PEDESTRIAN ACCIDENT CHARACTERISTICS IN A ONE-WAY GRID

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The unique traffic configurations of one-way grid systems provide opportunities to statistically isolate and evaluate several aspects of pedestrian accident experience. One-way intersections have two conflict sides where the pedestrian must share the green with turning vehicles and two nonconflict sides where the pedestrian has an exclusive green crossing phase. Also, left- and right-turn movements represent a direct vehicle-to-pedestrian confrontation, independent of other vehicular distractions. A limited investigation of 5 years of pedestrian accident reports for 32 contiguous one-way intersections in New York City shows that, of 172 reported intersection accidents, 69.7 percent occurred on the conflict side, where pedestrians and vehicles compete for traffic priority. Results of the study show that exclusive pedestrian crosswalks independent of conflicts from turning vehicles have a lower pedestrian accident experience, justifying increased institution of turning restrictions for pedestrian safety; that backing into crosswalks should be discouraged through geometric design and stricter law enforcement; and that more detailed research is required to determine the human dynamics involved in turning a vehicle, particularly the effects that the visual impairment by the left front roof support has on the driver's judgment of pedestrian movement and position.

•EACH YEAR an estimated 350,000 pedestrians are struck by vehicles, resulting in about 10,000 deaths and many serious injuries. Not enough is being done to reduce this intolerable toll. This may be partially attributed to the complexities and limited understanding of the nature of the man-vehicle conflicts that cause these accidents, but it also is the result of the absence of a definitive national program of pedestrian accident prevention. The programs that do exist are almost universally directed at pedestrian responsibilities with limited emphasis on concomitant driver responsibilities. Because the driver wields the instrument of death and injury, he has the overriding obligation to use it safely with forbearance and deference to the pedestrian.

This study and some other recent research suggest that there is a need to promote more "pedestrian conscious" driving and to make the driver more aware of the human perceptual and judgmental limitations that exist within his vehicle and their potentially lethal implications. In addition, increased attention must be give to the pedestrian's right to safe and convenient use of the urban street rather than conceding complete preemptive traffic priority to the vehicle.

RATIONALE OF ONE-WAY GRID STUDY

Statistical investigations of pedestrian accident experience represent a troublesome area of research because the relatively low frequency of occurrence, combined with the wide range of potential contributory variables, tends to obscure meaningful analysis. Added to this are deficiencies in pedestrian accident reporting procedures that are typically designed for the more common vehicle-to-vehicle accident. Statistical research of pedestrian accidents therefore tends to concentrate on gross comparison

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techniques, which examine a broad base of accident statistics either in large systems or in numbers of comparable cities over long periods of time. For example, Snyder and Knoblauch (1) collected data on 2,157 pedestrian accidents in 13 major cities for the purpose of identifying causal factors. Hermes (2) investigated pedestrian accident experience at 400 unsignalized intersections in San Diego over a 5-year period for the purpose of evaluating the effectiveness of marked and unmarked crosswalks. Yaksich (3) noted pedestrian accident reductions in Baltimore after conversion of a two-way street system to one-way operation.

Because of their unique traffic configurations, one-way grid systems provide opportunities to statistically isolate several specific aspects of pedestrian-vehicle interaction. There are two distinctive types of pedestrian crossing conditions in one-way system intersections: a conflict-side crossing within which the pedestrian must compete with turning vehicles during the so-called walk cycle and a nonconflict crossing within which the pedestrian has exclusive crossing rights during the walk cycle, independent of vehicular conflict (Fig. 1). This contrasts with two-way intersections where the pedestrian never has exclusive crossing rights but must contend with both right- and left-turning vehicles during the walk cycle, unless specialized pedestrian signalization is provided. The one-way intersection also isolates turning movements, so there are single right-turning and left-turning sides, independent of any vehicle-to-vehicle conflicts with either oncoming or turning vehicles. The one-way intersection therefore provides direct comparisons of the relative pedestrian accident experience in crosswalks with and without turning conflicts and the relative pedestrian accident experience for left- and right-turning vehicles where there is a direct pedestrian-vehicle confrontation without distractions from other vehicles.

