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Methodology for Evaluating the Safety of Midblock Pedestrian Crossings

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Spatial and temporal characteristics of midblock pedestrian crashes (MBPCs) were evaluated toward a better understanding of where and when the MBPCs occur. Existing databases related to traffic crashes were used. Other data used include traffic and geometric characteristics of the roadways under consideration as well as analyses of pedestrian and driver behaviors. General statistical analysis methods were used to evaluate various hypotheses. The statistical Z-test was used to evaluate the age and gender distribution, light condition, fatalities, and alcohol- or drug-use–related characteristics involved in MBPCs. The results correlated these factors with the potential for the occurrence of MBPCs. The Wilcoxon Signed Rank test was used as a nonparametric test to compare the safety of midblock crossings with the safety of crossings at intersections. The methodology was tested and validated using midblock locations in the Las Vegas metropolitan area. The results indicate that there is a significantly lower potential for conflict if pedestrians cross at an intersection instead of crossing at a midblock location. Although this methodology was applied to data from the Las Vegas metropolitan area, it is applicable to evaluating the safety of MBPC anywhere else, provided that appropriate data are available.

Transportation-related problems have become pressing and visible concerns of urban life. An important transportation issue in the mind of the public is traffic safety. One major aspect of safety on roadways relates to pedestrian crossing, especially pedestrian crossings at locations away from intersections. Travel by pedestrians is the most common mode of transportation throughout the world. Pedestrian traffic is a major component of traffic flow, especially in urban areas. It is also the most unpredictable component of the roadway environment due to the generally unrestricted mobility, travel paths, and actions that a pedestrian can perform. The increasing concern about the pedestrians as part of the traffic system stems from their vulnerability compared with that of drivers, who are protected by their motorized vehicles. In 2001, there were 4,882 pedestrian fatalities and 78,000 pedestrian injuries resulting from traffic crashes in the United States (*1*).

A typical urban pedestrian transportation system involves three basic elements: sidewalks or walkways; midblock or intersection corner, holding, or queuing areas; and pedestrian crossings of roads, railway lines, or other physical features of the transportation network (*2*). In urban settings, complex and inconvenient intersection crossings, or signal timing patterns that have long cycle lengths, often lead to pedestrians choosing to cross at midblock locations. Convenience is another aspect that leads to midblock pedestrian crossings.

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Over the last decade, the Las Vegas metropolitan area (located in Clark County, Nevada) has been at the top of the list of urban areas with the highest rate of pedestrian crashes per capita. During the 1993–1997 time period, statistics show that the "crossing—not at intersection (no pedestrian marked crosswalk)" type of pedestrian crash represents 55% of all fatal pedestrian crashes and more than 28% of all injury only pedestrian crashes in Clark County, Nevada. Such crashes are termed midblock pedestrian crashes (MBPCs). In fact, the 120 fatal pedestrian crashes of this type represented nearly 14% of all fatal traffic related crashes in Clark County during that period. To develop a program to address the phenomenon of MBPCs, such crashes need to be better understood. Commonly used statistical tools need to be adopted to assist the traffic safety engineer in objectively evaluating factors to understand where, when, and why such pedestrian safety problems occur, and what is entailed. Also, to develop effective pedestrian safety countermeasures, it is important to first understand what specific driver and pedestrian behaviors cause these crashes.

Several studies documented in the literature discuss factors potentially resulting in MBPCs as well as many kinds of countermeasures proposed or under test for real world projects. However, one of the major limitations faced by transportation analysts is the lack of a standard procedure to implement the analysis of MBPC. Because the MBPC involves many independent factors or factors that interact, thus making the situation really complex, a statistical tool and a standard procedure that provide quantified analyses are critically needed. This paper summarizes such a program to facilitate statistical analyses of MBPCs.

Previous studies were reviewed to identify factors affecting MBPCs and key variables that could be used in the procedure to define MBPC characteristics of urban areas. This paper focuses on developing a standard procedure for implementing MBPC analyses. A general statistical methodology was used to define MBPC characteristics and identify some of the key factors that affect MBPCs. A nonparametric statistical technique, the Wilcoxon Signed Rank test, was employed for analysis and quantification of pedestrian crossing safety based on the hazard areas identified in a previous study (*3*).

