Pedestrian Scramble Signal in Chinatown Neighborhood of Oakland, California

An Evaluation

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In 2002 the city of Oakland, California, implemented a scramble signal at the intersection of 8th and Webster Streets. Scrambles are traffic signals that give pedestrians exclusive access to an intersection by stopping vehicular traffic on all approaches, allowing pedestrians to cross diagonally or conventionally. The primary objective of this evaluation was to determine whether the installation of the pedestrian scramble at this location increased pedestrian safety. An analysis was conducted of pedestrian–vehicle conflicts and pedestrian violations occurring at the intersection before and after the signal was modified, and pedestrians were surveyed to ascertain public attitude toward and comprehension of the change. The modification to scramble signal phasing at the intersection resulted in a statistically significant decrease in conflicts between pedestrians and vehicles and a statistically significant increase in pedestrian violations. In general, pedestrians understood the change in the way the intersection operated and were accepting of the change. These results suggest that the scramble has been effective overall in improving safety conditions at the site. The increased number of violations occurring despite decreased conflicts is in part due to a proportion of pedestrians who cross illegally on the "safe side" crosswalk (i.e., the crosswalk parallel to moving traffic in which there are no opportunities for conflicts). It is important that the scramble signal be monitored over time to quantify the extent to which reduced vehicle–pedestrian conflicts associated with the scramble translate into measurable reductions in pedestrian injuries and fatalities.

A pedestrian scramble, a type of traffic signal phasing, was implemented at the intersection of 8th and Webster Streets in the Chinatown neighborhood of Oakland, California, in 2002. Developed in the 1950s, scramble phasing gives pedestrians an exclusive signal phase at an intersection after vehicle traffic on all approaches is stopped. Pedestrians can make diagonal crossings (hence the term "scramble") as well as conventional crossings without coming into conflict with turning vehicles.

Although limited, published evaluations of scramble phasing suggest the potential for increased pedestrian safety as long as vehicles and pedestrians are compliant with the signals. However, both pedestrians and vehicles experience increased delays because the cycle length is increased and the green ratio is decreased for both pedestrians and vehicles. Studies indicate that excess delay may reduce pedestrian compliance, which may negate the expected safety benefits of scramble phasing.

The implementation of scramble phasing at 8th and Webster provided the opportunity to study the effectiveness of the scramble system at that site and to produce recommendations concerning replication of the scramble system elsewhere.

REVIEW OF PUBLISHED EVIDENCE

The literature on the effectiveness of pedestrian scramble signals is mixed, with outcomes depending on the characteristics of the intersections evaluated. The few published evaluations of scramble signals have generally found that in cases in which vehicle volumes are high, scramble phasing has reduced crashes and traffic conflicts. Moreover, in cases with high pedestrian volume conflicting with turning vehicles, scramble phasing has been shown to be especially effective. For example, using a 10-year pre- and posttest design, Vaziri documented a significant reduction (66%) in pedestrian–vehicle crashes at high-volume pedestrian locations in Beverly Hills, California, after introduction of scramble phasing (*1*). Vaziri noted that before the signals were modified, turning vehicles were often not able to complete their turns because of the extremely high conflicting pedestrian volumes and that crashes were occurring as a result. The dramatic reduction in collisions as a result of the implementation of scramble phasing suggests that intersections with high volumes of pedestrians and turning vehicles may benefit from pedestrian-scramble phasing.

In a study of three scramble intersections in Sweden that used conflicts between pedestrians and vehicles as a surrogate measure for crashes, Garder found that scramble signals improved safety at locations only when the proportion of pedestrians crossing against the red signal was low (*2*). Garder suggested that scramble phasing may potentially increase the risk for pedestrians by causing an increase in the red-walking frequency because the proportion of total cycle time allotted to pedestrians to cross an intersection decreases under the scramble system. Abrams and Smith indicated that "if violations are frequent, the use of scramble timing may be more of a safety hazard than an accident prevention measure" (*3*).

In a study of urban intersections in Israel, Zaidel and Hocherman found that at locations with low vehicle volumes, scramble phasing made little difference in pedestrian safety (*4*). The authors noted that in such situations, pedestrians did not necessarily wait for the exclusive pedestrian "Walk" phase, choosing rather to cross during gaps in traffic regardless of the signal indication. Thus, at low traffic volumes "it is likely that non-compliance will be relatively high at [scramble crossings] when traffic volume is low, because of larger delays and perceived unjustification for waiting" (*4*). Zegeer and Cynecki also noted that high rates of violations were associated with

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low traffic and low pedestrian volumes at signalized intersections (*5*). Abrams and Smith reported that observations from several scramble intersections revealed that violations were more frequent on narrow streets. Zegeer and colleagues (*6*) and Zaidel and Hocherman concluded that exclusive pedestrian signal phases appear to be most advantageous at locations with high volumes of both pedestrians and vehicles. Abrams and Smith's findings indicate that scramble phasing may not be appropriate for narrow intersections.

