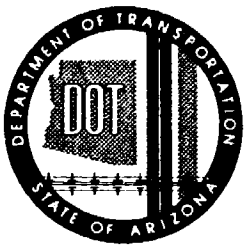

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PEDESTRIAN ACCIDENTS IN ARIZONA: AN INVESTIGATION OF CAUSATIVE FACTORS AND RECOMMENDATIONS FOR SAFETY IMPROVEMENTS

Final Report
Volume I

Prepared by:
J.S. Matthias
A. Stone
Center for Advanced Research in Transportation
College of Engineering and Applied Sciences
Arizona State University
Tempe, AZ 85287

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16. Abstract

This research investigated the causes of pedestrian accidents in Arizona to discover why Arizona's pedestrian accident rate is higher than the national average.

All pedestrian accidents for 1981, 1982, and 1983 that were computerized in the state accident report system were examined. All accidents (37,784) that could be located (2.6% could not be located) were plotted by location and reported cause. Accident rates for urban areas were higher than for rural areas. The only identified pattern was that urban accidents and fatalities tend to occur on wide, high speed arterial streets. Causes of approximately 50% of all accidents were failure to yield by motorist or pedestrian and not using a crosswalk.

It was concluded that there are no engineering countermeasures that would be useful. Education of the public, particularly children under 14 years of age seems to be the only useful countermeasure.

Arizona is heavily urbanized with very little rural population to offset the larger than average rate. The Indian reservations are similar to the rural counties and do not contribute to the high rate, although the rate on Indian reservations is higher than that of the rural counties.

Volume I contains the text and summary figures relevant to the discussion of the results of the research. Volume II, 113 pages, contains the appendices.

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Volume I

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Volume II

TABLE OF CONTENTS

LIST OF TABLES

SI (METRIC) UNIT CONVERSION FACTORS

The material contained in this report is presented in terms of English units. The following factors may be used to convert the measures used in this report to the International System of Units (SI):

1 mile per hour (mph) = 1.6093 kilometer per hour (kph)

1 kph = 0.6214 mph

1 foot = 0.3048 meter

1 meter = 3.2808 feet

INTRODUCTION

Growing urbanization and an increasing interest in saving energy and in physical fitness have caused an increase in pedestrian traffic in urbanized areas. Accompanying this increase is a rise in pedestrian accident rates. There are 8000 pedestrian deaths and 150,000 pedestrian injuries annually in this country. The majority of these occur in urban areas.

These numbers represent significant personal and economic losses, and the upward trend is a matter of great concern.

From 1972 through 1980, 1635 pedestrians have been killed on Arizona's roads. This represents over 20% of all fatalities.

In 1981, 22.6% of Arizona's 833 fatal accidents involved pedestrians (176). The national average is 18.7%, although in some large urban areas 40-50% of total traffic deaths are pedestrians. Only the District of Columbia, (42.1%) an urban area of Florida (29.8% of 2517), New York (29.78% of 2374), New Jersey (28.2% of 1023), and Hawaii (25.1%$ of 167), surpassed Arizona in percent of pedestrian-involved fatal accidents.

The large number of pedestrian fatalities in Arizona represents a serious safety problem. The problem is nationwide as well.

One factor of pedestrian accidents which has a particularly heavy impact is the number of fatalities among children of the 4-8 year old age group.(1) The involvement of children under fifteen in pedestrian accidents is twice that of all other age groups.(2) The elderly are also very vulnerable, both Arizona and Florida have large elderly populations which may contribute to the high incidences of fatalities in those regions.

The number of pedestrians killed and injured is highest in cases of pedestrian crossings not at intersections and crosswalks, followed by intersection locations and walking in the roadway in traffic. Urban pedestrians experience higher risks and severity of injury due to higher vehicle volumes and more pedestrian activity.

The nationwide rise in pedestrian fatalities has increased the need to determine the causes for pedestrian-vehicle accidents.

Several different methods are being used to study the problem, including factor analysis, conflict analysis, and pedestrian task analysis. Efforts are being made to identify and measure contributing factors such as pedestrian delay and gap acceptance, traffic regulations and enforcement, pedestrian knowledge and awareness, visibility, accident characteristics, alcohol involvement, and pedestrian exposure to risk, for example.

Arizona has only a few concentrated population centers, but they contain the majority of the state's inhabitants.

Arizona is highly urbanized per capita, but not with respect to total land area. There may be significant differences among conditions in Arizona and the five areas which have higher pedestrian fatality rates. Pedestrian accident rates on the Indian reservations may be significantly different than other areas of the state.

This study investigated the factors that have contributed to such a severe problem in Arizona.