BACKGROUND

Crashes have been defined as unexpected events and a bane on society (*4*). A crash definitely causes considerable pain, suffering, and economic loss. In a fatal incident, lives are shattered or changed forever. Crashes that result in injury can inflict pain and may disable a person, temporarily or permanently. Information relevant to pedestrians as part of the transportation system, as found in the literature, relates to pedestrian safety, human behavior, human factors, and pedestrian crash characteristics.

Human behavior has a direct influence on pedestrian safety. Human error reflects an undesirable behavior that has the potential for reducing traffic safety. Erroneous behaviors by either the pedestrian or the driver, or both parties, are important factors in pedestrian crashes. To identify the circumstances under which pedestrian crashes occur, a taxonomy of crash types was developed—categories that describe the nature of the pedestrian behavior and the circumstances before the crash (*5*). In the transportation sector, human factors are examined to identify human errors that lead to crashes. The literature that has been published over the last two decades on human factors related to pedestrians and to drivers has included efforts conducted throughout the world (*4, 6–12*). Much of the previous research has focused on pedestrian crash characteristics, such as distance from the nearest intersection (*13*), pedestrian crash severity (*14*), temporal distribution (*15, 16*), age and gender groups (*13*), light conditions (*15, 17*), alcohol or drug use (*15*), and land use categories (*18*). Countermeasures attempt to improve road user safety through the effects of education (*19*), legislation, and changes in the road environment (*4, 20*). Passive detection methods (*21*) and in-pavement lighting (*22*) are two relatively new interesting findings in that regard.

The development of effective countermeasures to help prevent pedestrian crashes is hindered by insufficient detail on computerized state crash files and databases. Analysis of these data can provide information only on where pedestrian crashes occur, when they occur, and characteristics of the victims involved. These data cannot provide a sufficient level of detail in regard to the sequence of events leading to the crash. A critical step to approaching the methodologies is that methods for classifying MBPCs were developed by NHTSA to better define the sequence of events and precipitating actions leading to pedestrian–motor vehicle crashes (*23*). The *Pedestrian and Bicycle Crash Analysis Tools Software and User's Manual* is a crash analysis tool developed to facilitate analysis of pedestrian- and bicycle-related crashes and to identify potential countermeasures (*24*). However, there is little discussion in the literature focused on MBPCs specifically, and there is a lack of a standard procedure to analyze this problem as a whole system, not based solely on individual characteristics.

GENERAL CHARACTERISTICS OF MBPCS

In this study, MBPCs are defined according to specific attributes and codes of crashes in the Nevada Department of Transportation (DOT) crash database (*25*). Midblock is defined as an area on a surface street at any point away from an intersection without a marked crosswalk. This term is based on the street geometry characteristics in Las Vegas, Nevada, and it may vary in other jurisdictions. The basic selection criteria used codes from the "Pedestrian Action" field in the Nevada DOT crash database. Owing to the low total number of MBPCs in any year at any one location, the identification of any patterns of concentration requires sampling over time. A 3-year time frame of recent crashes was used. The initial filtering was based on the extraction of all records for Clark County, Nevada, in the 3-year period of 1995 through 1997.

From a review of the literature, several MBPC characteristics directly related to pedestrian crossing safety were identified. They are discussed next.

Distance from Nearest Intersection

An initial analysis of crashes occurring not at an intersection or marked crosswalk examined the distance of crashes from the nearest intersection as identified in the Nevada DOT database. The results are summarized in the form of a histogram in Figure 1. The geocoded locations are based on distance from the cross streets or mileposts reported in the Nevada DOT database. They are subsequently referred to as the primary intersections and the primary distance.

An analysis of the distance distribution for 774 MBPC reports from 1995 through 1997 clearly shows one very prominent spike in a skewed distribution curve as shown in Figure 1. This distribution further was analyzed statistically. The curve exhibits a high positive skewness, 3.7. The distribution begins with a generally normal curve followed by a very long tail of increasingly large distances from the nearest intersection, a situation reflected by the large standard deviation in the distance measures. The spike peaks at the 150-ft distance and results in a very high kurtosis value of 17.9. A closer examination reveals that at between 135 ft and 165 ft, there were 136 crashes, with 96 reported at exactly 150 ft. This number represents approximately 18% of all MBPCs. A discussion with the Las Vegas Metropolitan Police Department's (LVMPD) Crime Analysis Division and Traffic Division officers indicated that this appears to be a valid percentage. LVMPD attributes the situation to the high number of corner strip mall driveways that are situated at that distance, a result of subdivision regulations pertaining to the minimum distance from corners to driveway access points.