When documented, the lack of effectiveness of scramble phasing has been attributed to poor pedestrian compliance with pedestrian regulations. These results suggest that scramble phasing may not be effective in situations with low vehicle volumes or narrow intersections and that to be effective, intersections with low pedestrian compliance may need additional countermeasures to increase compliance and consequently to increase the effectiveness of the pedestrian scramble signal.

STUDY SITE

Site Characteristics

The intersection of 8th and Webster is a busy downtown intersection in Oakland's Chinatown. Webster runs primarily north and south, and 8th Street runs east and west. In addition to carrying local vehicle traffic, both 8th and Webster Streets are major thoroughfares that carry traffic between Oakland and Alameda under the Oakland Estuary channel. The entrance to the Webster Street Tube, which connects Oakland to Alameda, is a block south of 8th and Webster at 7th Street. Figure 1 is a diagram of the study intersection. Eighth Street is a one-way westbound street with four travel lanes and parallel parking on both sides. Eighth Street's lane assignments at Webster are left only, left–through, and two through lanes, with the two left-turn lanes facilitating traffic flow to the Webster tube. Webster is one-way southbound with parallel parking on both sides, also with dual turning lanes to facilitate vehicles turning right onto 8th Street. There are pedestrian crosswalks on all four legs of the intersection; however, there are no crosswalks for the diagonal movements that have been permitted since the scramble was implemented. Painted striping on the ground was extended a few feet into the intersection on the diagonal to indicate pedestrians may cross diagonally.

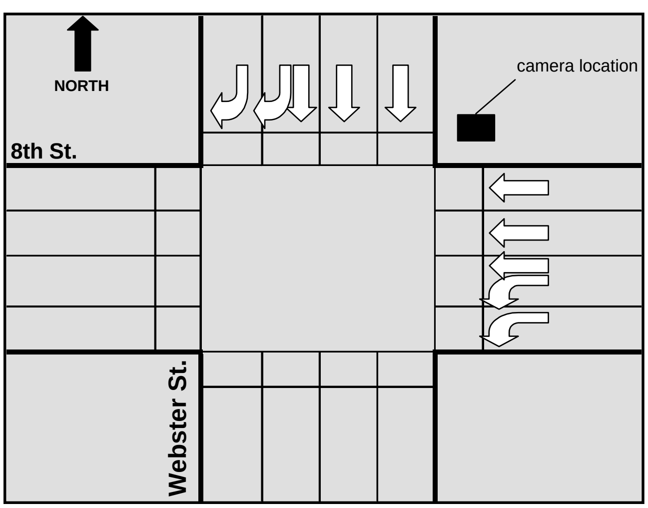

FIGURE 1 Intersection diagram.

In addition to relatively large vehicle flows throughout the day (combined hourly flows on both approaches at the intersection exceeded 4,000 vehicles per hour for each observation period studied), the site also experiences high pedestrian volumes (combined flows for each leg totaled more than 3,000 pedestrian crossings per hour at peak times). The site is also characterized by heavy turning-vehicle volumes (turning volumes ranged from 31% to 36% of total vehicular volume during the time periods observed). The intersection is in the heart of Oakland's Chinatown, a major destination attracting shoppers and tourists. Commercial and office buildings front directly onto the sidewalk on all four corners, and the vicinity immediately surrounding the intersection experiences high volumes of pedestrian traffic as a result of the concentration of commercial activity throughout the area. The high volumes of pedestrians at the intersection, coupled with high volumes of through and turning vehicular traffic, create conditions for conflicts between pedestrians and vehicles.

The signal phasing before the countermeasure was implemented was as follows for 8th street: vehicle green 17 s; vehicle yellow 3 s; all red 1 s; pedestrian "Walk" 7 s; pedestrian flashing "Don't Walk" 8 s; and pedestrian "Don't Walk" 6 s. The signal phasing before the countermeasure was implemented was as follows for Webster Street: vehicle green 20 s; vehicle yellow 3 s; all red 1 s; pedestrian "Walk" 10 s; pedestrian flashing "Don't Walk" 9 s; and pedestrian "Don't Walk" 5 s. The signal phasing after the countermeasure was implemented is as follows for 8th Street: vehicle green 25 s; vehicle yellow 3 s; all red 1 s; pedestrian "Walk" 10 s; pedestrian flashing "Don't Walk" 18 s; and pedestrian "Don't Walk" 3 s. The signal phasing after the countermeasure was implemented is as follows for Webster Street: vehicle green 26 s; vehicle yellow 3 s; all red 1 s; pedestrian "Walk" 10 s; pedestrian flashing "Don't Walk" 18 s; and pedestrian "Don't Walk" 3 s. Turns on red were permitted before the scramble was implemented. After implementation, turns on red were initially permitted during vehicle phases only; however, they were later prohibited completely between 7 a.m. and 7 p.m.