SCOPE AND OBJECTIVES

This study was initiated for the purpose of determining the causes of pedestrian accidents in Arizona. The intent was to use causal factors to develop countermeasures that might reduce the incidence and/or severity of pedestrian accidents. Specifically, the study objectives focused on:

1) A thorough examination of current research in determining causative factors of pedestrian accidents and effectiveness of possible countermeasures
2) Collection and analysis of data to determine the causative factors of pedestrian accidents
3) Identification of countermeasures which will reduce the number and/or severity of pedestrian accidents
4) Development of implementation procedures for recommended safety improvements

5) Development of evaluation procedures for the countermeasures using operational and statistical techniques.

METHOD OF STUDY

The method used in this study was to use all the pedestrian accidents reported in Arizona for 1981, 1982, and 1983. The Arizona Department of Transportation (ADOT) gathers accident records from all state, county, and city jurisdictions as well as the Indian Reservation Police Agencies. ADOT provided a computer printout for each year listing all reported pedestrian accidents with the information provided on the police accident report form (see Figure 1, 2.)

Each accident was located on a map of the appropriate jurisdiction, county or city street map; and (by location) intersection or non-intersection (mid-block).

In the three year period studied there were 3774 reported pedestrian accidents. A pedestrian accident is defined as an accident in which at least one participant was a person afoot on the highway or street right of way. A literature search was conducted to discover what other states and researchers have done to determine causitive factors and to develop countermeasures.

DATA COLLECTION

Data collection consisted of obtaining the printouts of the ADOT accident files. All accidents involving pedestrians for the years 1981, 1982, and 1983 were provided by ADOT. There were 3774 reported accidents listed, 1295 in 1981, 1165 in 1982, and 1314 in 1983. The accidents were those reported by all jurisdictions in Arizona that provide accident reports to ADOT.

Every accident that could be located was plotted on an appropriate street map. Maps were obtained from ADOT for each county and major metropolitan area. A few accident sites could not be located due to incomplete or missing information and were therefore not plotted. This amounted to 99 or 2.6% of the total. (See Table 1, below.)

TABLE 1

YEAR	TOTAL NUMBER OF ACCIDENTS IN AZ	NUMBER NOT ABLE TO LOCATE	% NOT ABLE TO LOCATE
1981	1295	33	2.55
1982	1165	30	2.58
1983	1314	36	2.74

Each accident was also coded according to the investigating officer's listing of the cause of the accident (see Table 2), location (intersection or non-intersection), time of day (daylight or dark), type of street, age of pedestrian (≤ 14; ≥ 65).

CODING KEY

BEHAVIOR - CAUSE CATEGORIES

VEHICLE

1 ● Excessive Speed

2 ● Failure to Yield (or Disregard Signal)

3 ● Turning Movement

VEHICLE AND/OR PEDESTRIAN

4 ● Unknown*

5 ● Inattention*

6 O Other*

PEDESTRIAN

7 ● Crossing Street

8 D Did Not Use Crosswalk

9 ● Failure to Yield (or Disregard Signal)

10 A Walking Against Traffic (On or Along Roadway)

11 L Lying in Roadway

12 P Pushing or Working on Disabled Vehicle

13 R Working on Roadway

14 O Getting On or Off Vehicle (In or Out of)

15 S Standing in Roadway

16 W Walking With Traffic (On or Along Roadway)

OTHER VEHICLE ACTIONS OR FACTORS

17 A Avoiding Obstacle, Vehicle, or other Pedestrian

18 B Backing

19 D Entering or Leaving Driveway or Alley

20 P Passing or Lane Change

21 S Entering or Leaving Parking Space

* These categories are similar and are not subject to interpretation. They are listed separately here because they are listed separately on the accident reports. They can be considered to be a single category.

A literature search was conducted as part of this study. While the articles listed in the bibliography do not include all reports on pedestrian accidents, a substantial cross section is represented.

DATA ANALYSIS

The research effort was directed towards identifying the causes of pedestrian accidents. After the accidents had been plotted by location and reported cause, an analysis was made to discover any patterns that resulted. No individual accident or specific site was analyzed separately; causes used were those listed on the police report.

Accidents were collated by cause, type of street (arterial, or collector or local), day-night, age (<14, >64). Accident rates were calculated for the 14 and under and 64 and over age groups. Percentage of total accidents for the age groups were also calculated and compared to the percentage of population of the age group for each jurisdiction studied. Accidents per 10,000 population were used as the basis for comparisons. Population data are based on the 1980 census data and were extrapolated to obtain values for 1981, 82, and 83. The percentage of population for these age groups was not available for Indian reservations. Only total population figures were used for the reservations.

