traffic behavior is extremely hazardous even under the best of circumstances. This is true even after training in a program that is both more intensive and more focused on critical behaviors than most [see Jones and Fleischer (9) for a full report].

CONCLUSIONS

Observations of critical pedestrian behavior have been shown to be highly reliable, provided (a) observations are limited to a small number of behavioral events at a time, (b) the behaviors are unambiguously defined, and (c) the observers are highly trained. Although the data reported were obtained on children, adult behavior can be coded as easily. If it is desired to look at other special behaviors, they can be carefully defined and substituted for any of those used here, since adding observational categories will overload the observers and destroy reliability. Training of observers must be continued until the index of agreement (Kappa) reaches a satisfactory level. With these provisos, this method of structured observation can provide the behavioral criterion necessary for the evaluation of pedestrian countermeasures.

REFERENCES

1. R. L. Dueker. Threat Detection Training Programs for Child Pedestrian Safety. Applied Science Associates, Valencia, PA, DOT-HS-339-3-726, 1975.
2. M. B. Snyder and R. L. Knoblauch. Pedestrian Safety: The Identification of Precipitating Factors and Possible Countermeasures. Operations Research, Inc., Silver Spring, MD, 1971.
3. R. L. Knoblauch. Urban Pedestrian Accident Countermeasures, Experimental Evaluation: Volume 2—Accident Studies. BioTechnology, Inc., Falls Church, VA, Final Rept., 1975.
4. M. H. Jones. Driver Performance Measures for the Safe Performance Curriculum. Traffic Safety Center, Univ. of Southern California, Los Angeles, Final Rept. DOT-HS-01263, March 1978.
5. M. H. Jones. A Real-World Bicycle Performance Measure. TRB, Transportation Research Record 739, 1979, pp. 26-29.
6. M. H. Jones and G. A. Fleischer. Evaluation of the California Passenger Safety Curriculum. Traffic Safety Center, Univ. of Southern California, Los Angeles, 1979.
7. J. Cohen. A Coefficient of Agreement for Nominal Scales. Education and Psychological Measurement, Vol. 20, 1960, pp. 37-46.
8. M. L. Reiss. Should the Young Pedestrian Be Considered a Handicapped Pedestrian? Paper presented at Conference on Pedestrians, TRB, New York, Sept. 11-15, 1977.
9. M. H. Jones and G. A. Fleischer. Evaluation of the California Pedestrian Safety Curriculum. Traffic Safety Center, Univ. of Southern California, Los Angeles, 1979.

Publication of this paper sponsored by Committee on Pedestrians.

Use of Pedestrian Conflict Analyses for Hazard Assessment in School Zones

Charles V. Zegeer, Dennis A. Randolph, Mark A. Flak, and Rathi K. Bhatacharya

The purpose of this study was to develop and test a traffic conflicts procedure to assist in the early identification of hazardous school-zone locations. Various pedestrian conflict types and severities were used to collect data and analyze 10 school-zone sites in the Rochester School District. Multivariate linear regression techniques resulted in high correlations between pedestrian conflict levels and site-related traffic and highway variables. A subjective danger index was developed based on various pedestrian conflicts and events. The 10 school-zone locations were priority ranked based on danger index and other conflict measures. A systematic flowchart procedure was used to help select site improvements based on conflict types, safety deficiencies, and corresponding safety improvements. Although pedestrian conflicts were found to be related to known hazardous conditions at the test sites, the relationship between pedestrian conflicts and pedestrian accidents has not been quantified. Further testing of accident-conflict relationships is recommended.

The interaction between pedestrians and motor vehicles results in a serious and costly toll of young lives each year. In the United States, the pedestrian fatality rate for young school children (5-14 years of age) is approximately 5 fatalities/100 000 population. Only the fatality rate for pedestrians over 65 years of age exceeds this rate. In addition, during 1977, there were approximately 1330 pedestrian fatalities among school children in the 5 to 14-year-old age group. An additional 34 000 pedestrians in this age group were injured (1). The school walking trip represents between 10 and 20 percent of the young pedestrian accidents, or 10 000-20 000 accidents annually (2).

Developmental factors have been found to affect a child's safe conduct in traffic. Among the factors are the following:

1. Misunderstanding by children regarding traffic rules and the physics of an automobile,
2. Lack of experience and limited judgment in traffic situations,
3. Restricted visibility due to a child's small size,
4. Limited powers of concentration, and
5. A child's tendency to be playful and impulsive (3, 4).

The vehicle and roadway also contribute considerably to the safety problem. One West Virginia study found that the most significant factors of influence on school-zone speeds were the approach speed limit, the distance of school buildings from the roadway edge, traffic volumes, and the length of school zones (5). The control of such vehicle speeds in school zones is often quite difficult. In one study, regulatory school signs with flashers (SCHOOL—25 MPH WHEN FLASHING) were evaluated in terms of speed reduction during flashing periods for 48 school zones. Average speed reductions were only 5.8 km/h (3.6 mph), and motorist compliance with the 40-km/h (25-mph) limit was only 18 percent (6).