Before the scramble, pedestrians crossed concurrently with vehicles on the parallel approach. With scramble signalization, pedestrians are no longer permitted to cross during the vehicle phases and may cross only during the exclusive pedestrian phase.

The intersection of 8th and Webster is part of a coordinated system of traffic signals. By the doubling of the prescramble cycle length, the scramble signalization scheme preserves the offset, allowing vehicles progressing to 8th and Webster from upstream intersections to pass through the intersection with minimal delay, while lengthening the cycle to accommodate the pedestrian-exclusive phase.

When the signal phasing was changed, additional pedestrian signals were placed at each corner of the intersection facing the diagonal direction. The change in signalization reduced the green ratio (the length of the green indication divided by the cycle length) and therefore the vehicle capacity of each approach. For example, vehicles approaching the intersection on 8th Street had a green ratio of 17/45 = 0.38 before the scramble and a green ratio of 25/90 = 0.28 with the scramble. The green ratio ("Walk" time) for pedestrians decreased from 0.38 to 0.11. However, this change has different effects on the pedestrian green ratio depending on the movement. For example, the subset of pedestrians on 8th crossing Webster experienced a drop in green ratio from 0.16 to 0.11, while those on Webster crossing 8th experienced a decrease in green ratio from 0.22 to 0.11. The green ratio is related to delay. Assuming pedestrian arrivals are uniform, the green ratio represents the probability the pedestrian will be able to proceed across the intersection with zero delay. A detailed analysis and calculation of the average delay is outside the scope of this evaluation. However, this brief explanation should illustrate that scramble-signal timing does not minimize delay to users, nor does it maximize the vehicle capacity of the intersection, common objectives of signal timing.

Although the scramble increases pedestrian delay by varying degrees, it reduces the distance pedestrians must travel, another measure of convenience. Using a computerized simulation, Marsh found that scramble signalization would have resulted in a 5% to 7% reduction in distance traveled by pedestrians at several intersections in New Zealand (*7*). Using pedestrian volumes at 8th and Webster recorded after the scramble was implemented, it was found that the scramble reduced the distance traveled by pedestrians by 13% on average.

Another objective of signal timing, the reduction of collisions, was the focus of this study. By separating vehicles and pedestrians into completely separate phases, scramble timing seeks to reduce collisions at the expense of an increase in delay.

Prescramble Conditions

Collision History

Statewide integrated traffic records system (SWITRS, a database of information abstracted from motor vehicle traffic collision reports received from local police and sheriff jurisdictions in California) data were used to document the recent collision history for 8th and Webster. Reports covering 1996 through 2001 listed five collisions involving pedestrians, and all were within 6 ft of the intersection. Three involved injuries, and one was a fatality.

Site Conditions

Before implementation of the scramble system, observations of the intersection indicated several conditions dangerous to pedestrians. The following observations were made during visits to the site on weekday afternoons during the commute peak and on Saturday afternoons.

- Pedestrians leaving curb before signal. Vehicles turning during the green phase (i.e., the westbound left from 8th onto Webster and the southbound right from Webster onto 8th) conflicted with concurrent pedestrian movements. Pedestrians often stepped out beyond the curb, perhaps in an effort to claim the crosswalk before the "Walk" indication appeared. Those who stepped off the curb generally stayed within a few feet of the curb, but they may not have been safe from a turning vehicle if it sharply cut the corner. At the start of the parallel green indication for vehicles and Walk phase for pedestrians, conflicts occurred.
- Vehicle encroaching onto crosswalk. Vehicles turning on red also conflicted with pedestrian movements. These vehicles would often encroach on the crosswalk to have a clear line of vision. This forced pedestrians to wind their way around turning vehicles that had stopped in one or two lanes.
- Vehicles experiencing delays. Vehicles turning left from 8th Street onto Webster often waited through an entire green interval before turning. Often when pedestrian travel was heavy, the vehicles in the far left-turn-only lane and the shared left–through lane could clear the intersection only after their signal turned red. This often caused conflict with southbound vehicles on Webster.

The objective of scramble phasing at 8th and Webster was to eliminate these types of conflicts.

Postscramble Conditions

The intersection was observed immediately after the scramble phasing was implemented (on April 29, 2002) as well as several months later. The scramble's implementation was accompanied by extensive public outreach both immediately before and just after the changes were made. In advance of the scramble's implementation, multilingual brochures were distributed explaining pedestrian safety, driver safety, and the changes that would take place with the scramble. Additionally, workshops and presentations were conducted at various locations throughout the community before the scramble's activation. Immediately following implementation, trained volunteers stood at the four corners of the intersection and handed out informational brochures while verbally giving pedestrians tips on crossing the street safely. This effort lasted about 6 weeks following the change. Additionally, law enforcement efforts were increased at the intersection during peak times. Since scramble phasing does not exist elsewhere in the vicinity of 8th and Webster, it was possible that the new system could cause confusion for both motorists and pedestrians. Actions taken to reduce confusion likely had the effect of reducing instances of pedestrian noncompliance and the number of conflicts with vehicles that might have occurred otherwise.