The accident location plots on the maps were used to locate any high accident locations or patterns. Accidents that could not be located were not included in the mapping phase of the study. They were included in the total number and in the analysis of causal factors.

Each cause as reported by the investigating officer was assigned a particular colored symbol (see Table 2). Each

accident was then located on the appropriate map, by year, and using the appropriate symbol. This permitted the evaluation of all reported accidents by cause, location, and year. (See Figures 3-8 for samples of accident mapping.)

Each accident also was identified by age group of the pedestrian(s) involved, alcohol involvement (driver and/or pedestrian), time of day, location on street (crosswalk or non-crosswalk in urban areas). An accident reported to be within 30 feet of an intersection was considered to be intersection or crosswalk related, whether there was a marked or un-marked crosswalk. It is difficult to determine from the accident printout whether there was a marked or un-marked crosswalk. Descriptions of violations were used to determine whether the pedestrian, driver, or both were at fault.

The only significant pattern that is apparent is that many accidents occur on arterial streets which tend to be wide and have relatively high posted speeds. For the urban areas, over 50% of the accidents occur on the arterial streets. Urban area arterials tend to be multilane (4-5 lanes) and be at least 64 feet wide with posted speeds of 30 mph or greater. Most (>50%) pedestrian accidents occur on this type of facility (see Appendix A, Table 21).

The combination of high vehicle speed (not necessarily higher than posted) and street width appear to be major factors. The causes listed, such as midblock crossing, inattention, or failure to yield, do not adequately describe

these accidents. Many occur at intersections and in crosswalks. The wide streets mean that a pedestrian will be exposed for a longer period of time. Using a walking speed of 3.5 feet/second, a pedestrian requires 18.3 seconds to cross a 64 foot wide street. A vehicle can be (for 35 mph) as far away as 940 feet or more when the pedestrian begins to cross the street and steps off the curb. The average person (pedestrian) cannot easily make an accurate assessment of the position and speed of an approaching vehicle which may be a quarter of a mile away. This is especially difficult at night, when vehicles are seen only as headlights and the associated glare.

Accidents on the Indian reservations were examined separately from those in the counties and cities. The rates for the reservations were slightly higher than for the rural counties but not as high as for the urban areas. A high number of accidents occurred in Window Rock (Navajo Reservation, Apache County, see Figure 8), probably due to population concentration. Alcohol involvement appeared to be more of a factor in accidents on the reservations than for the state as a whole.

Rural area accidents tend to involve persons walking along the road while urban accidents involve more of the crossing type accident. The distribution and number of pedestrians walking along the road or in the road type of accident virtually precludes any effective countermeasure other than education due to the wide disbursement of this

type of accident. However, under certain conditions, a pedestrian pathway could be provided to remove pedestrians from the pavement. (See Appendix D, Table 98, causes 10-16 for counties and reservations.)

REVIEW OF LITERATURE ON CURRENT RESEARCH ON PEDESTRIAN ACCIDENT CAUSATION AND COUNTERMEASURES

A review of the literature concerning research on pedestrian accidents serves to emphasize the seriousness of the pedestrian accident problem. An average of 8000 pedestrian deaths and 150,000 pedestrian injuries occur in this country annually mostly in urban areas (source 4). Although pedestrian accidents account for only about 1% of the total yearly accident occurrence, they represent almost 20% of the total yearly traffic fatalities.

There are few pedestrian-vehicle accidents which result in property damage only. Injuries to pedestrians are often severe and incapacitating.

The peak number of pedestrian fatalities occurs among children in the 4-8 year old age group (per Wolfe & O'Day (45), Zegeer & Deen (49), & others) and in adults over 64 years of age.

Because of the scope and severity of the pedestrian accident problem, there has recently been a great deal of research to determine possible causes and solutions.

Analysis of Causes of Pedestrian Accidents

The most widely shared conclusion about causes of pedestrian accidents is that they are a combination of human and environmental factors.

Environmental factors include:

- light conditions (dark, light, or dusk)
- time of day
- type and density of surrounding land use (urban, rural, residential, commercial)
- type and class of road - geometry and speed limits
- turning movement volumes
  traffic stream - volume, density, conflicts, vehicle types
- weather conditions - visibility, special road surface conditions
- roadway defects
- vehicle access to roadway (limited or full, number of driveways, alleys)
- presence and location of crosswalks
- presence and location of on-street parking
- presence and location of bus stops
- sight distance
- presence, type and duration of signalization
- type of pedestrian facilities (signals, sidewalks, crosswalks)
- maintenance level

Most pedestrian accidents occur outside of the crosswalk (70%), >50 feet from the intersection in urban areas, 40% in residential areas, between 2:00 p.m. to 8:00 p.m.- 53%, during daylight hours 68%, 88% no precipitation,

84% dry road, and good weather conditions without traffic control devices (67%).

