

Approximately 14 percent of the 1992 pedestrian fatalities consisted of children under age 15, and 22.8 percent were pedestrians over the age of 64 (*1*). The pedestrian problem has often been characterized as a problem "of the young, the old and the drunk." This characterization is misleading when considered in terms of pedestrian fatalities or involvement per 100,000 population. Since 1979, for example, pedestrian fatalities per 100,000 for those under age 14 have been lower than for pedestrians aged 14 to 64 and less than half the rate of adults 65 and older. Although the characterization may be misleading in some respects, it serves to demonstrate that certain segments of the pedestrian population are perceived as being overinvolved in accidents. This perception is based on the diverse physical and attitudinal characteristics of the pedestrian population.

One of the primary variables in pedestrian characteristics is walking speed. There is considerable variation in the walking speed of pedestrians depending upon their age and trip purpose. A study of free-flow walking speeds for 967 persons observed in two transportation terminals in New York City indicated that although 1.4 m/sec (4.5 ft/sec) was the observed average, 78 percent of the pedestrians normally walked more slowly than this (*3*). The median speed, considered to be more representative than the average, was 1.2 m/sec (4.0 ft/sec). The New York study stated that the normal average walking speed of 1.1 m/sec (3.6 ft/sec), observed in a laboratory study of healthy older men, was in the 25th percentile of the distribution. Studies of street crossing speeds display slightly different results because oncoming vehicles and impending signal change prompt nondisabled pedestrians to move faster. A time-lapse photography study of pedestrians in dense platoons crossing New York City streets indicated an average crosswalk walking speed of 1.0 m/sec (3.3 ft/sec) (*4*).

The *Manual on Uniform Traffic Control Devices* (MUTCD) indicates that normal walking speed can be assumed to be 1.2 m/sec (4 ft/sec) (*5*). The results of the New York study, however, indicate that if a walking speed of 1.2 m/sec (4 ft/sec) is used to determine the pedestrian clearance interval, 50 percent of pedestrians will have to walk faster than their normal walking speed to cross safely within the allocated green time. The Institute of Transportation Engineers (ITE) handbook suggests that a normal walking speed of 1.2 m/sec (4 ft/sec) is acceptable but speeds of 0.9 to 1 m/sec (3.0 to 3.25 ft/sec) may be more appropriate for slow walkers (*6*). The 1965 edition of the ITE handbook estimated that 35 percent of the pedestrians did not attain the 1.2-m/sec (4-ft/sec) rate (*7*). A recent study conducted in Florida at a location with a large number of elderly pedestrians determined that a walking speed of 0.8 m/sec (2.5 ft/sec) was appropriate for 87 percent of those pedestrians (*8*). In another study pedestrians aged 70 years or older were instructed to cross an intersection at fast, very fast, and normal speed. The results indicated that 60 percent of the older pedestrians considered a speed lower than 1.2 m/sec (4 ft/sec) as fast. Approximately 90 percent crossed at a speed lower than 1.2 m/sec (4 ft/sec), with 15 percent of the elderly sample walking at a rate less than 0.7 m/sec (2.3 ft/sec) (*9*).

The diversity of walking speeds presents a problem to traffic engineers in determining the minimum green time and appropriate clearance interval at signalized intersections. The *Traffic Control Devices Handbook*, which provides interpretation of the MUTCD, states: "Those having slower walking speeds have the moral and legal right to complete their crossing once they have lawfully entered the crossing" (*10*). The traffic engineer therefore has the task of selecting an appropriate walking speed and hence minimum green time while simultaneously providing the cycle splits required for progressive and efficient movement of vehicular traffic. The signal timing task involves decisions about the duration of the signal cycle, its phases, and the clearance interval with the goal of minimizing delay to vehicles. Pedestrian needs and vehicular needs, however, often conflict during the selection of optimal signal timing plans.

Department of Civil Engineering, Auburn University, 238 Harbert Engineering Center, Auburn University, Alabama 36849.