DESCRIPTION OF STUDY

The area selected for study is an eight-block long, four-avenue wide segment of the Manhattan, New York City, one-way street system. Located in the Chelsea section of west side Manhattan, it is bounded on the north by 21st Street, on the south by 15th Street, and on the east and west by 5th Avenue and 8th Avenue. Census tracts show that approximately 10,000 persons reside in the area, but daytime population on working days is at least five times that amount. The one-way system segment, which contains 32 intersections, is reasonably homogeneous in terms of land use and pedestrian and vehicular traffic activity. Two avenues run south, two run north, four streets run east, and four run west. The 32 intersections in the grid have 64 pedestrian conflict sides, consisting of 32 right-turning and 32 left-turning legs, and 64 nonconflict or exclusive pedestrian crossing sides.

The accident study consisted of a review of 5 years of accident records for the period 1967-71 and a classification of intersection accidents by type. A sample of the short-form accident record, which is filled out by the patrolman responding to an accident, is shown in Figure 2. This form is a dual-purpose one used for both vehicle-to-vehicle and vehicle-to-pedestrian accidents. To obtain data about individual accident characteristics required that the patrolman's written summary of the accident be referred to. There were naturally variations in the thoroughness of reporting accident detail. Also the form appears to be more applicable to the more frequent vehicle-to-vehicle accident. For example, the space allocated for the collision diagram is inadequate to portray detail at the point on the vehicle where the pedestrian was struck or to indicate the accurate location of the accident within the intersection. In spite of these deficiencies, sufficient information was obtained from patrolmen's reports to examine the specific areas of interest in the study.

Data were divided into intersection versus nonintersection accidents. An intersection accident was defined as one that occurred in or within 25 ft of an intersection. Intersection accidents were further classified by conflict versus nonconflict sides, with conflict-side accidents subdivided into straight, backing, right-turning, and left-turning. Additional classifications were made by time of day, day of week, weather conditions, and pedestrian age where determinable. Short counts of pedestrian and vehicular volume were also collected for half of the intersections in the study area.

Figure 1. Typical one-way intersection illustrating pedestrian conflicts.

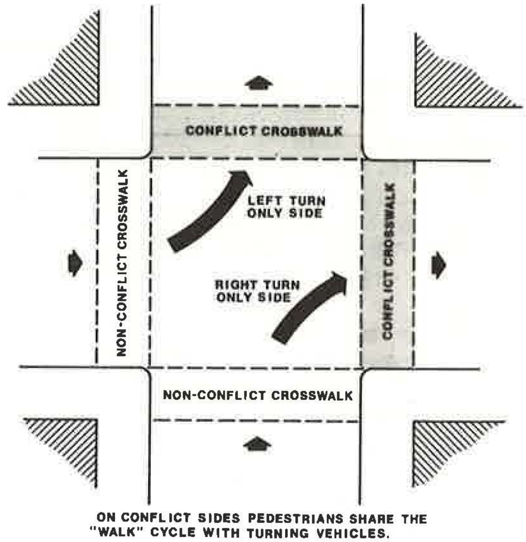


Figure 2. Sample short-form accident record.

POLICE DEPT. UF.6B

LOCATION

Date of Accident________ Day of Week________ Time______(A.M.)(P.M.) Borough________

Accident Occurred on________ Pct.________

St., Ave., Etc.

At Intersection With________ Acc. No.________

St., Ave., Etc.

Or If

Not at Intersection Indicate________ Of________

No. of Feet North, South, East or West — Nearest Intersecting St., Ave., Etc.

ACCIDENT INVOLVED
- ☐ Fatality
- ☐ Personal Injury
- ☐ Property Damage Only

TOTAL CASUALTIES
No. Killed_____
No. Injured_____

LIGHT CONDITION
- ☐ Daylight
- ☐ Dawn-Dusk
- ☐ Darkness

WEATHER
- ☐ Clear ☐ Snow
- ☐ Cloudy ☐ Sleet
- ☐ Rain ☐ Fog

COLLISION BETWEEN
- ☐ Vehicle—Vehicle
- ☐ Vehicle—Pedestrian
- ☐ Other

TRAFFIC CONTROL
- ☐ Police Officer
- ☐ S. C. Guard
- ☐ Signal Light
- ☐ Flashing Light
- ☐ Stop Sign
- ☐ Caution Sign
- ☐ Yield Sign
- ☐ Other
- ☐ None

PEDESTRIAN

A B C D
- ☐☐☐☐ With Signal } Crossing Intersection
- ☐☐☐☐ Against Signal } Crossing Intersection
- ☐☐☐☐ Diagonally } Crossing Intersection
- ☐☐☐☐ Crossing from Between Parked Cars

A B C D
- ☐☐☐☐ Playing in Roadway
- ☐☐☐☐ Other Acts in Roadway
- ☐☐☐☐ Not in Roadway
- ☐☐☐☐ Apparently Intox.