Human factors include physical and mental/psychological factors. Physical human factors include vision (acuity, peripheral vision, depth perception, glare recovery, night vision, etc.) hearing, physical condition (handicaps or infirmities) and age. Body height becomes a factor in child pedestrian accidents. The average eye height of a four year old child is 37.4 inches, just over 3 feet; of an eight year old, 43.3 inches (per Vanhon, Rothengatter & Vinje, source 39). The small size of young children not only blocks their view of events but also helps to conceal them from motorists, especially in the presence of on-street parking or high traffic volumes.

Physical factors are a major influence on pedestrian accidents involving the elderly. Reduced mobility and reaction time and the decrease of sensory abilities, such as sight and hearing, make this group particularly vulnerable to accident involvement. Per Yaksich (47), most accidents with elderly pedestrians occur at night or dusk and at intersections with low speed vehicles. Males are most vulnerable.

Human emotional and psychological factors are the most difficult to isolate and study but seem to be the key causes of many pedestrian accidents.

Psychological factors which seem to influence pedestrian behavior and accident experience include:

- o trip purpose
- o intelligence and information processing capabilities
- o attentiveness - degree and span
- o attitudes toward and understanding of traffic control devices and regulation (willingness and ability to comply)
- o impatience
- o regard for personal safety
- o propensity to take risks

Most pedestrians prefer to minimize delay, walking distance, and overall travel time. This purpose is often accomplished by crossing at midblock or against the signal or jaywalking (crossing 2 streets without reaching the intermediate curb).

Williams, in his study of pedestrian actuated signalized crossings, found that pedestrians are significantly more likely to accept naturally occurring gaps in the traffic stream as crossing opportunities than to wait for the signal to protect their crossing.

Judgement of the crossing situation involves the processing of situational and environmental data with respect to emotional and psychological factors. According to the American Automobile Association (May 1973) errors in judgement (violation of traffic laws or commission of unsafe acts) accounted for two-thirds of pedestrian fatalities.

Zegeer and Deen (49) found 69% of Kentucky pedestrian accidents were the fault of the pedestrian. Zegeer, Opiela and Cynecki (50) found that one-half of pedestrians in their studies violated traffic or pedestrian signals. One of the main errors in judgement is the acceptance of inadequate gaps between vehicles.

Jennings (21), in a study in Portland, Oregon, found that significant numbers of adult pedestrians do not even bother to search for oncoming traffic before entering the street (even with the "don't walk" signal actuated). At the signalized intersections, 72% of pedestrians neither stopped at the curb nor looked for traffic before entering the street on a walk signal. The same study found 62% of the signalized intersection pedestrian accidents occurred in the crosswalk.

Misuse of crosswalks is a recurrent theme in the literature. Cynecki (9) also found that crosswalks and pedestrian signals seem to give the pedestrian a false sense of protection and security. Lack of painted crosswalks or traffic or pedestrian signal promotes more attention and caution in crossing maneuvers. The pedestrian is on his own in such cases. The city of San Diego (8) in a five year study of 400 intersections each with one painted and one unpainted crosswalk found a greater relative number of accidents in the marked crosswalks than in those not delineated.

Judgement is frequently impaired by alcohol or drug consumption. According to an American Automobile Association survey on alcohol testing and pedestrian accidents, only one-half of the pedestrians killed are tested for alcohol. Nearly 60% of those tested had blood alcohol contents of >0.10%. The major alcohol involved age group for pedestrians is 35-44 years old. Blomberg, Dreusser, Hall & Ulmer compared alcohol involvement in pedestrians and pedestrian casualties in New Orleans and found that alcohol is "overrepresented" with respect to controls (discussed in source 5). High blood alcohol concentrations were found to be common in pedestrians involved in accidents. In California, 82% of drivers and 86% of pedestrians (who died within 6 hours of the accident) with a measurable BAC (meter) exceeded the 0.10% level. Younger pedestrians (15-64) are more likely to drink than those over 64.

Child Pedestrian Accidents

The pedestrian accident problem is most tragic and severe for children between the ages of 5-14 (kindergarten - 8th grade). Road accidents are a major cause of death in children (per Fortenberry) (16). Because they are such a large target group, children as pedestrians have been a focus for extensive research both in this country and Europe.

Reiss (33) found that in 1973, this population group accounted for 33% of all pedestrian accidents, and four times the number of accidents of any other age group.

Knoblauch (24-29) found this group represented 34% of the nearly 6000 pedestrian accidents he and his associates studied; 5-9 year group equals 21%, all $\leq$14 years equals 42%.