Many safety engineers have found that adequate pedestrian accident data are usually not available for proper identification of specific hazardous school locations. Pedestrian accidents are extremely rare events and are virtually impossible to predict based merely on the accident history of a site. An extremely dangerous school zone may go unnoticed for years by school and highway officials if no pedestrian accidents have occurred. In many cases, no improvements will be made at such school-zone locations until a child is killed or severely injured by a motor vehicle. A methodology was needed to assist in the early identification of school locations that have a high potential for pedestrian accidents. Actions can then be made to reduce the chance of such pedestrian accidents. In many cases, the early detection of potential accidents can lead to a simple or low-cost improvement that will greatly improve pedestrian safety near a school.

At the direction of the school board of the Rochester School District, a study was undertaken during 1979 that had as its major objective the improvement of the safety of school trips on highways in the vicinity of local school areas. In order to attain this objective, a comprehensive traffic study was formulated to (a) analyze the existing and potential factors that contribute to the safety of the school trip, (b) identify school-trip safety needs on a districtwide priority basis, (c) recommend short- and long-range improvement programs, (d) develop cost estimates for improvements, and (e) identify possible funding sources to enable implementation of the recommendations.

One of the safety analysis techniques developed and used in the Rochester School study was a pedestrian conflict methodology. By use of this conflict technique, the type and severity of pedestrian hazards was determined by quantitatively recording vehicle and pedestrian actions and interactions in school zones. Three basic assumptions were used for developing a pedestrian conflict procedure for school zones. First of all, an accident that involved a motor vehicle and a child pedestrian is a catastrophic event and should be prevented, if possible, by identifying and correcting locations where such accidents are likely to happen. Second, in the absence of sufficient accident data, the observation of near accidents (potential accidents) and unsafe pedestrian actions can provide useful information concerning locational hazards and the need for safety improvements. Finally, a careful analysis of pedestrian conflict data at selected school zones also requires the use of other appropriate traffic and geometric information to assist in identification of locations and recommendation of appropriate safety improvements.

TRAFFIC CONFLICT PROCEDURES

Traffic conflicts are considered to be possible measures of accident potential and operational problems at a highway location. A conflict occurs when a driver violates a rule of the road or makes an aggressive movement. Conflict studies may be treated in terms of objective criteria. They allow for the collection of an adequate data sample in as little as a few hours of observation. Operational problems found in this way may be resolved before accidents occur. Conflicts also may be used to make quick evaluations of changes in road design, signing, signalization, and the environment.

In 1967, the first formal procedure was published for identifying and recording traffic conflicts at intersections. The technique was developed by Perkins and Harris of General Motors (GM) Corporation and is commonly referred to as the GM technique (7). In 1969, a procedural manual was written by Perkins to give additional information for the collection of conflict data (8). The GM technique has gained widespread acceptance in recent years, with minor modifications, and is the basis of conflict studies used by several highway agencies, including those of Washington, Virginia, and Ohio (9).

The GM technique identifies five major classes of traffic conflicts: (a) left turn, (b) weave, (c) cross traffic, (d) red-light violation, and (e) rear end. Within these broad categories, 23 specific conflict types are recorded on a standard data form. Three conflict types, defined by GM, are related to pedestrians (8):

1. Single vehicle-pedestrian conflict—A single vehicle slows or weaves to avoid a pedestrian who is crossing the roadway.
2. Pedestrian rear-end conflict—One vehicle closely follows another; the lead vehicle slows or stops to avoid a pedestrian who is crossing the street, and the vehicle following brakes or weaves to avoid the lead vehicle.
3. Weave pedestrian conflict—Two vehicles travel in adjacent lanes; the lead vehicle weaves to avoid an illegal pedestrian, thereby encroaching on the path of the vehicle in the adjacent lane, which causes it to brake or weave.

A conflicts procedure was developed in Kentucky in 1977 that allows for the collection of pedestrian violations and bicycle conflicts (10). All three types of pedestrian conflicts could possibly give an indication of potential accidents between vehicles and pedestrians. The later two conflict types may also provide information on the potential for vehicle-vehicle accidents. The three pedestrian conflict types and the other conflict types described above might be adequate for an overall conflict study at individual intersections; however, they were not considered to be sufficient for an analysis of pedestrian safety in school zones. Greater detail of pedestrian and vehicle actions are needed to better assess the level of pedestrian hazard.

DEVELOPMENT OF A METHODOLOGY

A preliminary field investigation was made at several school-zone locations in the Rochester School District during peak pedestrian periods. Notes were made as to the events that could signify a pedestrian safety problem. A total of 13 such conflicts and events were defined to be appropriate for further testing:

1. Vehicle slows or stops for pedestrian—A pedestrian crosses the street in front of an approaching vehicle, causing it to slow or stop; brakelights are observed to signify the slowing of the vehicle.
2. Vehicle slows or stops for previous pedestrian conflict—A vehicle following is forced to slow or stop for a lead vehicle that has slowed for a pedestrian.
3. Vehicle weaves for crossing pedestrian—A pedestrian crosses the street, causing an approaching vehicle to weave around him or her.
4. Vehicle brakes or weaves for standing pedestrian—A vehicle brakes or weaves around a pedestrian

who is standing next to the roadway waiting to cross the street.