Pedestrians' Ages
A ______
B ______
C ______
D ______

Drivers' Ages
1. ______
2. ______
3. ______
4. ______

Vehicle
1 2 3 4 — **DRIVER**
- ☐☐☐☐ Exceeding Lawful Speed
- ☐☐☐☐ Disregarded Traffic Control
- ☐☐☐☐ Following Too Closely
- ☐☐☐☐ Improper Turn
- ☐☐☐☐ Other Improper Driving
- ☐☐☐☐ Inadequate Brakes
- ☐☐☐☐ Improper Lights
- ☐☐☐☐ Apparently Intox.
- ☐☐☐☐ Other

SKETCH OF ACCIDENT

USE SOLID LINE WITH ARROW TO SHOW PATH AND DIRECTION OF VEHICLE BEFORE IMPACT

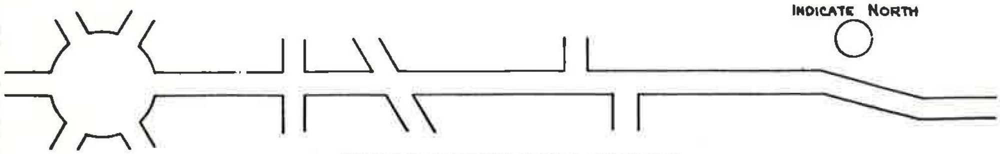
USE DOTTED LINE WITH ARROW TO SHOW PATH AND DIRECTION OF VEHICLE AFTER IMPACT

NUMBER EACH VEHICLE

INDICATE PEDESTRIAN BY ○

RAILROAD —I—I—I—I—

INDICATE NORTH



BRIEFLY DESCRIBE WHAT HAPPENED

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MAJOR RESULTS OF STUDY

During the 5-year period encompassed by the records, 253 pedestrian accidents occurred within the one-way grid system, and 172 or 68 percent of the total was at intersections. There were five fatalities, but only one occurred at the intersection. The single intersection fatality was caused by a left-turning vehicle when both pedestrian and vehicle had the green light. Two fatalities were caused by midblock dart outs, another by a vehicle attempting to avoid one pedestrian and hitting another, and the last directly caused by alcohol involvement of the pedestrian. All fatalities were males over 60, which follows the classic accident severity pattern among the aged. A much younger age distribution was noted for all intersection accidents, which is not typical of the general accident experience in this country (Fig. 3). There is a significantly higher involvement of younger, more agile pedestrians in intersection accidents in this system; 54 percent was in the 20 to 50 age bracket. This can probably be attributed to the high working-age population in the study area during daylight hours.

The main focus of the study, the comparison of accident experience in conflict versus nonconflict sides of the intersection, illustrates the value of exclusive pedestrian crossing rights. Crossing on the conflict side of the intersection, where both pedestrians and vehicles share the green, accounted for 69.7 percent of the intersection accidents. This total was composed of 44.7 percent turning accidents, 17.5 percent straight accidents, and 7.5 percent back up (Fig. 4). This illustrates that a pedestrian has more than twice the probability of being struck by a vehicle when he is crossing on the conflict side.

Short traffic counts of both pedestrian and vehicular volumes at half of the intersections in the system showed that pedestrian activity was balanced between conflict and nonconflict crosswalks. As a point of interest, expansion of vehicle short count data into equivalent annual volumes shows that the approximate probability of a driver striking a pedestrian at an intersection in this system is about one in 9,000,000, demonstrating the inherent difficulties connected with pinpointing causal factors at specific accident sites. The short counts point up one other significant fact. Although vehicle turning movements averaged only 14 percent of the total recorded traffic moving through the intersections, turning accidents accounted for 45 percent of the accidents. Turning vehicles therefore are approximately six times more likely to strike a pedestrian than are through vehicles.