Knoblauch, et al, determined that most accidents involving 5-14 year olds occurred on weekdays, in the first lane of two lane roads in residential areas without traffic controls, with the vehicle going straight. Significant numbers of accidents also occurred during midblock crossings, dart out, and with vision blocked by parked vehicles; 43% of accidents to young pedestrians happen between 8:00-9:00 a.m., 12:00-1:00 p.m. and the highest risk period, 2:00-4:00 p.m. This coincides with the school trip, which has been shown to represent 10-20% of child pedestrian accidents (Knoblauch, AAA 1968, Detroit Police Department Traffic Safety Bureau 1963, 1968). Zegeer (49) estimates this amounts to 10,000-20,000 accidents/year; 80-90% of child pedestrian accidents happen after school and within several blocks of the home.

The youngest children have the highest accident rate. This rate decreases with age, even though exposure to traffic situations increases, older children are away from home more than younger children. Risk taking also increases with age. Knoblauch determined the most prevalent child pedestrian actions by age as:

TABLE 3

ACTION	% BY AGE 5 - 9	10 - 14
DART OUT	42	31
DASHING FROM INTERSECTION	17	18
DASHING FROM MIDBLOCK	16	7

In her efforts to measure pedestrian behavior, M. H. Jones (22) observed 870 elementary school children crossing streets as part of school trips. Only 40% searched for traffic from the left, 25% searched right, and 5% checked behind for turning vehicles; 25-30% stopped at the curb, 20% "stepped into danger," 30% ran across at intersections, and 10% played while crossing; 60% of the children walked in groups. Midblock crossings were frequent - about one half the number of intersection crossings - and most of these occurred where parked cars blocked vision. These actions were observed after a safety course was presented. The observations showed the children's behavior to be very dangerous. The author expressed surprise that there are not more child pedestrian accidents.

Mattson and Lindensjo found that in 21% of 166 child accidents at pedestrian crossings the children were accompanied by an adult. There were only a few cases where the child actually broke away from the adult. Usually the adult was right there, and in one half the accidents behaved in the same manner as did the child. Sandels, who has done extensive research on child pedestrians, their developmental

stages and corresponding abilities (Children in Traffic, 1975) found many examples of poor parental crossing behavior. Among these were not stopping at the curb, crossing at an angle outside the crosswalk, and crossing in front of moving cars. Although the adults tended to behave more safely when accompanying a child than when not, supervision and accompaniment were deficient. The accompanied children did not actively participate in making crossing decisions or in searching for traffic.

Zegeer, Randolph, Flak, and Bhatcharya in assessing the hazards of school zones determined some of the major factors contributing to child pedestrian accidents to be:

1) Ability to comprehend hazardous situations and traffic rules
2) Lack of experience and limited judgement in traffic
3) Restricted visibility due to small size
4) Length of attention or concentration span
5) Youthful playfulness and impulsive behavior.

Other research seems to agree with these conclusions. This view explains why the problem is most severe with the youngest children (4-8); they can't comprehend the danger--play in the street, etc. Sandels feels strongly that their developmental level is simply not adequate to the tasks and skills required. There is some disagreement among researchers as to whether or not training or education can help compensate for the child's stage of development.

Pedestrian Behavior

Observation of pedestrian actions has become important to attempts to quantify behavior as a means of determining accident causation.

Some researchers (Zegeer, Knoblauch, and others) have extensively analyzed accident records to determine what types of pedestrian behavior precipitate accidents. In their study in Kentucky, Zegeer and Deen (49) determined the following percentages of pedestrian actions preceding the accident.

TABLE 4

ACTION	% OF TOTAL PEDS
CROSSING	69
WALKING WITH TRAFFIC	15
WALKING AGAINST TRAFFIC	5
STANDING, LYING, OR PLAYING IN ROAD	11
	100%

Zegeer, Opiela and Cynecki (50) found 49.2% of pedestrians struck were crossing with the signal. Knoblauch, et al, found the following pedestrian actions to be significant in a three year survey of nearly 6000 accidents in seven cities:

TABLE 5

ACTION	%
APPEARING SUDDENLY IN VEHICLE PATH (DART OUT OBSTRUCTED VIEW, UNEXPECTED LOCATION)	44
RUNNING	39
WALKING OR RUNNING INTO VEHICLE	17
UNDER INFLUENCE OF ALCOHOL OR DRUGS	6
COMBINED DART-OUTS AND DASHES	52

M. H. Jones (22), in her attempts to measure pedestrian behavior, determined the most important factors affecting accident experience are:

1) Search at curb--requires head movement
2) Stopping at curb
3) Position with respect to crosswalk
4) Walking versus running
5) Playing while crossing
6) Walking in street rather than on sidewalk
7) Crossing two streets without gaining the intermediate curb
8) Crossing at midblock
9) Crossing in the presence of an obvious threat
10) Crossing group size and type (ages)

She finds the two major causes of accidents are the pedestrian's failure to search for and detect vehicles, and his sudden appearance in the vehicle's path.