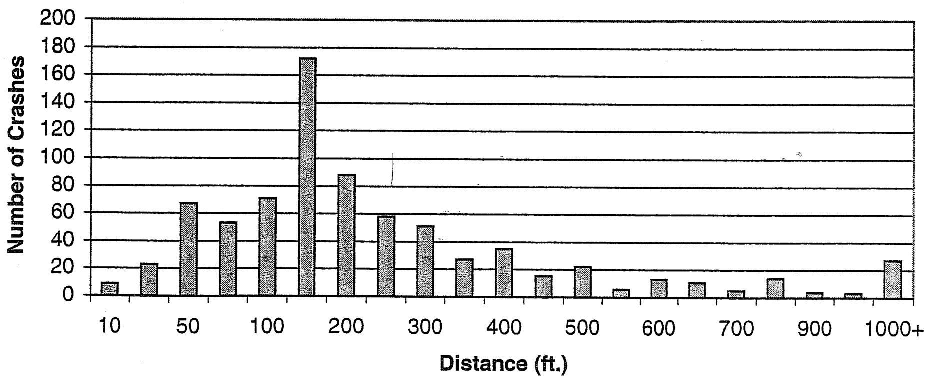

FIGURE 1 Frequency distribution of midblock crashes and distance to nearest intersection, 1995–1997.

Temporal Characteristics

The exploration of time with respect to MBPCs reveals some general trends. Figure 2 shows that the highest number of these crashes occurs in the early evening, particularly late in the week. The overall peak is on Fridays from about 5:00 to 6:00 p.m. The next largest concentrations are during the same hours throughout the week, starting as early as 3:00 p.m. on Thursdays. This situation is potentially related to the fact that people leave work at about this time, so that there is more travel occurring, both vehicular and pedestrian, especially on Friday evenings when the vehicle and pedestrian traffic are highest. There also is another period of concentration, Friday and Saturday evenings from 8:00 to 9:00 p.m. That situation probably results from recreational activities and high pedestrian volumes in the resort corridor—"the strip" in Las Vegas.

A slight variation is observed in the number of crashes by month as shown in Figure 3, with a range of 50 to 76 (3-year totals) and a mean of 64.5 pedestrian crashes, with a standard deviation of 9 and a 95% confidence level. The month of May had the fewest MBPCs, with 50, whereas March had the most, with 76. The summer months of July and August had 3-year totals of 57 and 52, respectively. These two are typically the hottest months, with the result of fewer people walking—plus there are longer daylight hours. December also had a high number of MBPCs, with 74.

Age and Gender Distributions in MBPCs

Approximately 68% of all pedestrians involved in MBPCs are male. The Nevada State Demographer's office estimated the 1997 population of Clark County at 1,192,200, with the proportion of males at 50.4% (*26*). The proportion of males involved in MBPCs appears to exceed the proportion of the males in the general population, a finding that was tested statistically as follows: let P_0 = proportion of males in the general population, P_c = proportion of males involved in MBPCs, and N = sample size.

The null hypothesis is H_0: The proportion of males involved in MBPCs is the same as the proportion of males in the general population, that is, $P_c = P_0$.

The alternative hypothesis is H_1: The proportion of males involved in MBPCs is greater than the proportion of males in the general population, that is, $P_c > P_0$.

The equation for the Z statistical test is shown as

$$Z = \frac{P_c - P_0}{\sqrt{\dfrac{P_0 * (1 - P_0)}{N}}} \tag{1}$$

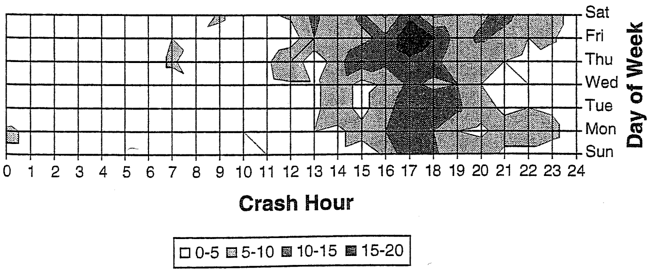

FIGURE 2 Temporal distribution of MBPCs, 1995–1997.

