Report No. FHWA-RD-79-117

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79-117

N ANALYSIS OF THE URBAN UTILITY POLE CCIDENT PROBLEM

December 1980
Final Report

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Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Environmental Division
Washington, D.C. 20590

FOREWORD

This report presents an analysis of police records for 8,000 single vehicle accidents which determines the extent of the utility pole problem in urban areas. The results indicate that utility pole accidents are a significant problem in these areas in terms of both frequency and severity. The report evaluates, on a cost-effectiveness basis, possible countermeasures.

Research of utility pole/motor vehicle traffic accidents is included in the Federally Coordinated Program of Highway Research and Development as Task 1 of Project 1K, "Accident Information Analysis." Mr. C. Philip Brinkman is the Project Manager.

One copy of this report is being distributed to each FHWA regional office. Additional copies are available from the National Technical Information Service (NTIS), U. S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

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15. Supplementary Notes

16. Abstract

This study was undertaken to determine the extent of the utility pole accident problem in urban/suburban areas and to identify factors which affect the probability of their occurrence and their severity so that potential countermeasures to the problem could be evaluated.

Police reports for 1975 were obtained for over 8,000 single vehicle accidents occurring in twenty urban/suburban areas throughout the United States; to supplement the police reported data, each accident site was visited and inventoried to record such data as utility pole spacing and offset, and relevant highway characteristics, etc.

The results indicated that utility pole accidents are a significant problem in urban areas, in terms of both frequency and severity. Utility poles were the most frequent object struck, accounting for 21.1% of all objects struck. This figure, when combined with national figures, suggests that 2.2% of all urban accidents involve utility pole impacts. Apart from accidents involving rollover, utility poles have the highest rate of injury involvement.

By comparing utility pole accidents to a sample of other single vehicle accidents not involving pole contact, parameters which affect the probability of pole contact were identified; these included - in order of their relative importance - the number of poles in the immediate roadside environment, their offset, road grade, road path, and speed limit. Injury severity in utility pole accidents appeared to be primarily a function of the stiffness of the struck pole and the impact speed.

Possible countermeasures to the utility pole accident problem were evaluated on a cost-effective basis. Installing barriers, undergrounding or moving the poles back further from the road edge were not cost-effective. Severity lessening countermeasures such as thinner or breakaway poles were potentially viable; however, the possibility of increased incidence of rollover after impact and technical problems concerning the poles wire carrying capacity and expected lifetime require further investigation. The data suggest that one of the most cost-effective solutions to mitigating severity is restraint use.

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Preface

During the conduct of this research study, other research efforts were also in progress which are investigating countermeasures for utility pole/motor vehicle traffic accidents. The results of these efforts are still several months away and were not available to the research staff conducting this study.

Presently, FHWA has research programs investigating inexpensive retrofit countermeasures for existing utility poles. In addition, the public utility companies have a task force reviewing the potential of some countermeasures. The results of these efforts could conceivably provide a cost-effective solution to the utility pole/motor vehicle traffic accident problem and impact the conclusions of this study.

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Atlanta, Ga.
Auburn, Me.
Bangor, Me.
Buffalo, N.Y.
Casper, Wy.
Cheektowaga, N.Y.
Cheyenne, Wy.
Lewiston, N.Y.
Lockport, N.Y.
Macon, Ga.
Memphis, Tenn.
Nashville, Tenn.
Niagara County (N.Y.) Sheriff's Department
Niagara Falls, N.Y.
North Tonawanda, N.Y.
Oakland, Ca.

Columbus, Ga.
Depew, N.Y.
East Aurora, N.Y.
Erie County (N.Y.) Sheriff's Department
Hamburg, N.Y.
Kenmore, N.Y.
Knoxville, Tenn.
Lackawanna, N.Y.
Lancaster, N.Y.
Orchard Park, N.Y.
Portland, Me.
Rapid City, S.D.
San Diego, Ca.
Sioux Falls, S.D.
South Portland, Me.
City of Tonawanda, N.Y.
Town of Tonawanda, N.Y.