Vehicle Actions

Though in most pedestrian accidents the vehicle is going straight, turning movements play a significant role especially in urban pedestrian accident experience.

All turning movements conflict with pedestrians, especially when the crossing phase is concurrent with the traffic signal. Robertson (34), while evaluating pedestrian signal displays and operations, found 25% of pedestrian accidents which occurred at intersections involved turning vehicles. Zegeer, Opiela and Cynecki (50) found turn movements were involved in 37% of their intersection population. Knoblauch, with his extensive data base, found turns involved in 9% of total pedestrian accidents.

All states now allow right turns during the red interval (RTOR) except where specifically prohibited. Zador (48) found that in areas which changed their laws to allow RTOR, there was a marked increase in pedestrian accidents involving right turns - 57% total increase, 79% increase in urban areas. Breakdown by age group:

TABLE 6

AGE GROUP	% INCREASE
$\leq$ 14	30
15-64	100
$\geq$64	110

Dreusser, Leol, deBartolo, Blomberg-Levy (12) found increases in four states ranging from 43% to 107%. The problem with RTOR is that the driver is looking to the left

while the pedestrian is crossing. Searching for traffic, especially over the shoulder-behind searching,is one of the major behavioral deficiencies of pedestrians. The first contact between driver and pedestrian may be physical rather than visual.

Left turn movements are also a problem. The pedestrian actions involved are the same as with RTOR. But unless the left turn phase for vehicles is protected, there is much more potential for vehicle-vehicle conflicts which may consume the driver's attention and distract him from observing the pedestrian. Intersections with protected left turns may or may not have pedestrian signals. Zegeer (50), Opiela and Cynecki found that for intersections without pedestrian signals, involvement of turning vehicles in pedestrian accidents was lower than those with pedestrian signals. Again, pedestrians seem to take responsibility for their crossing activities only when there is no control system to do it for them. Many pedestrians appear to believe that not only must all vehicles yield to them under any and all circumstances and to traffic control devices, but also that they will. An example of errors in judgement.

Knoblauch (24-29), et al, found that 40% of the drivers involved in pedestrian accidents had attempted to take evasive action. In 11% of the cases he studied, the driver did not see the pedestrian.

Other vehicle actions often involved in pedestrian accidents are passing or overtaking another vehicle, entering or leaving driveways and alleys, and backing up.

Countermeasures

The purpose of determining the causes of pedestrian accidents is to help alleviate the large number of injuries and deaths due to these causes. Appropriate countermeasures can then be taken to remove or offset the causes.

Pedestrian accidents are only a small part (1%) of total accidents. They occur randomly, rarely, and only in exceptional circumstances are they very concentrated at a location. Countermeasures in this area are not very cost-effective. The real criterium here is not economic; it is the amount of human suffering which may be prevented by their installation.

Choice and effectiveness of countermeasures depend on environmental, human, and economic factors. Options include:

- reduce or prohibit on-street parking
- one-way streets
- restrict turning movements
- remove sight obstructions
- improved overhead street lighting
- crosswalk improvements (relocation, painting)
- installation of pedestrian actuated signals
- installation of pedestrian barriers to limit access to roadway

- prohibit pedestrian activities
- lower speed limit
- improve regulations
- install pedestrian refuge islands
- reflectorized apparel for pedestrians
- install special pedestrian signing and marking
- install warnings to motorists of pedestrian access points
- widen shoulders or parking lanes
- install sidewalks
- provide longer pedestrian clearance interval
- grade separation at crossings
- creation of pedestrian malls
- construction of playgrounds
- designation of urban "play streets"
- pedestrian safety education programs
- increased enforcement of regulations pertaining both to drivers and pedestrians

After the chosen countermeasures have been implemented, they must be evaluated for effectiveness. This can be a problem, as accidents are such rare and random events for individual locations that data may not be available.

Conflict analysis can be quite useful in determining safety problems where accident data is not available. Cynecki (9) has developed a technique with 13 specific categories of pedestrian conflicts which can point out dangerous conditions and pedestrian behavior. This method

can be used before and after improvements to determine their effectiveness and if further changes may be required. Conflict analysis has not yet been proven to mirror accident experience, but there is definitely some relation between them.