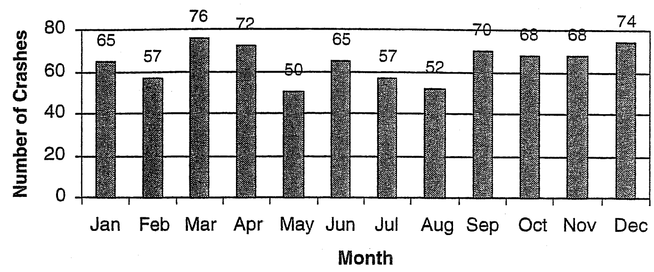

FIGURE 3 Midblock pedestrian crashes, by month, 1995–1997.

For $P_0 = 0.504$, $P_c = 0.68$ and $N = 774$, the value of the Z-statistic for the test $H_0 : P_c = P_0$ versus $H_1 : P_c > P_0$ is $Z = 9.83$, with a P-value less than 0.001 (very small number). The P-value is obtained from the Normal Distribution table (*27*). The P-value is used to reach a decision at an acceptable error rate α. If the computed P-value is less than the acceptable error rate (a generally acceptable error rate is $\alpha = 0.05$ or 5%), then the null hypothesis is rejected, and the alternate hypothesis is accepted. So it can be concluded that the proportion of male pedestrians involved in MBPCs exceeds the proportion of males in the general population.

Similarly, a total of 10 characteristics related to MBPCs in the Las Vegas area were tested using the Z-statistic test. The 10 hypotheses are listed in Table 1, and the results of the statistical tests are presented in Table 2.

EVALUATION OF MBPC SAFETY

Are pedestrians crossing at intersections safer than those crossing at midblock locations? That is a question whose answer is sought in this research. To provide an answer, statistical tests were employed to compare the safety of crossings at intersections with crossings at midblock locations.

Statistics based on the ranks of measurements are called rank statistics (*28*). The Wilcoxon Signed Rank test is suitable for testing the differences between two pairs of data sets in which there is more than one observation. That is an advantage over the Z-statistic test. In this paper, the Wilcoxon Signed Rank test, a nonparametric test, was used to test the hypothesis that the frequency distributions (e.g., those of pedestrians at midblock crossing and at intersection crossing) were identical against the alternative hypothesis that one distribution was different from the other. It should be noted that this test does not use the overall rates, but instead uses the rank order of the differences between pairs of observations. Thus, large differences in overall rates between pairs of observations do not necessarily result in significant differences with the use of this nonparametric test.

Selection of Sites

A number of candidate sites were identified based on a previous study (*3*). A field survey was undertaken to examine the sites and subsequently the number of sites was narrowed to 24. Those 24 sites represented 12 signalized intersection legs and 12 in their vicinity at midblock locations. All selected sites are away from the Las Vegas strip to avoid its unique scenario, except for one location in the downtown area. From interviews of midblock pedestrians crossing