UTILITY COMPANIES

Bangor Hydroelectric
Black Hills Power and Light
Central Maine Power
Cheyenne Light, Fuel, and Gas
Georgia Power Company
Knoxville Utilities Board
Memphis Light, Gas, and Electric
Nashville Electric Service

New York State Gas and Electric
Niagara Mohawk
Northern States Power
Northwestern Public Service
Pacific Gas and Electric
Pacific Power and Light
San Diego Gas and Electric
Savannah Electric and Power

TELEPHONE COMPANIES

American Telephone and Telegraph

Mountain Bell

New England Bell

New York Telephone

Northwestern Bell

Pacific Telephone

South Central Bell

Southern Bell

HIGHWAY DEPARTMENTS

Erie County Highway Department

Georgia State Department of Transportation

Maine State Department of Transportation

Niagara County Highway Department

Oakland City Traffic Engineering and Parking Department

San Diego City Department of Transportation

South Dakota State Department of Transportation

Tennessee State Department of Transportation

Wyoming State Highway Department

METRIC CONVERSION FACTORS

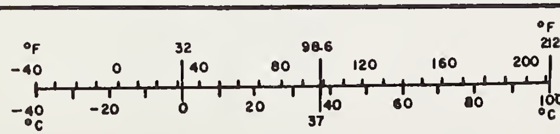
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286. Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



1. INTRODUCTION

As a result of recent controversy concerning proposed countermeasures associated with wooden utility poles located along the roadside, this study was undertaken to examine the utility pole accident problem in urban and suburban areas. The major objectives of the study were twofold: 1) define and analyze the nature and extent of the problem associated with single vehicle collisions with utility poles, and 2) assess the feasibility of potential means for correcting the problem within the legal, institutional, and technical constraints.

Accordingly, data were collected for over 3,000 utility pole accidents occurring in 1975 in twenty-one urban-suburban areas selected from seven states. During the course of the study, it was realized that in order to properly define the utility pole accident problem, information regarding other single vehicle accidents would be required; thus, a sample of run-off-road accidents was collected in six of the data collection areas. A total of over 8,000 accident sites were visited by the data collection teams, resulting in data for over 5,000 relevant accidents. The specifics of the data collection methodology can be found in Section 3.

Section 2 of this report provides a brief review of previously published literature, which, in addition to putting the utility pole accident problem in perspective, presents countermeasures which have been suggested in the literature. Section 4 provides the results of the data analysis, followed in Section 5 by an application of the results as input to cost-effectiveness analyses of selected countermeasures. The final section contains conclusions and recommendations regarding the utility pole accident problem.

Throughout the report, reference is made to three types of accidents: single vehicle accidents, run-off-road accidents, and utility pole accidents. Run-off-road accidents are defined as single vehicle accidents in which a utility pole was not contacted; this terminology (which is unique to this study) will be used consistently throughout this report.

2. SURVEY OF PERTINENT LITERATURE

2.1 The Utility Pole Problem

It is well documented that single vehicle accidents account for a disproportionate number of fatalities relative to their occurrence; the National Safety Council (Reference 1) reported that in 1974, 18.5 percent of all accidents involved only one vehicle, but 36.3 percent of the fatal accidents were single vehicle accidents. Wright and Mak (Reference 2) reported that single vehicle accidents comprised 8.6 percent of the traffic accidents in Atlanta and 32.3 percent of the fatal collisions; similarly, the National Safety Council found 26.0 percent of urban traffic fatalities occurred in single vehicle accidents, which made up only 10.4 percent of the total urban accident population.

The majority of these fatalities resulted from vehicular contact with a fixed object; the National Safety Council figures indicated that single vehicle-fixed object collisions were responsible for 76.2 percent of fatal urban single vehicle accidents, and 60.1 percent of all fatal single vehicle accidents (this does not include those accidents in which rollover may have been precipitated by prior contact with a fixed object).

The extent to which collisions with utility poles contribute to these data is not clear. One reason for this is the definition of a utility pole varies from study to study; the present investigation was confined to wooden, cable-carrying or support poles. Others have not differentiated between light standards (wood or metal) and utility poles (obviously, these categories are not mutally exclusive, as some bona fide utility poles do have street lamps attached to them). Still other investigations have combined utility poles with trees prior to data reduction.