TABLE 1 Pedestrian Observations by Age Group, Crossing Location, and Median Type

Age Group	Midblock		Signalized Intersection		Total
	TWLT	Undivided	TWLT	Undivided	
18 to 60	179	46	175	141	541
>60	20	3	24	20	67

Problems at signalized intersections are complicated by geometric design and vehicle movement paths. The majority of vehicular left-turn movements often takes place at the end of the green phase. At this time slower-moving pedestrians may still be in the roadway, partially fatigued, and concerned with arriving at the far curb line. The driver of the left-turning vehicle is concerned with oncoming traffic and may not be aware of pedestrians in the crosswalk into which the turn is being made. The result is an increased potential for pedestrian vehicle conflicts and subsequent accidents (*11*).

The differences in pedestrian walking speeds, vehicular travel distances, and vehicular signal timing needs are among the difficulties encountered by pedestrians in crossing roadways and by traffic engineers in producing optimal intersection signal timing plans. The magnitude of these problems increases as the vehicular volumes and roadway widths increase. Solutions to the problems include separating the paths of pedestrians and vehicles, narrowing the roadway cross section at intersections, and providing medians.

Medians are classifications of traffic control islands defined as areas between traffic lanes for control of vehicle movements or for pedestrian refuge. Medians can be designed to serve more than one purpose, including controlling or protecting vehicle crossover or other turning movements, providing a landscaped area, channelizing traffic, and providing pedestrian protection.

The results of an analysis of pedestrian walking speeds and conflicts for a project sponsored by the Federal Highway Administration are presented here. The project included analysis of urban and suburban medians located on unlimited-access arterials.

PEDESTRIAN OPERATION ANALYSIS

Walking Speeds

Pedestrian crossing behavior was obtained at selected intersections and midblock segments in Atlanta, Georgia; Phoenix, Arizona; and Los Angeles–Pasadena, California, using video cameras that had time-imaging capabilities to a hundredth of a second. The crossing times were extracted from the tapes, entered into a data base, and merged with the geometric data base. The width of the roadway from a developed geometric file and the crossing times were used to develop pedestrian walking speeds. Pedestrian age was estimated from the videotapes and grouped into three categories:

- Less than 18 years old,
- Aged 18 to 60, and
- Older than 60 years.

These categories identified age groups in which behavioral differences could be expected and reliability of age estimation is high.

The majority of pedestrian observations occurred in the central business district (CBD) or commercially developed suburban areas in which pedestrian activity was high. Because of the site collection criteria, the majority of observations were of pedestrians older than 17 years. Table 1 presents the number of pedestrian observations obtained by age group, crossing location, and median type. Efforts were concentrated on obtaining the walking speeds of pedestrians crossing two-way left-turn (TWLT) and undivided arterials since raised medians provide the opportunity for refuge.

Table 2 presents the mean walking speed, by age group, and *t*-test results to determine if there are statistically significant differences in pedestrian walking speeds by type of median and location. Pedestrians aged 18 to 60 exhibit a significantly higher walking speed at TWLT medians for both signalized intersections and midblock locations. Elderly pedestrians also exhibited higher walking speeds at TWLT signalized intersection locations, but the sample size of elderly pedestrian observations is too small for reliability. The increased walking speed for TWLT lanes may be due to the pedestrian perception of increased walking distance resulting from the presence of the TWLT lane.

TABLE 2 Test for Significance of Median Type on Pedestrian Walking Speed

Ho: Walking speed at midblock = walking speed at signalized intersection Significance level of t-test = 0.05						
	Midblock			Signalized Intersection		
	Mean Speed, m/sec		Prob > |t|	Mean Speed, m/sec		Prob > |t|
Age	TWLT	Undivided		TWLT	Undivided	
18 - 60	1.47	1.17	0.001*	1.46	1.19	0.001*
>60	1.18	--	--	1.30	0.63	0.001*

* Indicates significant difference in mean walking speeds.
1 m/sec = 3.3 ft/sec

Table 3 presents the mean walking speed by age group and *t*-test results to determine if there are significant differences in age group means by crossing location. The walking speed for the age group 18 to 60 is significantly higher than that of the over-60 age group for both signalized intersections and midblock locations. An analysis of the difference in walking speed between locations is presented in Table 4. Both age groups have significantly higher walking speeds at midblock locations than at signalized intersections. This may indicate that pedestrians feel protected at signalized intersections and do not feel the same urgency to cross as they do at midblock locations.