During observations made during the first month after activation of scramble phasing, the following was noted:

- Diagonal crossings. Pedestrians took advantage of the opportunity to cross diagonally, even without painted crosswalks to encourage this movement.
- Vehicle movements facilitated. The new phasing facilitated movements of turning vehicles from both approaches. Before installation of the scramble, conflicts between pedestrians and turning vehicles were common, restricting the flow of turning vehicles.

Nevertheless, problematic conditions were observed during this first month.

- Vehicles encroaching on crosswalk. Vehicles on 8th Street tended to anticipate their green phase after the opposing vehicle green phase on Webster, so they tended to roll forward, at times encroaching on the crosswalk at the beginning of the pedestrian phase. Indeed, general confusion about which phase came next was observed on the part of both vehicles and pedestrians. Months later, this appeared to have become less of a problem.
- Pedestrians walking against "Don't Walk" signal. Some pedestrians would walk on the parallel vehicle green indication against the "Don't Walk" signal, taking their cues from the vehicle signal rather than the pedestrian signal. Because of the presence of volunteers, this pattern of pedestrian movement was probably greatly reduced in the period immediately after the scramble was implemented. Many instances of pedestrian noncompliance observed during the postscramble observation periods were of that type.
- Pedestrians entering during flashing "Don't Walk" phase. A number of pedestrians began walking against the flashing "Don't Walk" indication. Although this pedestrian behavior was frequently observed before the scramble signal, the risks of such behavior are now more serious because pedestrians could be caught in the center of the intersection when the signal turns green for vehicles. In one instance, we observed four pedestrians (two elderly adults and one person pushing another in a wheelchair) caught in the middle of the intersection with their backs to opposing traffic when the vehicle green phase began on Webster.

• Vehicles turning during pedestrian phase. When the scramble was initially implemented, signs posted at the intersection for vehicles stated, "No Turn When Ped Crossing," which may have been confusing to vehicle drivers. The intent was that vehicles could turn on red except during the pedestrian phase. Occasionally, vehicles were observed turning during the pedestrian phase. Later, the signs were changed to "No Turn on Red, 7 a.m. to 7 p.m.," which is less ambiguous. No quantitative analysis of this change has been made in this evaluation.

METHODS

Research Plan

This evaluation assessed the performance of the scramble phasing at 8th and Webster in relation to three primary questions.

1. How does the scramble signal affect the rate of pedestrian–vehicle conflicts at the intersection?
2. How does the scramble signal affect the number of pedestrians violating the signal?
3. Has implementation of the scramble system at 8th and Webster been consistent with previous research findings concerning other scramble systems?

The primary objective of this evaluation was to determine whether installation of the pedestrian scramble at 8th and Webster Streets would increase pedestrian safety, that is, whether it would reduce the number of pedestrian–vehicle collisions. Because of the rarity of pedestrian–vehicle collisions, this study used pedestrian–vehicle conflicts as a surrogate measure for collisions. In general, traffic conflicts are actions that may lead to crashes, and they can provide measures of traffic safety when crash rates are not available. Even when crash data are readily available, detailed analyses are usually not viable because of the low frequency of such data. Glauz and colleagues recommend that conflict data not be used to predict crash rates, but rather be used as a surrogate measure of safety when crash data are insufficient (*8*).

By separating movement of vehicles and pedestrians into separate phases, the scramble system was expected to decrease the rate of conflicts between pedestrians and vehicles. One anticipated side effect of the signal change was an increase in pedestrian and vehicle delays at the intersection. Because some users might have switched routes in response to changes in trip time, vehicle and pedestrian traffic at the target intersection might be reduced. It was therefore necessary to control for pedestrian and vehicle volumes in the analysis of conflicts and violations.

For a traffic conflict to occur, the road users must be on a collision course or attempting to occupy the same space at the same time. The primary requirement of a traffic conflict is that the action of the first user places the other user on a collision path unless evasive action is taken (*9*). Garder defines a conflict as "an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged" (*2*). Since crashes and conflicts share many similar characteristics, crashes may be avoided by circumventing conflicts (*10*).