TABLE 1 Hypothesis Tests for Characteristics of MBPCs

Test Items	The Null Hypothesis: $H_0\!:\!P_c = P_0$	The Alternative Hypothesis: $H_1\!:\!P_c > P_0$
Test 1.	The proportion of males involved in MBPCs (P_c) is the same as the proportion of males in the general population (P_0).	The proportion of males involved in MBPCs is greater than the proportion of males in the general population.
Test 2.	The proportion of children (under the age of 18) involved in MBPCs (P_c) is the same as the proportion of children in the general population (P_0).	The proportion of children (under the age of 18) involved in MBPCs is greater than the proportion of children in the general population.
Test 3.	The proportion of males involved in MBPCs (P_c) is the same as the proportion of females involved in MBPCs during darkness (P_0).	The proportion of males involved in MBPCs is greater than the proportion of females involved in MBPCs during darkness.
Test 4.	The proportion of males involved in MBPCs under darkness (P_c) is the same as the proportion of males involved in MBPCs in daylight (P_0).	The proportion of males involved in MBPCs under darkness is greater than the proportion of males involved in MBPCs in daylight.
Test 5.	The proportion of male children involved in MBPCs (P_c) is the same as the proportion of male adults involved in MBPCs (P_0).	The proportion of male children involved in MBPCs is different from the proportion of male adults involved in MBPCs.
Test 6.	The proportion of males under the influence involved in MBPCs (P_c) is the same as the proportion of females under the influence involved in MBPCs (P_0).	The proportion of males under the influence involved in MBPCs is greater than the proportion of females under the influence involved in MBPCs.
Test 7.	The proportion of either driver or pedestrian under the influence involved in MBPCs (P_c) is the same as the proportion of influence involvement in all crashes (P_0).	The proportion of either driver or pedestrian under the influence involved in MBPCs is greater than the proportion of influence involvement in all crashes.
Test 8.	The proportion of alcohol related MBPCs during darkness (P_c) is the same as the proportion of all MBPCs during darkness (P_0).	The proportion of alcohol related pedestrian MBPCs during darkness is greater than the proportion of all MBPCs during darkness.
Test 9.	The proportion of alcohol related MBPCs during darkness (P_c) is the same as the proportion of alcohol related MBPCs during daylight (P_0).	The proportion of alcohol related MBPCs during darkness is the same as the proportion of alcohol related MBPCs during daylight.
Test 10.	The proportion of alcohol related fatal MBPCs (P_c) is the same as the proportion of ALL alcohol related fatal crashes (P_0).	The proportion of alcohol related fatal MBPCs is greater than the proportion of ALL alcohol related fatal crashes.

TABLE 2 Variables, Results, and Conclusions for Hypothesis Tests of MBPC Characteristics

Test Items	P_0	P_c	N	Z-value	P-value	Null Hypothesis Result	Conclusion
Test 1.	0.504	0.68	774	9.83	<0.001	Rejected	The proportion of male pedestrians involved in MBPCs exceeds the proportion of males in the general population.
Test 2.	0.31	0.34	794	1.83	0.034	Rejected	The proportion of children (under the age of 18) involved in MBPCs exceeds the proportion of children in the general population.
Test 3.	0.40	0.45	794	2.83	0.002	Rejected	The proportion of males involved in MBPCs under darkness exceeds that of the proportion of females involved in MBPCs under darkness.
Test 4.	0.42	0.58	344	6.01	<0.001	Rejected	A significant majority of the adult males involved in MBPCs are involved during hours of darkness.
Test 5.	0.63	0.69	254	2.51	0.12	Accepted	The percentage of male children involved in MBPCs is almost identical with that of the percentage of adult population.
Test 6.	0.16	0.84	171	24.26	<0.001	Rejected	The percentage of males under the influence involved in MBPCs exceeds that of females.
Test 7.	0.06	0.22	171	8.86	<0.001	Rejected	The proportion of either driver or pedestrian under the influence involved in MBPCs exceeds the proportion of influence involvement in all vehicular crashes.
Test 8.	0.43	0.78	774	12.09	<0.001	Rejected	The proportion of alcohol related MBPCs during darkness exceeds the proportion of MBPCs in all crashes during darkness.
Test 9.	0.09	0.40	171	14.17	<0.001	Rejected	The proportion of alcohol related MBPCs during darkness exceeds the proportion of alcohol related MBPCs during daylight.
Test 10.	0.25	0.40	412	7.03	<0.001	Rejected	The proportion of alcohol related fatal MBPCs exceeds the proportion of ALL alcohol related fatal crashes.

at the selected sites, it was determined that the majority of those people were local residents.

Definition of Conflicts

Traffic conflicts have been used to measure the potential for traffic crashes. A traffic conflict occurs when a driver has to take some evasive action—that is, change direction or speed, or both, to avoid a collision (*29*). Three conflict measures that were used in previous studies (*29*) were used as measures of effectiveness in the field data collection effort. They are as follows:

1. Through vehicle conflict—in which the projected paths of a through vehicle and a pedestrian cross, and either the pedestrian or the vehicle, or both, must change direction or speed, or both, to avoid a collision.
2. Right-turn vehicle conflict—in which the projected paths of a right-turning vehicle and a pedestrian cross, and either the pedestrian or the vehicle, or both, must change direction or speed, or both, to avoid a collision.
3. Left-turn vehicle conflict—in which the projected paths of a left-turning vehicle and a pedestrian cross, and either the pedestrian or the vehicle, or both, must change direction or speed, or both, to avoid a collision.