A summary of the number of pedestrians using raised and TWLT medians as refuge during the crossing maneuver is presented in Table 5. Over 18 percent of the observed pedestrians used the raised medians for refuge, whereas only 5 percent gained refuge from TWLT medians. A number of pedestrians were observed standing on the marks dividing the pavement during crossing of undivided roadways. The number of these observations was not, however, sufficiently large for meaningful analysis.

PEDESTRIAN CONFLICTS

Pedestrian conflict data were obtained by placing video cameras at areas with high pedestrian activity. Conflicts were taped for pedestrian crosswalks at signalized intersections and at midblock locations. The primary purposes of the conflict observations were to (*a*) determine if certain types of conflicts were indigenous to, or predominant at, particular median types; and (*b*) investigate if conflicts could be related with average daily traffic (ADT) to accident type.

The latter purpose was addressed in an effort to determine if use of the traffic conflict technique could be increased as a measure of safety by associating it with realistic data collection methods. Because of a number of factors, including the time required for data collection and its correlation to accident occurrence, traffic conflicts are not widely used. Obtaining accurate data on pedestrian conflicts and exposure is especially difficult since both pedestrian and vehicle counts are required. In addition, the conflicts are site specific and are not applicable to another location

TABLE 3 Test for Significance of Crossing Location on Walking Speed of Each Age Group

Ho: Walking speeds of (18-60) age group = walking speed of (>60) age group Significance level of t-test = 0.05			
Location	Mean Speed, m/sec		Test Results
	Age		Prob > | t |
	18-60	>60	
Midblock	1.41	1.19	0.002*
Signalized Intersection	1.35	1.03	0.001*

* Indicates significant difference in mean walking speeds.
1 m/sec = 3.3 ft/sec

TABLE 4 Test for Significance of Age on Pedestrian Crossing Speeds at Each Crossing Location

Ho: Walking speed at midblock = walking speed at signalized intersection Significance level of t-test = 0.05			
Age	Mean Speed, m/sec		Test Results
	Location		Prob > | t |
	Midblock	Signalized Intersection	
18 - 60	1.41	1.34	0.0176*
>60	1.19	0.99	0.0122*

* Indicates significant difference in mean walking speeds.
1 m/sec = 3.3 ft/sec

TABLE 5 Summary of Pedestrian Use of Medians for Refuge During Crossing Maneuver

Midblock	Raised	TWLT
Observations	164	591
Refuge	30	31
Percent	18.29	5.25

TABLE 6 Summary of Pedestrian Conflict Data Collection Activity

Area	Signalized Intersection			Midblock		
CBD	Raised	TWLT	Undivided	Raised	TWLT	Undivided
Conflicts	2	61	362	0	119	16
Hours	2.5	8.15	32.61	0	4	1.41
Locations	1	2	10	0	2	1
Suburban						
Conflicts	113	51	77	9	54	0
Hours	10	9.02	11.32	1.22	5.19	0
Locations	4	3	4	1	3	0

unless pedestrian and vehicle volumes are also available at the second location. The current technology in obtaining accurate pedestrian volume counts requires manual collection, which is time consuming and generally not performed by local agencies.

Pedestrian conflict data were obtained at 25 signalized intersections and midblock locations in both the CBD and suburban areas as summarized in Table 6. The majority of CBD observations were found at TWLT and undivided arterials because of the insufficient availability of raised medians in CBD areas.