For the purpose of this study, a conflict was defined as a pedestrian or vehicle taking sudden evasive action to avoid a vehicle–pedestrian collision that would have occurred had the users' paths remained unaltered. The scramble's effectiveness was evaluated by reductions in the number of pedestrian–vehicle conflicts after its implementation using a pre- and postintervention design. In addition, because some previous studies of scramble phasing noted increases in pedestrian noncompliance with signals, changes in pedestrian compliance were also measured and analyzed. Last, results of a pedestrian survey were used to assess attitudes toward and understanding of the signal modification.

Data Collection

Video recordings of the intersection were taken before and after the pedestrian scramble was activated. Recordings were taken from an overhead vantage point with a stationary recorder. Video-based counts were used to obtain information about pedestrian and vehicle flow, pedestrian–vehicle conflicts, and pedestrian noncompliance with signals. The recordings were then scored manually for each of the variables of interest.

Video data were collected for several separate observation periods before the scramble's implementation and several times again 5 months after the scramble's implementation. Weather on each of the observation dates was sunny with mid-60°F to mid-70°F temperatures. The times of day for the study were chosen because they represented time periods of increased pedestrian activity. Three prescramble and three postscramble observation periods were selected for analysis. Video observation dates and times prescramble were as follows: Wednesday, 4/24/02, 12:00 to 1:00 p.m.; Wednesday, 4/24/02, 4:15 to 5:15 p.m.; and Saturday, 4/20/02, 11:00 a.m. to 12:00 p.m. Video observation dates and times postscramble were as follows: Thursday, 9/12/02, 12:00 to 1:00 p.m.; Wednesday, 9/11/02, 4:15 to 5:15 p.m.; and Saturday, 9/14/02, 11:00 a.m. to 12:00 p.m. It should be noted that postscramble observations were made several weeks after the initial increased public awareness and enforcement efforts had been discontinued.

The following describes the variables and methods of measurement for each variable. Three-minute count intervals were chosen as the unit of analysis for all of the count variables because 3 min was an integer multiple of the signal cycles for both pre- and postscramble, thus simplifying the conversion to comparable before- and after-implementation time intervals.

Pedestrian Flow

Manual counts by direction were conducted for each leg of the intersection. Pedestrians on each leg of the intersection were counted by direction of flow during each signal phase. The counts for each phase were then collapsed into 3-min count intervals. These counts allowed us to control the outcome variables for fluctuations in the number of pedestrians during the intervals observed.

Pedestrian flows recorded before and after the pedestrian scramble was implemented are not directly comparable. Pedestrians who previously would require two signal phases to reach the diagonal corner could, with the scramble in place now cross the intersection at a diagonal during one signal phase. Given the same number of pedestrians using the intersection during both the before and after periods, it would be expected that the postscramble pedestrian count would be lower compared with the prescramble count. Whereas a pedestrian wishing to reach a diagonal corner would previously have crossed in two phases, and been counted twice, this same pedestrian (now crossing diagonally) would be counted only once in the postscramble period. To make the recorded number of pedestrians directly comparable, the number of diagonal crossings would need to be doubled. But to ensure a conservative estimate of conflict reduction for the purposes of comparing the conflict rate per pedestrian pre- and post-scramble, the observed flow was used (i.e., the number of diagonal crossings was not doubled). Thus, the calculation of pedestrian flows refers to the actual number of crossings, not necessarily the actual number of pedestrians.

Vehicle Flow

Manual counts by movement (through, right, left) were conducted. Like pedestrian counts, vehicle counts were a control variable. Counts were taken from observation of the video footage using the same methods that were used for the pedestrian counts. Vehicle counts were categorized by approach and direction. For the purposes of data analysis, this allowed us to test the sensitivity of conflicts and violations to the total number of vehicles and the number of turning vehicles.

Pedestrian–Vehicle Conflicts

Manual counts of instances that fit the definition of conflict were conducted. Conflicts were classified by location (crosswalk) using 3-min intervals. Video recordings proved useful for this process because of the opportunity they gave to rewind and review events that were questionable, which would not have been possible using on-site observers only. Additionally, since collection of these data requires judgment on the part of the collector, the same observer scored the conflicts both before and after the pedestrian scramble was implemented. This helped to ensure consistency in the classification of conflicts across all observation periods. The reliability of this observer was subsequently tested by comparing his results with a sample of the same intersection video recordings scored by another observer. The correlation coefficient of the two sets of scores (by crosswalk and signal phase) was 0.69, suggesting fairly strong agreement between the two observers.

Pedestrian Noncompliance (Violations)

Manual count of pedestrians who begin crossing outside of “Walk” phase were conducted. The level of pedestrian noncompliance at the intersection was scored from counts of pedestrians entering the intersection after the flashing “Don’t Walk” phase began until the beginning of the next “Walk” phase. Similar to incidents of conflicts, incidents of pedestrian noncompliance (or violations) were categorized by location (crosswalk) by 3-min intervals.