Backing movements manifest an even greater propensity for striking pedestrians, for, although the backing movement amounts to less than 1 percent of the observed traffic activity, it resulted in 11 percent of the accidents. An automobile backing into a crosswalk would therefore have more than 15 times the probability of striking a pedestrian that straight and turning movements combined have. This is attributed to the restricted visibility of the driver, combined with the pedestrian's lack of expectancy of a vehicle making this maneuver.

THE LEFT-TURN ENIGMA

An unusual characteristic of the intersection accident pattern is that left-turning accidents exceed right-turning by a ratio of 2 to 1 (31 percent versus 14 percent). Short count surveys showed that this imbalance was not attributable to differences in either pedestrian or vehicular volumes. Although this difference might be understandable in a two-way system where left-turning vehicles are subjected to attention conflicts from right-turning and/or straight through vehicles, it is a surprising pattern for a one-way system where right- and left-turn conditions are seemingly equal in every respect. This same predominance of left-turn pedestrian accidents has been noted in the national pedestrian accident survey conducted annually by the American Automobile Association (4). This survey involves reports of accident experience from about 2,000 cities in the United States and Canada. Interestingly, England with its left-side traffic system and right-side driver's seat has a predominance of right-turn accidents (Table 1).

These accident statistics strongly suggest that there are different factors operable in pedestrian accidents that occur during turns on the driver's side. Turning a vehicle itself is a complex human motor task, requiring continuous sensory feedback for velocity judgment and wheel adjustment through the turn. The turning driver has a much more complicated visual task and sensory feedback problem because he must observe and evaluate relative closing distances between his vehicle and a moving pedestrian from the constantly changing angular variations of a curved vehicle path. Controlled laboratory experiments (5) have shown that visual acuity is measurably reduced when the visual target is moved through a circular path.

To examine the premise that physical factors might vary between left and right turns, contributing to an accident differential, series of left and right turns were photographed by means of a slow-motion movie camera mounted in the approximate driver's position of a vehicle that was driven through the system. Subsequent review of the slow-motion film failed to reveal any apparent physical difference between the two types of turns, although the camera angle admittedly did not duplicate the full range of human vision. However, the films did show that even the small New York State motor vehicle inspection sticker affixed to the left front windshield could obscure pedestrians during part of the left turn. In addition, although not accurately represented in the camera's limited field of view, the vehicle's left front roof support post was found to occupy a considerable amount of the driver's field of vision during left turns.

IS IT THE FRONT LEFT ROOF SUPPORT?

The results of this limited accident investigation seem to suggest that the front left roof support could be a causative factor in a significant number of left-turn accidents in urban intersections. If true, the post may be responsible for other types of left-side pedestrian accidents as well. The predominance of left-turn pedestrian accidents noted in two-way systems might also be connected with visual impairments caused by this post rather than the attention conflicts from other vehicles as suggested by others. Vehicles represent massive visual targets in the driver's field of view, compared to pedestrians who may easily be obscured by the vertical post.

Allen (6) reported that a survey of 1960-62 automobiles showed that the front left roof support occupied 5 to 17 deg of the driver's field of view and was located between 10 and 26 deg left of straight ahead of the driver's eyes. Measurement of a late-model sedan in the company pool showed a 10-deg obstruction of the field of view. Figure 5 shows such a 10-deg visual impairment at the beginning of a left turn. At the point of initiating a turn, the driver turns his head away from center in the direction of the turn, gradually moving his head back to center as the turn is executed. It is at the point of turn initiation that the post causes the most obstruction, creating a blind zone that could encompass an area of more than 100 ft^2 with the more extreme post designs. As the driver turns, the blind zone is reduced, but it would be possible for the driver to assume that there were no pedestrians in the crosswalk based on his field of vision when initiating the turn, and therefore he would be unprepared to stop. At 10 mph a driver can execute a turn in less than 3 sec; during this same time a pedestrian on the blind side would move about 12 ft. This allows a very small margin of safety for the motorist to react and stop his vehicle to avoid a pedestrian he had not initially observed.

Accident reports were reviewed after this analysis of the visual impairment on the left side to determine whether a significant number of accident victims were also approaching from the left. Because of the nature of the reports this was not possible for all the accidents, but, where determinable, a relatively insignificant imbalance was noted for left-side accidents ($^{55}/_{45}$). On the basis of the available accident information, it is not possible to conclude the specific factor, or possible combination of factors, that is operable on left-turn accidents that causes their greater frequency of occurrence. But the human dynamics of turning, with the greater pedestrian accident potential, appear worthy of more detailed research.