For protected left-turn signals, pedestrian movement is not allowed. However, in the case of permissive left-turn movements, the situation is different. In that case, the driver making a left turn has to watch out for the pedestrians, who have the right-of-way, as well as for opposing through vehicles. The driver is therefore tempted to accept smaller gaps in opposing traffic, resulting in higher turning speeds and increased conflicts. Also, conflicts result when vehicles make right turns. In that case, the vehicle that is making the right turn is in the path of pedestrians who have the right-of-way. Straight through conflicts are possible when a pedestrian steps out into the roadway and is directly in the path of the vehicle going straight.

In Nevada, pedestrians crossing at midblock are not breaking any laws as long as they yield to traffic. In such a situation, pedestrian safety depends on many characteristics, such as the gap in the vehicular traffic stream, pedestrian behavior, light condition, and geometrics of the street. Because no law exists to prohibit pedestrians from crossing at midblock, all midblock crossing areas should be considered as locations of potential conflict with vehicles. An exception is that sometimes there are large gaps in the traffic stream for pedestrians to cross, without any conflict.

Data Extraction

Data related to pedestrian crossing both at midblock and at the nearest intersection, vehicular movements, and conflicts were collected in April 1999. A 2-h period of time was assigned for each of the sites on a weekday during the daytime. Three trained crew groups were present at the sites. While one of the groups was counting the number pedestrians crossing, another was recording traffic volumes. At same time, a video camera was set up focusing on pedestrians who were crossing the street, to record their behavior and any conflicts with vehicles. For the 2-h period for each selected site, the number of pedestrians crossing at each intersection and the proximate midblock location (within 300 ft) were observed. The pedestrians' movements were videotaped. Interviews were conducted to identify a midblock pedestrian's origin and destination, purpose for crossing, and whether he or she was a local resident or tourist. All these investigations were conducted simultaneously during the 2-h period. The exact number of pedestrians using the crosswalks of the nearest intersection and of those crossing at midblock was respectively counted for each selected area. The following list describes the data extracted:

- Pedestrian movements: Pedestrian volumes in the 2-h period were recorded at the legs of the selected intersections and the nearby midblock locations. Also, actions that were considered to be pedestrian conflict with vehicles or vice versa were recorded. Those actions included (1) pedestrians crossing at one leg of the intersection, conflicting with right-turn or left-turn vehicles, and (2) pedestrians crossing at midblock near the intersection, making the vehicles slow down or stop.
- Vehicle movements: The total volumes of vehicles that fed into the approach at the leg of selected intersection. For example, for an approach located on the north of an intersection, the movements considered were eastbound traffic left turning, westbound traffic right turning, and northbound through traffic. At midblock, the total traffic equals the sum of the three types of movements. The following vehicle violations were extracted from the field observation: vehicles not yielding to a pedestrian when the pedestrian has right-of- way.
- Conflicts: For this study, three types of pedestrian–vehicle conflicts at an intersection were identified as discussed previously: (1) left-turn conflicts, (2) right-turn conflicts, and (3) straight-through conflicts. Midblock conflicts are observed when a pedestrian who is crossing makes vehicles slow down or stop, or when a vehicle approaching makes pedestrians stop crossing or hesitate to cross.

The literature review indicated that most studies measure pedestrian safety on the basis of "occurrences (conflicts) per unit of exposure" (*29*). Typically for conflicts, the units of exposure are calculated as the product of the number of pedestrian crossing volumes and the number of vehicles on potential conflict trajectories (left, right, and through movements across the location at which pedestrians cross the street), as shown in Equation 2:

$$E = P * V \qquad (2)$$

where

E = units of exposure,
P = pedestrian crossing volume, and
V = number of vehicles on potential conflict trajectories.

In calculating indicators of pedestrian safety, the exposure term forms the denominator. The numerator consists of conflicts. Pedestrians that affect vehicles are expressed in terms of violations per 100 pedestrians (all midblock crossing and crossing against signal), whereas vehicle violations are expressed in terms of violations per 100 vehicles (not yielding to the pedestrian when the pedestrian has right-of-way), shown in Equations 3 and 4.

$$P_{AV} = \frac{P_v}{P} * 100 \qquad (3)$$

where

P_{AV} = proportion of pedestrians affecting vehicles,
P_v = pedestrian–vehicle conflicts, and
P = pedestrian crossing volumes.

$$V_{AP} = \frac{V_v}{V} * 100 \quad (4)$$

where

V_{AP} = proportion of vehicles affecting pedestrians,
V_v = vehicle–pedestrian conflicts, and
V = vehicle volumes.