Before implementation of the pedestrian scramble, the most common types of violations were pedestrians crossing just after the flashing “Don’t Walk” had begun. During the postimplementation period, pedestrians crossing with the parallel vehicle green indication rather than waiting for the exclusive “Walk” phase were most common.

Public Perception

Surveys were conducted. The principal objective of the pedestrian survey was to gain further understanding of the public’s perception of the scramble signal. A multilingual survey was administered to pedestrians approximately 6 months after the scramble was implemented. The survey was designed to determine how often pedestrians cross the intersection and their level of acceptance and comprehension of the signal timing change at the intersection.

Respondents were asked whether they were aware of the change in signal timing and, if so, they were asked to describe the change. They were also asked whether they perceived a longer or shorter waiting time to cross with the scramble and whether they felt safer or less safe crossing with the new system.

Other Outcomes

A number of other outcomes were not evaluated here. These include the study of nearby intersections for changes in vehicle or pedestrian volumes that might result from implementation of the pedestrian scramble at 8th and Webster. Likewise, if pedestrians who had previously used the intersection avoided the scramble intersection because of added delays or other perceived inconvenience, the safety benefits of the scramble may be reduced. Finally, the study of motorist violations of the signal in response to the change is warranted.

DATA ANALYSIS AND RESULTS

The strategy used for analysis of both conflicts and violations was to construct a model for each that included all variables expected to influence the outcome variables and then to eliminate any variables from each model that did not meet statistical significance (with $p \leq .10$).

Pedestrian–Vehicle Conflicts

There were a total of 6,823 pedestrian crossings and 77 conflicts in the 3 h of prescramble video footage chosen for analysis, and 6,356 pedestrian crossings and 35 conflicts in the 3 h of post-scramble footage. The outcome variable for pedestrian–vehicle conflicts was the conflict count per 3-min interval divided by the number of pedestrians per 3-min interval:

$$\text{conflict rate} = \frac{\text{number of conflicts}}{\text{number of pedestrians}} \times 1{,}000$$

Variables included in the final model were the treatment (pre- versus postimplementation of the pedestrian scramble) and the observation periods: weekday 12 to 1 p.m., weekday 4:15 to 5:15 p.m., and Saturday 11:00 a.m. to 12:00 p.m. (time 1, time 2, and time 3, respectively). The total number of vehicles, the number of turning vehicles, and the number of violations were not significant variables.

To evaluate these parameters a generalized linear modeling approach was used assuming a Poisson distribution (the probability function describes the probability of a certain number of random events occurring in a fixed time interval given an overall rate of occurrence) for the number of conflicts occurring in each time interval. A log link function was used to describe the relationship between the expected value of conflicts and the linear predictor model, assuming the following form:

$$\log(\text{conflict rate}_i) = \beta_0 + \beta_1 \times \text{treatment}_i + \beta_2 \times \text{time } 1_i + \beta_3 \times \text{time } 2_i,$$

where treatment is a dummy variable associated with the pre- or postscramble observation period, and time is a dummy variable associated with the time-of-day observation period.

As shown in Table 1, the presence of the pedestrian scramble (treatment) and the time period of observation had highly significant

TABLE 1 Pedestrian–Vehicle Conflicts

Model parameters for the analysis of conflict rate (n=120)				
Parameter	**Coefficient**	**Stand. Error**	**Chi-square**	***p*-value**
Treatment				
Pre	Referent	-	-	-
Post	-0.61	0.06	266.8	<0.0001
Time				
Time1 (wkday 12-1)	0.56	0.08	42.46	<0.0001
Time2 (wkday 4:15-5:15)	1.09	0.08	185.3	<0.0001
Time3 (Saturday 11-12)	Referent			

Least squares means estimates, conflict rate parameters		
Variable	**Conflict Rate Estimate**	***p*-value**
Pretreatment (pre-scramble)	2.465	<0.0001
Posttreatment (post-scramble)	1.851	<0.0001
Time1	2.171	<0.0001
Time2	2.695	<0.0001
Time3	1.607	<0.0001

effects on the conflict rate occurring at the intersection. The 95% confidence interval of the coefficient for the treatment variable was −0.495 to −0.733. Thus, the rate of conflicts per 1,000 pedestrians without the treatment (i.e., before the scramble) was between 1.64 and 2.08 times greater than the conflict rate occurring with the treatment (log inverse of the confidence interval for the coefficient is $e^{.495} = 1.64$, $e^{.733} = 2.08$). This is further illustrated by the least squares means estimates for the parameters, which are shown in Table 1.

The least squares means given by the model are the estimate of the natural log of the rate of conflicts. Table 1 provides these estimates for the rate of conflicts. The presence of the pedestrian scramble had the effect of decreasing the conflict rate at the intersection by almost 50%, controlling for the observation time period effect (estimates are $e^{2.465} = 11.8$ conflicts per 1,000 pedestrians in the prescramble period, and $e^{1.851} = 6.4$ conflicts per 1,000 pedestrians in the postscramble period).