POSSIBLE APPLICATIONS OF RESULTS

The extremely high probability of backing accidents as related to vehicular activity noted in this study indicates that backing into the crosswalk should be more strictly enforced as a moving traffic violation to focus the attention of both driver and pedestrian on the danger connected with this maneuver. Inasmuch as signal standards are located near crosswalks, signs on these standards noting that this is a violation might increase

Figure 3. Age of pedestrians involved in one-way intersection accidents in New York City.

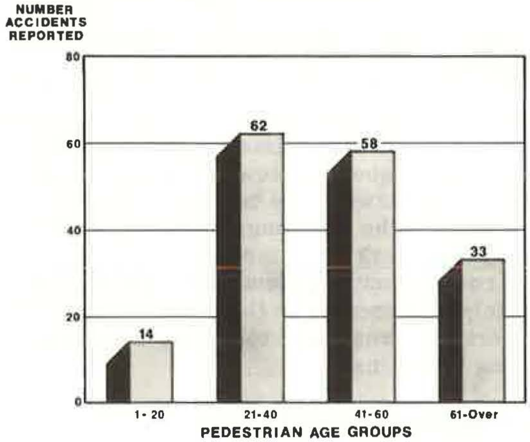


Table 1. Pedestrian accidents at roadway junctions in England.

Intersection Layout	Number of Accidents: Right Turn	Number of Accidents: Left Turn
T or Y		
Controlled	22	13
Uncontrolled	273	131
Crossroads		
Controlled	75	58
Uncontrolled	49	34
Total	419	236

Source: Correspondence from S. J. Older, Road Research Laboratory, reference TB/417/450/01.

Figure 4. Conflict-side versus non-conflict-side pedestrian accidents at 32 one-way intersections in study area.

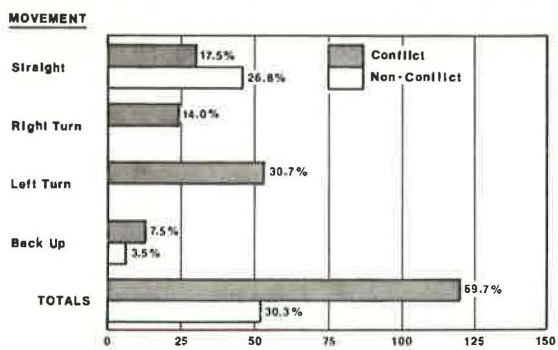
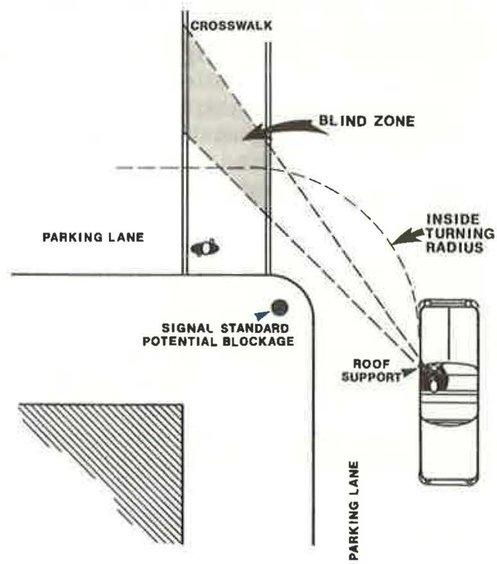


Figure 5. Impairment of driver's field of vision in left-turn movement by roof support.



compliance with the law. The higher pedestrian accident experience noted in the conflict crosswalk suggests that some differential markings between conflict and nonconflict crosswalks might be of value. The San Diego experience, where accidents were higher in marked crosswalks, is indicative that a new approach to crosswalk marking must be developed, not directed toward giving the pedestrian the impression that the crosswalk is his "territory" but toward alerting both driver and pedestrian that the crosswalk is at the critical point of man-vehicle interaction and that extreme caution is required from both. The higher accident probability of turning (in terms of vehicle volume) implies that restrictions on turns should be more generally applied in busy pedestrian areas. Also it suggests that there should be more investigation of the human dynamics of turning and more detailed study of the principles and warrants governing application of right turn on red.

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