Pedestrian-vehicle conflicts were categorized by the type of vehicle maneuver taking place at the time of the conflict. For example, a pedestrian stepping off the curb at the start of the green interval and incurring a conflict with a right-turning vehicle was classified as a right-turn conflict. Similarly, a pedestrian within the roadway at the start of the red interval and incurring a conflict with a through vehicle was categorized as a through conflict. This broad classification scheme had a number of advantages. First, it simplified the data collection task and removed judgment error prevalent with a large number of traffic conflict categories. Second, the scheme permitted comparisons of pedestrian conflict types with vehicle maneuvers from the accident data base on a site-specific basis. The conflict observations for signalized intersections are normalized by the total number of entering vehicles since conflicts were obtained from the four approaches simultaneously. Conflict observations for midblock locations are normalized by the ADT and the length of the effective visual field of the camera. Field measurements combined with the ability to view in both directions resulted in the use of a 0.16-km (1/10-mi) effective visual field.

Conflict rates at intersections were determined by assuming that the ADT of entering vehicle volumes was equally distributed throughout the 24-hr period. It is realized that the ADT is not equally distributed throughout the day and that it does not approximate the actual vehicles present during the conflict observations. The purpose in its use, as previously discussed, is to investigate the possible use of ADT as the base for conflict measures. This would facilitate use of the procedure by highway agencies. Conflict rates for midblock observations were obtained in a similar manner, with the exception that the effective visual field of the camera was used to obtain an estimate of miles. The equations used to obtain the conflict rates are presented below:

$$\text{Intersection conflict rate} = \frac{\text{Observed conflicts}}{\left(\frac{\text{ADT}}{24}\right)(\text{observation time})}$$

$$\text{Midblock conflict rate} = \frac{\text{Observed conflicts}}{\left(\frac{\text{ADT}}{24}\right)(\text{observation time})(\text{visual field})}$$

Table 7 presents the results of the statistical analysis to determine if differences existed in midblock and signalized intersection conflict rates between CBD and suburban areas. The purpose of this test was to determine if the increased pedestrian activity, typ-

TABLE 7 Statistical Difference in Pedestrian Conflict Rates Between CBD and Suburban Areas

Ho: Conflict rate at CBD = conflict rate at suburban
Significance level of t-test = 0.05

Location	Mean Rate		Prob > |t|	Significant Difference
	CBD	Suburban		
Midblock[1]	0.1920	0.0544	0.3118	no
Intersection[2]	0.0096	0.0068	0.5246	no

[1]Conflict rates for midblock locations in conflicts per vehicle-km.
[2]Conflict rates for intersections in conflicts per vehicle.
1 km = 0.62 mi

TABLE 8 Significant Difference in Type of Conflict Between Median Types

Ho: Conflict type raised = conflict type TWLT = conflict type undivided Significance level = 0.05						
Conflict Type	Mean Rate			Test Results		
	Raised	TWLT	Undiv	F	Prob > F	Significant
INTERSECTION[1]						
Right turn	0.0037	0.0026	0.0063	0.68	0.5153	no
Through	0.0014	0.0004	0.0010	0.0010	0.6676	no
Left turn	0.0021	0.0014	0.0014	0.0007	0.8417	no
MIDBLOCK[2]						
Through	0.0242	0.1396	0.3938	0.23	0.8038	no

[1]Intersection conflict rate in conflicts per vehicle.
[2]Midblock conflict rate in conflicts per vehicle-km.
1 km = 0.62 mi

ically found in CBD areas, could be used as a surrogate measure of pedestrian volume. The results of the test indicate that there were no significant differences between the conflict rates at CBD and suburban areas. The absence of a difference is probably more due to the project site-selection criteria (i.e., high pedestrian activity at both CBD and suburban locations) than to actual differences that may have existed by a random site-selection process.

Since there is no difference in the conflict rates between CBD and suburban locations, the conflicts were combined, retaining intersection and midblock stratification, for further analysis. Using analysis of variance (ANOVA), Table 8 summarizes the analysis to determine if there were significant differences in the type of conflict observed between median types at signalized intersections and midblock locations. Inspection of Table 8 indicates that there are no significant differences in the type of conflict observed between the different median types.