Pedestrian Violations

Pedestrian violations were analyzed using a multivariate linear model. The dependent variable was the number of violations occurring in a 3-min interval. The significant independent variables (main effects) were the treatment (before or after implementation of the pedestrian scramble), the observation periods [weekday 12 to 1 p.m., weekday 4:15 to 5:15 pm, and Saturday 11 a.m. to 12 p.m. (time 1, time 2, and time 3, respectively)], and pedestrian volume. Additionally, an interaction effect between the time and treatment variables (time*treat) was found to be significant. Again, neither total vehicle nor turning vehicle volumes were found to be significant and consequently were not included in the model.

The linear model takes the following form:

$$\text{violations}_i = \beta_0 + \beta_1 \times \text{treatment}_i + \beta_2 \times \text{time } 1_i + \beta_3 \times \text{time } 2_i + \beta_4 \times \text{pedvolume}_i + \beta_5 \times \text{time*treat}_i$$

Table 2 shows the parameter values, standard errors, and levels of significance that were obtained using this procedure. Table 2 shows that the pedestrian scramble (treatment) had a significant effect on the number of pedestrian violations. Figures 2 and 3 illustrate the interaction effect on the least squares means estimates for the independent variables.

Figure 2 displays the least squares means estimates for violations pre- and posttreatment. An increase from 12 to almost 15 violations per time interval was observed. Figure 3 illustrates the interaction

TABLE 2 Model Parameters for Analysis of Violations

Parameter	Coefficient	Stand. Error	*t*-stat.	*p*-value
Treatment				
Prescramble	Referent	-	-	-
Postscramble	7.93	1.40	5.68	<0.0001
Time				
Time1 (weekday 12-1)	-6.47	1.45	-4.45	<0.0001
Time2 (weekday 4:15-5:15)	-1.42	2.32	-0.61	0.54
Time3 (Saturday 11-12)	Referent	-	-	-
Pedestrian volume	0.16	0.02	7.01	<0.0001
Time*treatment				<0.0001

The results of the analysis of the interaction parameters were

parameter	coefficient	st. error	*t*-stat.	*p*-value
Time1*treatment	-6.79	1.97	-3.44	0.0008
Time2*treatment	-7.76	1.92	-4.04	<0.0001
Time3*treatment	referent	-	-	-

NOTE: $n = 120$.

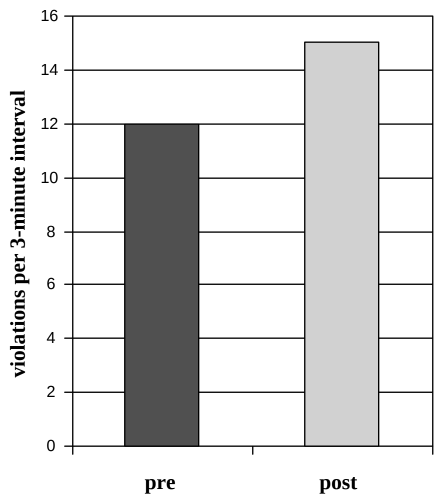

FIGURE 2 Least squares means, pedestrian violations.

effect between time period and treatment. From the figure, it can be seen that the highest pre–post difference occurs during the Saturday observation period. Figure 3 makes it clear that the difference during the Saturday time period is responsible for most of the difference observed in Figure 2. Thus, the analysis of violations demonstrates that more violations occurred after introduction of the pedestrian scramble, but that most of that increase was limited to a specific time period.

Public Acceptance

Public acceptance was assessed with survey data. Respondents varied by age and ethnicity, with the vast majority crossing the intersection of 8th and Webster on at least a weekly basis for a mix of purposes. In general, results indicate a positive attitude in the community toward the signal modification and a clear understanding of how the intersection now operates. Most respondents were aware of a change at the intersection. In detailed responses, most respondents exhibited the understanding that they could cross diagonally at the intersection but that they were no longer permitted to cross on the parallel vehicle green signal. For example, in their responses to the open-ended question asking what was different about the intersection, respondents who were aware of a change most commonly mentioned the new diagonal crossing or vehicles stopping on all approaches. Most respondents noticed that they waited longer to cross the scramble intersection, and most respondents reported feeling safer to cross the intersection with the pedestrian scramble.

In responses to open-ended questions, several respondents expressed concerns that they saw many pedestrians crossing with the vehicle green indication, that it took too long to wait for the pedestrian signal, or that a longer pedestrian crossing time was needed to cross the intersection safely. In contrast, the overall survey results suggest that the majority of pedestrians are not confused about how the intersection operates, even if some expressed confusion about the rationale for the modification or concerns about particular aspects of it.