Behavioral observations are also useful in evaluating countermeasures. An example of this is the efforts of researchers to quantify the effects of pedestrian signals and timing on pedestrian accidents (23). The findings of Shelton, Bruce, and Trenchard showed that most drivers and pedestrians do not understand the functions of pelican crossings. A pelican crossing is controlled by traffic lights actuated by a pedestrian and shows a flashing amber so a vehicle can proceed if no pedestrian is in the crosswalk after a short red indication for vehicular traffic. In Robertson's (34) survey in Buffalo and Phoenix, 21% of respondents either do not use or understand pedestrian signal indications. Zegeer, Opiela, and Cynecki (50) found only 35% of pedestrians use the actuater when it is present.

Mortimer (23) found increased compliance with the presence of pedestrian signals, and a reduction in serious pedestrian-vehicle conflicts. The only type of pedestrian signalization which has a significant effect on accident experience is an exclusive pedestrian phase which increases intersection delay to all parties. (Zegeer (50), Opiela, Cynecki)

Inwood and Grayson (Transport and Road Research Laboratory (23) found actuated crossing accident rates to be the same as those at zebra crossings (wide white stripes), but the injury accident rate decreased. Wilson (23), also of TRRL, discovered audible pedestrian signals slightly decrease crossing time. Retzko and Androsch (23) determined that an amber pedestrian clearance interval increased compliance. S.A. Smith (23) says compliance is best when clearance interval is the minimum and decreases with increased clearance time.

There is, as yet, no sure link between compliance with signals and regulations and pedestrian accident experience; 49.2% of pedestrians struck in one study population were crossing with the signal. Lack of understanding and uniformity of pedestrian signals and their functions impair their effectiveness.

CONCLUSIONS

The plots of pedestrian accidents show that the causal factors as reported on the accident reports form no discernable pattern. The only apparent pattern is the preponderance of accidents, of all listed causes, that occur on arterial streets in the urban areas. This indicates high speed and high traffic volumes.

While less than half of all pedestrian accidents occur during periods of darkness, it must be realized that exposure is low due to the fewer numbers of pedestrians after dark in most areas. Visibility of pedestrians by motorists is a factor and may be aggravated by lowered expectations of encountering a pedestrian when few are seen.

The combination of high speed, darkness, and wide (arterial) streets is the only pattern that can be determined from the accident locations.

The predominant cause of pedestrian accidents appears to be not using a crosswalk, marked or unmarked; and failure to yield the right of way by either a motorist or a pedestrian. There are no traffic control countermeasures for these actions which account for approximately fifty percent of all urban area pedestrian accidents (see Appendix D, Table 98, causes 2, 8, 9). These causes are human errors that involve people who ignore or disregard signals, signs, and rules of the road. It must be remembered that no specific site analyses were made; there may be specific

sites that have sight restrictions or other conditions that could contribute to accidents.

There are only a few locations that merit specific mention: Window Rock (see Figure 8) appears to have a high number of accidents as well as the intersection of Santa Fe Avenue and San Francisco Street in Flagstaff (see Table 7).

Speedway Boulevard in Tucson and University Drive in Tempe appear to have high concentrations of accidents. These locations appear to have high accident rates, however, these locations also have very high concentrations of university students crossing both streets. Other than these locations, specific intersections do not appear to be factors. The exposure to traffic, which is also high, appears to be a significant factor although no predominant cause was apparent for either location. The only conclusion is that the combination of high numbers of pedestrians and major arterial street traffic volumes are factors. Such areas need better enforcement (both of motorists and pedestrians) as well as clearly marked pedestrian crossings which are present with proper siganls at both locations.

The severity of accidents is related to vehicle speed. A greater percentage of fatal accidents occur on the arterial streets in the urban areas than on other types. (See Appendix A, Table 21.) Rural area accidents also have a higher percentage than average of fatalities, also due to higher speeds on rural roads.

TABLE 7

FLAGSTAFF

Intersection: Santa Fe/San Francisco Street

YEAR	# OF ACCIDENTS	# ALCOHOL INVOLV-DR	% ALCOHOL INVOLV-DR	# ALCOHOL INVOLV-PED	% ALCOHOL INVOLV-PED	AGE GROUP
1981	6	0	0	6	100.0	28-38
1982	7 *	0	0	5	71.43	23-57
1983	3	1	33.33	2	66.67	17-49
Average:	5.33	1/3	11.11	13	79.37	

* Physical condition is unknown for both driver and pedestrian in one accident.

The accident rate on the Indian reservations is not significantly different from that of the rural counties. (See Appendices B and C.) It cannot be concluded that pedestrian accidents on the reservations is a contributing factor to the accident rate in Arizona.