5. Vehicle brakes or weaves for pedestrian walking on shoulder—A pedestrian walking either with or against traffic causes a vehicle to brake or weave.

6. Vehicle disregards crossing guard—A vehicle, passing through a school zone, disregards a stop indication by the crossing guard by swerving around children or the crossing guard.

7. Turn conflict—A vehicle turns into a driveway or side street and must slow for a crossing pedestrian.

8. Pedestrian runs across street—A pedestrian runs across the street as a car approaches, but the vehicle is not forced to brake or weave.

9. Pedestrian stops in street—A pedestrian maneuvers through traffic and must stop in the median or in the center of roadway to await an adequate gap before completing his or her crossing.

10. Traffic signal violation—A pedestrian crosses against the traffic signal at a signalized intersection.

11. False start across street—A pedestrian starts into the street and, realizing an error in judgment, must retreat to starting point.

12. Jaywalking—A pedestrian crosses the street in violation of appropriate crosswalk locations.

13. Total pedestrian volume crossing street—The number of pedestrians crossing the street within the shcool zone, where they may be exposed to approaching vehicles, is counted.

A standard data form was developed for the recording of these pedestrian conflicts and events, as shown in Figure 1. The first 11 categories of conflicts and events can be assigned a subjective rating based on its nearness to an accident. A routine conflict is a conflict that is judged to be not very close to an accident. A moderate conflict involves a quick maneuver by a vehicle or pedestrian, such as an abrupt vehicle deceleration or swerve, as subjectively rated by the observer. A severe conflict (near-miss accident) is an event where an accident is barely avoided due to a last-second reaction by a driver or pedestrian.

These three severities of pedestrian conflicts were defined to closely correspond to the time-to-accident (TA) or time-to-collision (TC) concept, as developed by Hayward in 1972 (11) and Hyden in 1975 (12). TA or TC is the time required for two vehicles (or a vehicle and a pedestrian) to collide if they continue at their current speeds and direction. A high TA (e.g., above 3 s) represents a small amount of danger since ample time is available to react and avoid a collision. A low TA (below 1 s) indicates that extreme evasion reaction is necessary to avoid a collision (13). In this study, a TA of approximately 1 s or less was termed a severe conflict and a TA of about 1-1.5 s was termed a moderate conflict. Conflicts that have a TA of greater than about 1.5 s were termed routine. Since conflict severities were classified subjectively, variation in TA among observers was estimated to be as high as 0.5 s.

At many school-zone locations, safety problems exist that are related to the school buses and vehicles that load or unload school children. A separate data collection form was developed to record conflicts and events in such situations as follows:

1. School bus passes—a count of the number of school buses that pass through the school zone,
2. School bus stops—a count of the number of school buses that stop in the school zone to load or unload school children,
3. Slow for bus conflict—the number of times that one or more vehicles must slow for a school bus in the school zone,
4. Stop for bus conflict—the number of times that one or more vehicles must stop for a bus in the school zone,
5. Illegal bus passes, same direction—the number of vehicles traveling in the same direction that unlawfully pass a stopped school bus,
6. Illegal bus passes, opposite direction—the number of vehicles traveling in the opposing direction that unlawfully pass the school bus,
7. Slow for loading or unloading vehicles—the number of events where one or more vehicles slows behind a vehicle that is loading or unloading a school child,
8. Stop for loading or unloading vehicles—the number of events where one or more vehicles stops behind a vehicle that is loading or unloading a school child, and
9. Weave for loading or unloading vehicles—the number of events where one or more vehicles weaves around a loading or unloading vehicle.

Figure 1. Data collection form for pedestrian events.

Location ________________ Observer ________ Date ______ Weather ______

Time		Slow or Stop for Ped.	Slow or Stop for Ped. Previous	Weave for Ped. Cross.	Brake or Weave—Ped. Standing	Brake or Weave—Ped. Walking on Shoulder	Vehicle Ignore Crossing Guard	Turn Conflict	Ped. Run Across Street	Ped. Stop In Street	Ped. Traf. Signal Violation	False Start Across Street	Jay-walking	Total Ped. Volume
Start	End													

1 = Routine, * = Moderate, ⊛ = Severe

DATA COLLECTION PROCEDURE

Data were collected at each approach to the school zone by trained observers during times of peak pedestrian activity. For example, if school activity began at 8:00 a.m. and ended at 2:55 p.m., data were collected from about 7:30 to 8:00 a.m. and from 2:50 to 3:30 p.m. Generally, 30-60 min of data per location each day was found to be representative of day-to-day pedestrian volumes and conflicts.