Pedestrian conflicts and pedestrian accidents at signalized intersections were analyzed to determine if there were statistically significant differences in vehicle maneuvers contributing to the conflict and accident rates between the median types. Only those pedestrian accidents that occurred at the same sites from which pedestrian conflict data were obtained were used in the analyses. Since the results of Table 8 indicated no statistical difference in conflict types between the different median types, an analysis was performed to determine if there were differences in vehicle maneuvers before vehicle-pedestrian accidents at the same locations used for the conflict analysis. The results of this analysis, presented in Table 9, indicate no significant difference in vehicle maneuvers between the different median types. The results of the vehicle-pedestrian conflict and accident analysis indicate, therefore, that the type of conflict and accident are not influenced by the type of median present.

The final step in the analysis of conflict data was to determine if there was a relationship between types of conflicts and types of accidents. A study by Migletz determined that a relationship did exist and developed a model to predict accidents on the basis of conflict observations (*12*). The relationship between conflict types and accident types for this project was determined by applying a paired-*t* analysis to the data of Table 9. Table 10 contains the site-specific rates for conflict and accident types observed at intersections. The analysis was not performed for midblock locations because of the difficulty in accurately locating the positions of accident occurrences. The results of the paired-*t* test, presented in Table 11, indicate rejection of the hypothesis, with 95 percent confidence, that mean conflict types and mean accident types are equal for left-turning vehicles. However, the data indicate a relationship between pedestrian conflicts and accidents for both through and right-turning types.

TABLE 9 Statistical Difference in Intersection Accident Maneuvers Between Median Types

Ho: Accident maneuver raised = accident maneuver TWLT = accident maneuver undivided Significance level = 0.05						
Conflict Type	Mean Rate[1]			F	Prob > F	Significant
	Raised	TWLT	Undivided			
Right turn	0	1.200	2.7115	0.67	0.5372	no
Through	5.2491	0	3.1608	0.86	0.4543	no
Left turn	0.5176	2.4002	9.1324	0.35	0.7134	no

[1]Accident rate per 100 million entering vehicles.

TABLE 10 Summary of Conflict Rates and Accident Rates by Vehicle Maneuver

Location No.	Conflict Rate (per 10^8 vehicles)			Accident Rate (per 10^8 vehicles)		
	LT	TH	RT	LT	TH	RT
1	1.4826	0.3955	0.9489	0	0	0
2	0.3053	0	0	0	8.4279	0
3	0	0.3053	0	0	8.4279	0
4	0	0.0435	0	0	4.1406	2.0703
5	0.2523	0.0505	0.1262	2.4002	0	4.8005
6	0.4634	0.0211	0.0211	0	0	0
7	2.6674	0.0363	1.4734	12.0142	0	0
8	1.9200	0.7200	0.2400	0	13.6986	54.7945
9	0.5031	0	0.0479	0	0	0
10	0.7682	0.1035	0.0205	0	0	0
11	0.8780	0	0.1244	4.2546	1.4182	0
12	0.0809	0	0	0	3.8479	0

TABLE 11 Paired Comparisons *t*-Test for Different Vehicle Maneuvers

Ho: (mean of conflict type) - (mean of accident type) = 0 Significance level = 0.05			
Maneuver Type	t	Prob > |t|	Significant
Right	-1.85	0.0912	no
Through	2.13	0.0563	no
Left	-3.06	0.0108	yes

The analysis of conflicts and accidents indicates that there is no difference in the type of conflict observed among raised, TWLT, and undivided median types for either intersection or midblock locations. There is also no difference in the conflict rates observed between CBD and suburban environments. The absence of the difference between CBD and suburban locations may, however, have been due more to the selection of high-pedestrian-volume locations than to the environment. The data did indicate that there is a relationship between conflicts and accidents for through and right-turn types. This relationship should be verified by a larger study. If a definite relationship can be established, the use of ADT as a normalizing agent for conflicts and the use of conflict types to estimate accidents and develop countermeasures can be established.

CONCLUSIONS

The following conclusions on pedestrian walking speeds and conflicts are applicable to raised, TWLT, and undivided median arterials located in CBD and suburban environments. The conclusions are not applicable to rural environments or limited-access roadways.