Accidents involving children <14 years of age) accounted for 23.71% of all pedestrian accidents. The percentage for the 14 and under age group is higher for the metropolitan areas than for the rural areas. The young age groups are involved in accidents in urban areas at a greater percentage than their age group of the general population (see Tables 22-24). This indicates a serious problem with young persons. They are inexperienced, are hard to be seen by motorists due to their size and because of their size they have restricted sight distance. A general lack of awareness of the time and distance factors on the part of young children also contributes to the problem and high accident incidences for this age group.

The accident rate for the Indian reservations is higher than for the rural counties. The only difference appears to be that there are more accidents involving pedestrians walking with traffic on the reservations than in other rural areas. Another factor is that alcohol involvement for pedestrians is higher on the reservations than for the non-reservation rural areas. The state percentage of alcohol involved pedestrians is 19 percent (Appendix D, Table 99) while for the Indian reservations the percentage is over 40

percent. Alcohol involvement of drivers is less than 10 percent for the state; this may reflect inadequate screening of drivers involved in pedestrian accidents as it appears to be very low when compared to accident statistics regarding alcohol involvement of motorists.

The accident rate appears to be a function of the size of metropolitan area. Figure 9 shows the accident rate with decreasing size of metropolitan area population. Santa Cruz and LaPaz counties appear to be out of place; however, these counties attract large numbers of tourists which can be expected to affect rates in these two areas.

Since only the computer printouts were available, traffic volumes and land use data were not available. Peak or non-peak could only be estimated by time of day.

Arizona is a heavily urbanized state; most of the population lives in the two large metropolitan areas in Maricopa and Pima counties. The rural areas contain very few people; only two metropolitan areas other than Phoenix and Tucson reach 50,000 population.

The exposure rate due to high vehicular and pedestrian volumes in the urban areas create the conditions for a higher than national average for pedestrian accidents. There is no large rural population to offset the high urban rate. This apparently is responsible for the fact that Arizona's pedestrian accident rate is higher than the national average.

COUNTERMEASURES AND RECOMMENDATIONS

There appear to be no engineering countermeasures that would reduce the incidence of pedestrian accidents. An effective countermeasure could be an education program in the urban areas that would explain and encourage the proper use of the "Walk" and "Don't Walk" signal indications at signalized intersections. Due to the lack of any concentration of pedestrian accidents in areas where such signals are not in place, it is probably not cost effective to install such devices at signalized intersections where they do not now exist or where low pedestrian volumes exist.

An education program for use on television that addresses the problem of crossing a wide street, at night, with speed limits in excess of 30 mph could be effective. This program should address clothing color, proper use of signal phasing, the use of crosswalks (marked or unmarked), and the inherent danger of midblock (non-intersection) crossing. The programs should be directed to both pedestrians and motorists.

A program to educate young pre-school and K-8 age children should be undertaken to reduce the large number of pedestrian accidents involving this age group $\leq$14 years). This would be most effective in the urban areas. The program should emphasize the proper way to use signals especially the Walk-Don't Walk phases as well as the necessity to look both ways constantly while crossing any street.

The accident reporting of pedestrian accidents could be upgraded to produce more information than is currently available using the standard accident reporting form. Additional coding of the computer records needs to be done. Figures 10 and 11 illustrate supplementary pedestrian accident data forms and procedures used or suggested in other states. This type of supplement should be separate from the standard form so that it can be used only for pedestrian accidents. It is realized that use of such a form would increase police work at a pedestrian accident; however, consideration should be given to use of such a form in order to improve the data base regarding pedestrian accidents.

There may be site specific causes that should be investigated for individual intersections. Such factors might be inadequate sight distance caused by lack of lighting, screening of pedestrians or vehicles by signs, vegetation, etc. Adequate sight distance should be provided for motorists and pedestrians, using warning signs if necessary.

In areas with high pedestrian volumes, the use of pedestrian signals should be considered. Enforcement action against mid-block (jaywalking) could be effective in certain areas.

FURTHER RESEARCH

1) The problems facing pedestrians and motorists crossing wide, high speed arterial type streets need to be examined to determine the actions of people. Specifically, the search efforts made by pedestrians (by age group) before and after they begin crossing. Previous research indicates some people make only a cursory search, if any, and assume if the street is clear, it will remain so during the time required to cross or that by being in a marked crosswalk, they are safe.

2.) An effort should be made by a designed survey to determine the extent of people's knowledge (by age group) regarding pedestrian signal indications, pertinent traffic laws, and their obligations, duties, and rights as a pedestrian. There is an apparent lack of such knowledge and that may influence accidents. This applies to drivers as well as pedestrians.

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