DISCUSSION OF FINDINGS

Findings here demonstrate a significant decrease in the rate of pedestrian–vehicle conflicts at the target intersection after the pedestrian-scramble phasing was implemented, apparently increasing pedestrian safety at the site.

However, findings also demonstrate an increase in the number of pedestrian violations after implementation of the scramble, most notably during the Saturday midday observation period. These results, especially the dramatic increase in violations on Saturday, suggest decreased safety at the site. Furthermore, there may be important characteristics of Saturday pedestrian or vehicular traffic conditions that were not captured by the model that contributed to increased violations after the pedestrian scramble was implemented. One hypothesis is that because the neighborhood becomes more of a regional shopping trip attractor on Saturdays, the population of pedestrians observed using the intersection on Saturday is different from that using the intersection on a weekday, consequently leading to a larger increase in violations (controlling for pedestrian volume) during that observation period.

The decrease in pedestrian–vehicle conflicts despite an increase in pedestrian violations after introduction of the scramble suggests that the types of violations occurring with the scramble signal may not increase the violators' risk of being involved in a conflict. This is further supported by subsequent observations that on average, approximately 25% of the violations occurring in the scramble observation periods were "safe-side" crossings. Pedestrians crossing on the safe side are those crossing with the concurrent parallel vehicle traffic movement on the crosswalk where there are no conflicts with turning vehicles. In the case of 8th and Webster, this is the north crosswalk when vehicles on 8th have the green, and the east crosswalk when vehicles on Webster have the green. Safe-side crossings could

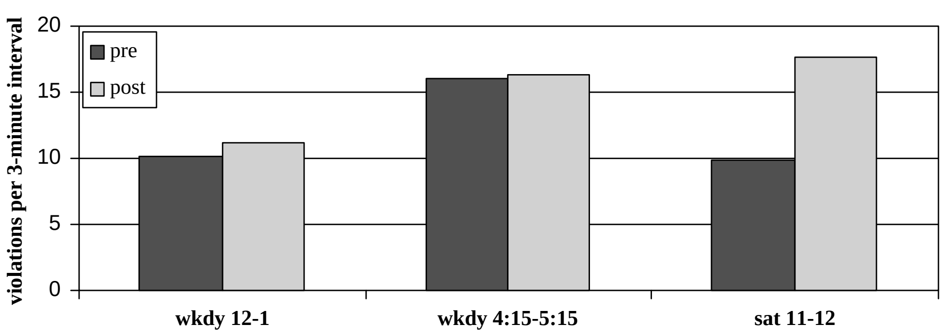

FIGURE 3 Interaction effect: treatment and time.

in part explain the seemingly contradictory decrease in conflicts and increase in violations.

Although some confusion and potentially dangerous conditions were observed in the time period shortly following the signal modification, the pedestrian survey, along with subsequent observations, indicated that in general, pedestrians have adapted to the change and understand how the intersection operates. It is important to note that extensive public outreach and education about the pedestrian scramble, as well as increased enforcement efforts in the time period immediately following the modification, certainly played important roles in the transition to the new system.

CONCLUSIONS AND RECOMMENDATIONS

Findings of this evaluation of scramble signalization at the intersection of 8th and Webster indicate that the scramble has reduced the number of pedestrian–vehicle conflicts at the intersection, although it has increased the instances of pedestrian noncompliance during the time periods observed. Over the long term the expectation is that the decrease in the rate of conflicts will result in reduced pedestrian–vehicle collisions at the intersection.

The decrease in conflicts is consistent with the findings of Zaidel and Hocherman and Zegeer et al., who found scramble phasing to be advantageous at locations with high volumes of both pedestrians and vehicles (*4, 6*). Although an increase in red walking occurred at 8th and Webster, this increase in violations was not accompanied by an analogous increase in conflicts [as predicted by Garder (*2*)]. These results suggest that other candidate intersections for scramble signals are those that have high pedestrian volumes coupled with high turning-vehicle volumes.

Although these results indicate that the introduction of scramble phasing has improved pedestrian safety by reducing conflicts, it is important to note that it is difficult to pass judgment on the scramble's overall value without a complete analysis of the effects of vehicular delay and route diversion.

The incorporation of pedestrian safe-side crossings into the scramble timing could potentially decrease the number of violations, and merits further study at this location. Permitting safe-side crossings would serve to reduce pedestrian delay while continuing to provide passage for pedestrians free of opposing vehicle movements. Additionally, since scramble signal timing seeks to eliminate conflicting movements from occurring simultaneously, a reduction in all types of violations through increased enforcement would reduce the opportunity for pedestrian–vehicle crashes to occur. On a final note, it is important that the scramble signal be monitored over time to quantify the extent to which reduced pedestrian–vehicle conflicts associated with the scramble translate into measurable reductions in pedestrian injuries and fatalities.

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