Data were normally collected in 5-min intervals, and a single observer was generally able to handle both forms for one direction of vehicle travel. Two observers are typically used to observe all necessary data during a counting period within the school zone. Care was taken to avoid double counting of pedestrian crossings and other events. The school zone was generally divided into two sections for counting purposes in order to resolve this problem.

Observers were stationed inconspicuously off the roadway edge to permit observation of the entire school zone. For unusually long school zones, where sight distance was limited, additional observers or extra counting periods were required and the school zone was separated into several segments. At least 30-60 min of useful data about pedestrian activity was considered necessary for these sites. Both morning and afternoon counting periods were desired, as well as any other activity times (e.g., lunch and recess) if appropriate.

As a general rule, data collection and analysis efforts represented a relatively small amount of time, amounting to approximately two to four person-hours per location. This will differ, dependent primarily on the pedestrian and vehicle activity, the length of the school zone, the duration of pedestrian activity, and the travel time to the site. Data analysis averaged only about an hour per site and varied, depending on data characteristics.

CONFLICT SUMMARIES

The 10 locations selected for collection of conflict data were thought to be particularly hazardous, as determined by (a) citizen complaints, (b) vehicle volumes and speeds at the locations, (c) volume of pedestrian street crossings, (d) level of existing pedestrian protection (crosswalks, crossing guards, and pedestrian signal phases), and (e) preliminary field inspections of all locations for possible locational deficiencies (such as sight-distance restrictions).

The 10 school zones are listed in Table 1 and include four elementary school zones, three junior high school zones, and three senior high school zones. Lengths of the school zones ranged from 169 m (550 ft) to 406 m (1320 ft). Data were collected during the spring of 1979 at peak pedestrian times, and the other pertinent information in the table includes the school name, street of the school zone, cross street, dates of data collection, and data collection times.

The number of routine, moderate, and severe conflicts for each event are given in Table 2 for each of the 10 school zones. The data collection times at each site ranged from 15 to 85 min. At most sites, each of the pedestrian activity periods lasted only 10-20 min, and only one to three days of such data were found to be necessary to represent the level of conflicts at a site. For the 10 locations combined, the most common events were the following:

1. Slow or stop for pedestrians—80 routine, 30 moderate;
2. Pedestrians running across the street—85 routine, 14 moderate;
3. Previous conflicts—43 routine, 5 moderate, 1 near miss; and
4. Pedestrian stopping in road—40 routine, 1 moderate.

Of the 1113 pedestrian crossings recorded, 255 were jaywalkers. Five near-miss accidents (severe conflicts) were observed at Reuther Junior High School in 30 min of data collection.

In order to compare numbers on an equivalent time basis, events were summarized by total number per hour per site (Table 3). The greatest number of crossings per hour occurred at Ewell Elementary (397) and at Reuther Junior High (258). Total conflicts per hour were also computed for each category of event and conflict. The most common events (per hour per location) were jaywalking (46.5), running across street (19.5), slow or stop for pedestrian (15.3), and stop in median (8.7). Not all types of conflicts and events were observed during the data collection periods.

Of the 10 school zones selected for this study, only one location (Woodward Elementary) had a problem with the loading and unloading activities of children near the

Table 1. Characteristics of school-zone test sites.

Section Number	School	Street	Cross Street	Section Length (m)	Date	Time
1	Reuther Junior High	Auburn	Culbertson-Weaverton	229	5-31-79 6-8-79	3:50- 4:00 p.m. 3:50- 4:10 p.m.
2	Rochester Senior High	Livernois	Walton toward Willowgrove	274	6-1-79 6-8-79	2:30- 2:45 p.m. 2:25- 2:40 p.m.
3	Rochester Senior High	Walton	Livernois toward Rockdale	244	6-8-79	2:25- 2:40 p.m.
4	West Junior High	Old Perch	Belle Vernon-Ansal	174	5-31-79 6-1-79	3:00- 3:20 p.m. 3:00- 3:20 p.m.
5	Woodward Elementary	Pine	Drace-Ferndale	229	6-5-79	2:55- 3:25 p.m.
6	Disco Elementary	23 Mile	E. Robinwood-W. Robinwood	168	6-7-79 6-7-79	8:40- 9:05 a.m. 3:05- 3:25 p.m.
7	Ewell Elementary	Shelby	23 Mile-Van Buren	174	6-6-79 6-7-79	8:00- 8:30 a.m. 3:05- 3:25 p.m.
8	Ewell Elementary	23 Mile	Shelby-Mile End	287	6-6-79 6-7-79 6-7-79	8:00- 8:30 a.m. 8:00- 8:30 a.m. 3:05- 3:25 p.m.
9	Van Hoosen Junior High	Adams	Mohawk-Potomac	402	5-31-79 6-5-79 6-8-79	2:35- 2:45 p.m. 12:15- 1:00 p.m. 12:15-12:45 p.m.
10	Adams Senior High	Tienken	Adams toward Medinah	317	6-8-79	12:15-12:45 p.m.