- Pedestrians aged 18 to 60 years exhibit a significantly higher walking speed at TWLT medians for both signalized intersections and midblock locations (1.47 m/sec = 4.81 ft/sec, 1.46 m/sec = 4.79 ft/sec) than that exhibited at undivided median arterials (1.17 m/sec = 3.84 ft/sec, 1.19 m/sec = 3.90 ft/sec). Elderly pedestrians also exhibited higher walking speeds at TWLT signalized intersection locations, but the sample size of elderly pedestrian observations is too small for reliability. The increased walking speed for TWLT lanes may be due to the pedestrian perception of increased walking distance resulting from the presence of the TWLT lanes.
- The walking speed for the 18 to 60 age group is significantly higher than that of the over-60 age group for both signalized intersections and midblock locations. Both age groups have significantly higher walking speeds at midblock locations than at signalized intersections. This may indicate that pedestrians feel somewhat protected at signalized intersections and do not feel the same urgency to cross as they do at midblock locations.
- Pedestrian conflict data were obtained at 25 signalized intersections and midblock locations in both CBD and suburban areas. The majority of CBD observations were made at TWLT and undivided arterials because of the unavailability of raised medians

in CBD areas. Pedestrian-vehicle conflicts were categorized by the type of vehicle maneuver taking place at the time of the conflict.

• The analysis of conflicts and accidents indicates that there is no difference in the type of conflict observed among raised, TWLT, and undivided median types for either intersection or mid-block locations. There is also no difference in the conflict rates observed between CBD and suburban environments. The absence of the difference between CBD and suburban locations may, however, have been more due to the selection of high-pedestrian-volume locations than to the environment. The data did indicate that there is a relationship between conflicts and accidents for through and right-turn types. This relationship should be verified by a more comprehensive study. If a definite relationship can be established, the use of ADT as a normalizing agent for conflicts and the use of conflict types to estimate accidents and develop countermeasures can be established.

ACKNOWLEDGMENT

The partial results are presented of a project sponsored by the Federal Highway Administration of which Carol Tan was the COTR.

REFERENCES

1. *Traffic Safety Facts 1992: Pedestrians.* National Highway Traffic Safety Administration, U.S. Department of Transportation, 1993.
2. Ybarra, S. Welcoming Remarks. In *Proceedings of the Fourth Annual Pedestrian Conference*, University of Colorado, Boulder, July 1984.
3. Fruin, J. *Pedestrian Planning and Design.* Metropolitan Association of Urban Designers and Environmental Planners, New York, N.Y., 1971.
4. Fruin, J. J., and G. Benz. Pedestrian Time-Space Concept for Analyzing Corners and Crosswalks. In *Transportation Research Record 959*, TRB, National Research Council, Washington, D.C., 1984.
5. *Manual on Uniform Traffic Control Devices.* FHWA, U.S. Department of Transportation, 1988.
6. Homburger, W. S., L. E. Kelfer, and W. R. McGrath. *Transportation and Traffic Engineering Handbook,* 2nd ed. Prentice-Hall, Inc., Englewood Cliffs, N.J., 1982.
7. Baerwald, J. R. *Traffic Engineering Handbook,* 3rd ed. Institute of Traffic Engineers, Washington, D.C., 1965.
8. ITE Committee 4A-6. *Traffic Control Devices for Elderly and Handicapped Pedestrians.* Institute of Transportation Engineers, Washington, D.C., undated.
9. Dahlstedt, S. *Walking Speeds and Walking Habits of Elderly People.* National Swedish Road and Traffic Research Institute, Stockholm, undated.
10. *Traffic Control Devices Handbook.* FHWA, U.S. Department of Transportation, 1983.
11. Bowman, B. L., J. J. Fruin, and C. V. Zegeer. *Handbook on Planning, Design and Maintenance of Pedestrian Facilities.* Report FHWA IP-88-019. FHWA, U.S. Department of Transportation, March 1989.
12. Migletz, D. J., W. D. Glauz, and K. M. Bauer. *Relationships Between Traffic Conflicts and Accidents.* Report FHWA/RD-84/042. FHWA, U.S. Department of Transportation, July 1985.

Publication of this paper sponsored by Committee on Pedestrians.