The difference between crossing at intersection crosswalks and at midblock locations was examined by determining whether a reduction of pedestrian–vehicle conflicts is more significant for a pedestrian crossing at an intersection than for one crossing at midblock.

Computation of Wilcoxon Signed Rank Test

For the 24 selected sites, there were 12 sample points of data at intersections, and there were another 12 sample points of data at midblock. These sample points were used for statistical analysis to test the difference of the two crossing types. The analysis involved a statistical comparison of the observations made at the intersection crosswalk and at midblock. If the statistical analysis indicated that the observations were significantly different, then it could be concluded which type of crossing is safer.

The analysis was conducted in two steps. First, the overall rates of pedestrian and vehicle conflicts were estimated for each of the selected sites. Total pedestrian and vehicle conflicts were summed at each of the specific sites, and then divided by the total units of exposure shown in Equation 5. The result is defined as the conflict rate, R_c.

$$R_c = \frac{P_v + V_v}{E} \quad (5)$$

where

R_c = conflict rate (conflicts per unit of exposure),
P_v = pedestrian–vehicle conflicts,
V_v = vehicle–pedestrian conflicts, and
E = units of exposure.

The conflict rate is an indicator of safety. Therefore, pedestrian versus vehicle conflicts per 1 million exposures at midblock locations (R_{c-m}) is an indicator of midblock pedestrian crossing safety. Pedestrian versus vehicle conflicts per 1 million exposures at intersection (R_{c-i}) is an indicator of pedestrian crossing safety at intersection. R_{c-m} and R_{c-i} for the 12 sites are shown in Columns 2 and 3, respectively, in Table 3.

Second, statistical tests were performed to determine if the changes were significant. It should be noted that this test does not use the conflict rates, but instead uses the rank order of the differences between pairs of observations. This is shown in Table 3. D is the differences between R_{c-m} and R_{c-i} · $|D|$ is the positive value of D. Rank $|D|$is the $|D|$value order from the first to the last of the data set in ascending order. Sign D represents the sign of D value whether positive (+) or negative (−). Thus, because the rank order of differences between pairs of observations is used, large differences in conflict rates do not necessarily result in significant differences using the Wilcoxon Signed Rank test.

The result of a statistical test of hypothesis is frequently expressed in terms of P-values. In general, the P-value for an observed value of the test statistic is the probability under the H_0 (null hypothesis) of obtaining a sample result as extreme as that observed in a particular direction, as indicated by the one-sided alternative. The P-value to be used to reach a decision depends on the acceptable error rate α (small number usually $\alpha = 0.05$). H_0 is rejected when the P-value < α. The Wilcoxon Signed Rank test statistic is defined as either

T_+ = sum of positive ranks (sum all positive Rank $|D|$), or
T_- = sum of negative ranks (sum all negative Rank $|D|$).

TABLE 3 Calculations for Wilcoxon Signed Rank Test

Order	R_{c-m}	R_{c-i}	$D=R_{c-m}-R_{c-i}$	$\|D\|$	Rank $\|D\|$	Sign D
1	45.6	64.0	-18.4	18.4	6	-
2	42.1	40.0	2.1	2.1	1	+
3	62.8	36.4	26.4	26.4	7	+
4	123.4	58.1	65.3	65.3	11	+
5	82.6	28.3	54.3	54.3	10	+
6	79.9	73.7	6.2	6.2	3	+
7	142.8	30.8	112.0	112.0	12	+
8	87.5	45.1	42.4	42.4	8	+
9	61.7	53.9	7.8	7.8	4	+
10	131.9	175.9	-44.0	44.0	9	-
11	64.7	52.0	12.7	12.7	5	+
12	52.1	54.7	-2.6	2.6	2	-

Under the null hypothesis here, it is expected that the sum T_+ of the ranks of observations that were originally positive is about equal to the corresponding sum T_- of the ranks for the negative observations. Therefore, it is assumed that the distribution of differences is symmetric and the Wilcoxon signed rank test is performed. Let D denote the midblock crossing conflict rate minus the intersection crossing conflict rate ($R_{c-m} - R_{c-i}$). M_D is the median of the population of differences D. The appropriate hypothesis set is that if there is no significant difference between R_{c-m} and R_{c-i}, accept the null hypothesis, $H_0 : M_D = 0$. Otherwise, if there is significant difference, reject the null hypothesis, $H_1 : M_D > 0$, given that reduced conflict rate is anticipated after treatment.