Note: 1 m = 3.28 ft.

Table 2. Summary of pedestrian conflicts and events by site.

School	Total Time (min)	Slow or Stop for Pedestrians R	Slow or Stop for Pedestrians M	Slow or Stop for Pedestrians, Previous R	Slow or Stop for Pedestrians, Previous M	Slow or Stop for Pedestrians, Previous N	Weave Around Pedestrians N	Pedestrians Run Across Street R	Pedestrians Run Across Street M	Pedestrians Stop in Median or on Centerline R	Pedestrians Stop in Median or on Centerline M	False Stop Across Street R	False Stop Across Street M	Crossing Against Signal or Jaywalking	Total Pedestrian Volume Crossing Street
1	30	5	8	5	2	1	4	29	2	6	1	6		56	129
2	30	10	19					15	11	29		2		85	85
3	15	2			2			9		3				11	11
4	40	5	1	1				20		2		5		73	102
5	30														77
6	45	4		1				9						8	43
7	50	11		6											331
8	80	41		30											299
9	85	2	2		1			3	1				1	20	34
10	30													2	2
Total	435	80	30	43	5	1	4	85	14	40	1	13	1	255	1113

Note: R = routine; M = moderate; N = near miss.

main school entrance. Ten events per hour were observed to involve vehicles unlawfully passing school buses. At the same site, 12 private vehicles per hour were noted loading or unloading children, which resulted in two conflicts per hour.

Relationships Between Conflicts and Other Variables

An ideal analysis would have been a comparison of the pedestrian conflict measures with pedestrian accidents at the school sites. This would have allowed for the determination of whether pedestrian conflicts are statistically related to pedestrian accidents at the test sites. However, since virtually no pedestrian accident data were available for analysis purposes, this was not possible.

Although such a conflict-accident analysis was not possible, conflict measures were compared with known hazards. For example, past experience suggests that the degree of pedestrian hazard may increase for a combination of variables such as many pedestrian street crossings, a high traffic volume, a low number of acceptable vehicle gaps, and high vehicle speeds. If a pedestrian conflict measure is found to be highly related to combinations of such known pedestrian hazards, then pedestrian conflicts can be considered to be a useful substitute for other subjective measures of pedestrian danger (under certain conditions). However, not all hazardous locations are also high-accident locations; the relationship between pedestrian conflicts and accidents is still unknown and should be tested.

To test the relationship between pedestrian conflicts and various traffic and pedestrian variables, stepwise multiple-regression analyses were used. The dependent variables tested included the following:

1. Total pedestrian conflicts per hour (C_t),
2. Routine pedestrian conflicts per hour (C_r),
3. Moderate pedestrian conflicts per hour (C_m), and
4. Severe pedestrian conflicts per hour (C_s).

The independent variables tested included the following:

1. Pedestrian crossing per hour (P),
2. Level of school (elementary, junior high school, and senior high school, using assigned numerical values for the three levels) (S),
3. Traffic volume per hour (V),
4. Number of acceptable vehicle gaps per hour (G),
5. Log (S),
6. Log (P),
7. Log (G),
8. Log (V),
9. Reciprocal of S,
10. Reciprocal of P,
11. Reciprocal of G, and
12. Reciprocal of V.

The analysis consisted of linear plots using the Statistical Package for the Social Sciences (SPSS) computer package. By use of a bivariate analysis technique, total conflicts, routine conflicts, and moderate conflicts were plotted separately against each of the other variables listed above. For total conflicts, the r^2 values ranged from 0.03 (plotted against log of V) to 0.52 (plotted

Table 3. Pedestrian conflicts and events per hour.

Section Number	Slow or Stop for Pedestrians	Slow or Stop for Pedestrians, Previous	Weave for Pedestrians	Pedestrians Run Across Street	Pedestrians Stop in Median or on Centerline	False Start Across Street	Jaywalking Cross Not At Crosswalk	Total Pedestrian Volume Crossing Street
1	26	16	8	62	14	12	112	258
2	58			52	58	4	170	170
3	8	8		36	12		44	44
4	9	2		30	3	8	110	153
5								154
6	5	1		12			11	57
7	13	7						397
8	31	22						224
9	3	1		3		1	14	24
10							4	4
Total	153	57	8	195	87	25	465	1485
Average	15.3	5.7	0.8	19.5	8.7	2.5	46.5	148.5

against 1/G). The r^2 values for routine conflicts ranged from near 0.00 to 0.40. For moderate conflicts, the best correlation was with 1/G, where the r^2 value was 0.79.

The second type of analysis was a multivariate, stepwise regression. In this analysis, the computer program was used to add the independent variables one at a time, in an attempt to explain the variance in the conflict values. Corresponding r^2 values were calculated at every level in the process and are shown in the table below.

Dependent Variable	Independent Variable	Stepwise r^2 Value
Total conflicts per hour	Reciprocal of G	0.52
	Log of P	0.64
	Reciprocal of S	0.82
	Log of V	0.83
Routine conflicts per hour	Reciprocal of G	0.40
	Log of P	0.58
	Log of S	0.79
	Log of V	0.83
Moderate conflicts per hour	Reciprocal of G	0.79

For total conflicts, four variables were included in order of importance with a combined r^2 of 0.83, as shown above. A best-fit equation was also found for total conflicts by using the reciprocal of G, log (P), reciprocal of S, and log (V).

For moderate conflicts, from 40 percent (using only one variable) to 83 percent (using four variables) of the conflict variation was explained (r^2 = 0.40-0.83). The equation for moderate conflicts (C_m) was also given as computer output. Very low interrelationships were found between independent variables in each analysis, which supports the validity of including several of the variables in the analysis.

This analysis showed that none of the defined variables alone can be used to accurately explain total or routine pedestrian conflicts. However, the value of vehicle gaps (1/G) correlates well with moderate conflicts (r^2 = 0.79). When several of the variables were combined, up to 83 percent of the variation in conflict numbers was explained for the test sites. However, care should be used in interpreting these results, due to the limited number of locations (only 10 sites) in the analysis. Different relationships might be expected if the data base is expanded or if a different data base is used. However, the analysis illustrated that pedestrian conflict measures are related to known site-related hazards for the sites tested.

Priority Ranking of Locations

A priority ranking of the 10 school-zone sites was desired based on the pedestrian conflicts and events. Thus, a single numerical value, which would include the combined effect of all severities of conflicts and other events, was necessary for each location. A priority ranking of the locations was developed based on an assessment of the danger level (danger index) of each type of event.

By use of a Delphi session, the weighting factors for each type of conflict was subjectively developed and input into the form of a model to be used to describe the danger level at a specific site. The events were grouped into five levels, including the following:

1. Severe conflicts (S),
2. Moderate conflicts (M),
3. Routine conflicts (R),
4. Jaywalkers (J), and
5. Legal street crossings (C).

Weighting factors were developed for the five levels of events based on average weightings assigned by the Delphi participants. A routine conflict was preestablished as having a weight of 1.0 in order to develop a basis for comparison, and weighting factors were individually assigned to the other four events.

The danger index (DI) based on pedestrian conflicts and events was developed as follows:

$$DI = 7.4(S) + 2.8(M) + 1.0(R) + 0.7(J) + 0.2(C) \quad (1)$$

where

DI = subjective danger index for a school-zone location based on the weighted conflicts and events at the location (in terms of weighted conflicts per hour),
S = hourly number of severe conflicts,
M = hourly number of moderate conflicts,
R = hourly number of routine conflicts,
J = hourly number of jaywalkers, and
C = hourly number of pedestrian crossings.

By using the DI equation, it is evident that a severe conflict is weighted as 7.4 times more serious than a routine conflict. A moderate conflict is 2.8 times more serious than a routine conflict, and jaywalkers and legal crossings are counted as 0.7 and 0.2 times a routine conflict, respectively. This equation allows for inclusion of various types of events to compare the suspected hazard of various locations.

Values of DI were computed for each of the 10 school zones, as given in Table 4. The top priority location was Livernois Avenue at Rochester High School, which had a DI of 399. The next two locations, in priority order, were Reuther Junior High School (DI = 356) and West Junior High School (DI = 141).

The use of subjective rating factors as developed for the DI (in the Delphi session) is not uncommon for high-

Table 4. Data summary for computation of DI and priority ranking.

Location Number	Conflicts per Hour: Routine	Conflicts per Hour: Moderate	Conflicts per Hour: Severe	Jaywalkers per Hour	Volume of Pedestrians, Excluding Jaywalkers	DI	Priority Ranking
1	102	26	10	112	146	356.4	2
2	112	60	0	170	0	399.0	1
3	56	8	0	44	0	109.2	4
4	50	2	0	110	43	141.2	3
5	0	0	0	0	154	30.8	8
6	18	·0	0	11	46	34.9	7
7	20	0	0	0	397	99.4	5
8	53	0	0	0	224	97.8	6
9	4	4	0	14	10	27.0	9
10	0	0	0	4	0	2.8	10

way priority ranking formulas. For example, virtually every state highway agency currently uses a methodology known as an adequacy rating (or sufficiency rating) for the priority ranking of highway sections for major reconstruction. Nearly all of these adequacy rating methods include subjective weighting factors for each highway and traffic variable in the formula.