Table 3 shows the differences D, their absolute values $|D|$, and the ranks of $|D|$. The computed values of the test statistics are $T_+ = 61$, $T_- = 17$, and the corresponding one-tailed P-value is 0.046, which is less than α ($\alpha = 0.05$). Thus, the null hypothesis is rejected. Therefore, it could be concluded with 95.4% confidence that potential conflicts when pedestrians cross at intersections are less than when they cross at midblock locations.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn from the statistical tests regarding the general characteristics of MBPCs in the Las Vegas metropolitan area:

1. The proportion of males involved in MBPCs exceeds the male proportion in the general population.
2. The proportion of children involved in MBPCs is higher than the proportion of children in the general population.
3. Males are more likely to be involved in MBPCs during hours of darkness than are females.
4. The adult males involved in MBPCs during darkness are a significant majority of all males involved in MBPCs.

5. The percentage of male and female children involved in MBPCs is almost identical to that of the percentage of males and females in the adult population.

6. Males are more likely than females to be involved in alcohol use–related MBPCs [driving under the influence (DUI)].

7. The proportion of MBPCs with alcohol involvement exceeds the proportion of alcohol involvement crashes for all vehicular crashes.

8. The proportion of DUI-related MBPCs in darkness exceeds the proportion of all MBPCs during darkness.

9. The proportion of MBPCs during darkness that involved alcohol use is greater than the proportion of daylight MBPCs that involved alcohol use.

10. The proportion of alcohol-related MBPC fatalities exceed the proportion of all roadway fatalities that are alcohol related.

The following observations are derived from the analyses of MBPC characteristics:

1. The spike peaks of MBPCs at the 150-ft distance from the intersection were suspected to be caused by the high number of corner strip mall driveways situated at this distance, based on subdivision regulations pertaining to the minimum distance from corners to driveway access points.

2. The exploration of time with respect to midblock pedestrian crashes reveals some general trends. The overall peak is on Fridays from 5:00 to 6:00 p.m.

The results from the nonparametric statistical Wilcoxon Signed Rank test indicate that a pedestrian who is crossing at an intersection has a lower conflict potential than a pedestrian randomly crossing at midblock, with a statistical significance of 95.6%. However, this result does not imply that a pedestrian crossing at an intersection has no conflicts.

In interpreting the findings of this research, one should consider the following points:

1. Pedestrians crossing at intersections do not always have the right-of-way. Unfortunately, sometimes they were crossing against the signal. Under such circumstances, potential conflicts occurred.

2. Even though a pedestrian was crossing with the right-of-way, right-turning vehicles that should yield to pedestrians and left-turning vehicles with permitted turn phasing still have potential conflicts with pedestrians.

3. In Nevada, a pedestrian crossing at midblock is not breaking any laws as long as he or she yields to traffic. In such a case, the pedestrian's safety depends on many characteristics. One of them is the gap in the vehicular traffic stream, for example, if the gap is big enough, there is no conflict at all when a pedestrian is crossing. Other important factors include pedestrian behavior as a function of age and physical ability, light conditions, geometrics of the street, and others.

The results of this paper may be validated later by conducting a larger-scale study with a large sample size. To facilitate this sort of study for further analysis, the placement video cameras or detectors are recommended at selected locations with high concentrations of midblock crossings. The crosswalks selected at the nearby intersections must be recorded as well.

Because there are no data available for pedestrian crossing volumes at midblock crosswalks, it is not feasible to compare midblock crossing safety between crossings with and without crosswalks. A future study should conduct such an analysis.

Countermeasure programs that need to be evaluated using the methodology presented in this paper include barriers applied, marked crosswalks, pedestrian crossing detectors combined with marked crosswalk, and in-pavement lighting.

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