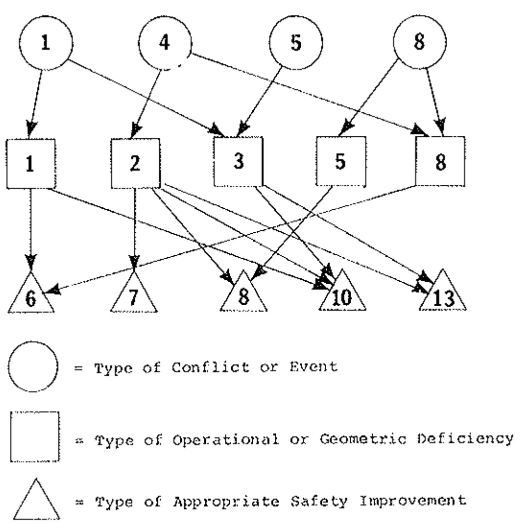
An example of subjective rating factors for priority ranking of hazardous highway was developed by Taylor and Thompson in a research project in 1977 sponsored by the Federal Highway Administration (FHWA) (14). In that study, a hazardousness index method was developed by using 10 different variables, including accident numbers, accident rate, accident severity, traffic conflicts, erratic maneuvers, driver expectancy, information-system deficiency, sight distance, and volume/capacity ratio. For each of the variables, a weighting factor was used, based on the subjective ratings of their importance by numerous highway safety experts in a workshop setting. The ranking of locations was based on the available data variables and their subjective weightings (14).

Care should be taken in the interpretation and use of the DI. Due to the limited available data base, the value of DI cannot be used as a measure of accident potential. Further research is necessary to determine whether there is a significant relationship between pedestrian accidents and the pedestrian DI. The DI value was used only as a priority ranking tool based on pedestrian conflicts and events. A DI value of 300 is not necessarily three times as hazardous as a DI of 100.

A pedestrian conflict study is only one of many engineering studies that should be made at school zones to identify safety problems and to select safety improvements. Other important engineering studies should also be conducted, such as the following:

1. Vehicle volume and gap studies,
2. Sight-distance studies,
3. Vehicle speed studies,
4. Inventory of traffic control devices,
5. Availability of pedestrian facilities,
6. Geometric deficiencies of the roadway, and
7. Other studies.

Figure 2. Flowchart of interrelationships between conflicts, locational deficiencies, and candidate safety improvements.



Improvement Selection by Using Conflict Data

By using the data collected from the conflicts and events as given in Figure 1, the most appropriate improvements for implementation can be selected. A chart was developed for use in this procedure, as shown in Table 5, which provides a summary list of conflict types, deficiencies, and improvements. The predominant types of conflicts and events should first be recorded for a site. Next, the corresponding geometric or operational deficiencies causing the specific conflict (column two) should be identified. From the list of deficiencies, a list of appropriate safety improvements can be determined.

To illustrate the interrelationships between events, deficiencies, and improvements, a flowchart was constructed, as shown in Figure 2. For example, the four conflict and event types identified were slow or stop for pedestrian (item 1), pedestrian run across street (item 4), pedestrian stop in median (item 5), and jaywalking (item 8). Those four items are each given in circular nodes at the top of the flowchart.

The next step is to identify the deficiencies that correspond to each event at the specific school zone, which requires a knowledge of the study site. Square nodes represent the five deficiency types (items 1, 2, 3, 5, and 8) as listed in Table 5. Conflict type 1 (slow or stop for pedestrian) was caused by high-speed vehicles (deficiency node 1) and inadequate vehicle gaps (deficiency node 3). Arrows are drawn from each predominant conflict type to corresponding deficiencies (square nodes).

Finally, the five selected improvements (items 6, 7, 8, 10, and 13) are given as triangular nodes on the bottom level of the flowchart. Arrows are then drawn from each deficiency to the corresponding safety improvement. For example, deficiency number 2 (high pedestrian volumes) is taken into account with four different improvements (items 7, 8, 10, and 13). Deficiency 8 (vehicles disregarding crossing guard) was addressed only with improvement number 6 (police enforcement).

The example illustrated above represents the location of Livernois Road near Rochester High School. This location was the top-priority location in this study based on the DI. Different interrelationships were also found for other locations. Such a flowchart will help to ensure that locational deficiencies are identified for subsequent selection of appropriate safety improvements.

CONCLUSIONS AND RECOMMENDATIONS

A pedestrian conflict procedure was developed to assist in the identification of hazardous school zones in the Rochester School District. The following conclusions were reached based on the analysis results. Specific conflicts and events that were observed to occur in 10 school zones under study were defined and tested. Nine other conflicts and events were also defined and tested as related to school buses and other vehicles used to transport children. Severities of all conflicts and events were recorded with respect to nearness to an accident.

Pedestrian conflicts were found to be related to known traffic and pedestrian variables. This indicated that pedestrian conflicts can provide useful information concerning known pedestrian dangers in school zones. A DI formula was developed based on the subjective weightings of five severities of pedestrian events. This formula was used to priority rank the 10 school zones based on suspected degree of hazard. The relationship between the DI and pedestrian accidents could not be

Table 5. Listing of conflicts, locational deficiencies, and candidate safety improvements.

Conflict or Event	Operational or Geometric Deficiencies	Appropriate Safety Improvements
1. Slow or stop for pedestrian	1. High vehicle speeds	1. Install regulatory speed limit signing
2. Slow or stop for pedestrian—previous	2. High pedestrian crossing volume	2. Install warning signs
3. Weave for pedestrian	3. Inadequate vehicle gaps	3. Paint pavement markings
4. Pedestrian run across street	4. Insufficient pedestrian control	4. Prohibit curb parking
5. Pedestrian stop on median	5. Pedestrian crosswalk needed	5. Construct pedestrian overpass
6. Intersection crossing against light	6. Limited sight distance	6. Initiate police speed enforcement
7. False start across street	7. Pedestrian signal phase needed	7. Construct sidewalk railings
8. Jaywalking	8. Vehicles disregard crossing guard	8. Paint pedestrian crosswalk
9. Slow for bus	9. Vehicles ignore speed limit	9. Use crossing guard
10. Stop for bus	10. Random street crossing	10. Install pedestrian midblock signal
11. Weave around bus	11. Wide street with insufficient gaps	11. Install pedestrian signal phase
12. Vehicle stop to unload children	12. Pedestrian crossing from behind parked cars	12. Construct wide median for pedestrian refuge
13. Slow for unloading vehicle—previous	13. Pedestrian disregard of traffic control	13. Safety education for children
14. Weave for unloading vehicle	14. Insufficient parent parking area	14. Initiate driver awareness training
15. Vehicle brakes or weaves for standing pedestrian	15. Insufficient bus parking area	15. Construct parking drop-off areas for buses
16. Vehicle brakes or weaves for pedestrian walking on shoulder	16. No sidewalk	16. Construct parking drop-off areas for vehicles
17. Vehicle disregards crossing guard	17. No shoulder or sidewalk	17. Construct sidewalks
18. Turn conflict	18. Inoperative pedestrian control	18. Maintenance control device
	19. Worn school signs	19. Remove unwarranted signs, markings, and signals
	20. Worn pavement markings	20. Additional school bus usage
	21. Unwarranted traffic control devices	21. Others
	22. Others	

tested due to the unavailability of sufficient accident data.

A flowchart methodology was described to simplify the task of relating observed pedestrian events to corresponding locational deficiencies and appropriate safety improvements. Various other highway and traffic information is also needed to conduct the total analysis.

The refinement and use of this pedestrian conflict methodology deserves further research. In particular, more data are needed at a large sample of school zones to define other types of pedestrian events. The comparison between pedestrian conflicts and pedestrian accidents should also be made to determine whether such a relationship exists.

REFERENCES

1. Accident Facts: 1978 Edition. National Safety Council, Chicago, IL, 1978.
2. M. L. Reiss; BioTechnology, Inc. School Trip Safety and Urban Play Areas: Volume 1—Executive Summary. Federal Highway Administration, Nov. 1975. NTIS: PB-254 898/OSL.
3. Pedestrian Safety Report: AAA Special Study of School Child Pedestrian Accidents. American Automobile Assn., Falls Church, VA, 1968.
4. M. L. Reiss. Knowledge and Perceptions of Young Pedestrians. TRB, Transportation Research Record 629, 1977, pp. 13-19.
5. Engineering Experiment Station, West Virginia University. Establishing Criteria for Speed Limits in School Zones. West Virginia State Road Commission, Morgantown, Rept. 21, 1967.
6. C. V. Zegeer. The Effectiveness of School Signs with Flashing Beacons in Reducing Vehicle Speeds. Kentucky Bureau of Highways, Frankfort, July 1975.
7. S. R. Perkins and J. I. Harris. Traffic Conflict Characteristics—Accident Potential at Intersections. General Motors Corp., Warren, MI, Res. Publ. GMR-718, Dec. 1967.
8. S. R. Perkins. GMR Traffic Conflicts Techniques Procedure Manual. General Motors Corp., Warren, MI, Aug. 1969.
9. W. T. Baker. An Evaluation of the Traffic Conflicts Technique. TRB, Transportation Research Record 384, 1972, pp. 1-8.
10. C. V. Zegeer and R. C. Deen. Traffic Conflicts as a Diagnostic Tool in Highway Safety. TRB, Transportation Research Record 667, 1978, pp. 48-55.
11. J. C. Hayward. Near-Miss Determination Through Use of a Scale of Danger. TRB, Transportation Research Record 384, 1972, pp. 24-34.
12. C. Hyden. Relations Between Conflicts and Traffic Accidents. Univ. of Lund, Sweden, 1975.
13. C. V. Zegeer. Traffic Conflicts, Erratic Maneuvers, and Near-Miss Accidents: State of the Art. Kentucky Bureau of Highways, Frankfort, Nov. 1977.
14. J. I. Taylor and H. T. Thompson; Pennsylvania Transportation Institute. Identification of Hazardous Locations. Federal Highway Administration, Dec. 1977. NTIS: PB-283 922-SET/SL.

Publication of this paper sponsored by Committee on Pedestrians.