It is not surprising then,that the results of studies investigating single vehicle or utility pole accidents are not consistent. Baker (Reference 3) investigated single vehicle accidents occurring on selected road segments along U.S. Route 66. Eight hundred and fifty accidents were examined, and none were reported to have involved utility pole contact! There is no obvious explanation for this phenomenon, although, since guardrails were the object most often struck, extensive use of guardrails may possibly account for it. Another possibility is that the roadside environment was relatively clear of utility poles, but there are no data to support this hypothesis.

Huelke and Gikas (Reference 4) analyzed 111 fatal accidents that had been investigated on-scene, in and around Washtenaw County, Michigan. In looking at single-car collisions, they found that in 35 out of 67 fatal accidents (52.2 percent), the object struck was a tree or a utility pole. The exact "contribution" of utility poles to this figure was not reported, although the authors did state that the majority of these 35 accidents involved trees rather than utility poles.

Graf, et al. (Reference 5) reviewed the utility pole problem, and reported that there were only scanty data available. From State Summaries of Traffic Accidents, they found that utility pole involvement in fatal accidents ranged from 1 to 8 percent (these figures are from Oklahoma and Massachusetts, respectively). The authors concluded that utility poles are responsible for more than 5 percent of United States traffic fatalities, or 15 percent of fixed-object accident deaths. In 1972, this would have amounted to 2,750 fatalities and 110,000 casualities attributable to utility pole accidents.

Newcomb and Negri (Reference 6) sampled police and driver reports submitted during one week to the New York State Department of Motor Vehicles in an attempt to determine the costs associated with telephone pole accidents. This data set does not contain all accidents occurring in New York State; the police are required to send in only a fraction of their accident reports, and the proportion mailed varies among jurisdictions. The drivers of accident-involved vehicles also do not always submit the driver report form as required. However, the authors found that in their sample, 619 (or 7.7 percent of all accidents) were single vehicle accidents. Utility poles were determined to be the second most frequently struck object (after guardrails)*; they accounted for 15.5 percent of single vehicle accidents (or 1.2 percent of all accidents).

Newcomb and Negri also calculated that each utility pole accident cost $2,740; this figure was based on automobile and pole repair costs plus the societal costs of any injuries suffered in the accidents. In 1970, then, it was estimated that New York State utility pole accidents cost society, as a whole, over 19.9 million dollars. By way of comparison, if these accidents had been merely run-off-the-road types, the corresponding average cost would have been $2,354 per accident; this assumes that no damage (and thus no repair costs) was sustained by any fixed object. In the absence of all utility poles, the corresponding cost to society would have been $17.1 million dollars - a reduction of 2.8 million dollars.

The subject of utility poles has been dealt with in Australia as well. Statistics on pole-related data from two data sources were presented by Good and Joubert (Reference 7). From accident data collected between 1 July 1969 and 30 June 1971 in New South Wales, the authors determined that pole accidents made up 2.2 percent of the total accident population; unfortunately, the data were such, that one could not separate light poles from utility poles. In 58.7 percent of the 4,071 pole accidents identified, injuries to vehicle occupants were reported. As in the United States, relative to their frequency of occurrence, poles were involved in a disproportionate number of all casualty and fatal accidents: 4.8 and 4.5 percent, respectively.

Good and Joubert's second source of data included trees in the same category with utility and light poles. These data, collected during 1970 in South Australia, showed trees or poles were involved in 4.7 percent of reported accidents, resulting in 8.0 percent of fatal and 8.1 percent of all injury accidents. Good and Joubert also compared the Australian data to the

*The authors point out that ambiguities between "utility" and "light" pole classifications may have existed.

accident experience of other countries. Of note is that pole contact is more frequent in Australia than the United States.

Vaughan (Reference 8) has also looked at the utility pole accident problem in New South Wales. To determine whether pole accidents were predominately single vehicle accidents, he analyzed a sample of New South Wales accident reports submitted during the first two weeks of 1975; 86 percent of all pole accidents involved only one car. He concluded that constraining the data analysis to single vehicle pole accidents would not substantially limit the study.

Vaughan subsequently analyzed police accident data for mishaps occurring in New South Wales during 1973; there were over 120,000 accidents. Within the sample, 2,557 pole accidents (2.1 percent) were identified. The crashes accounted for 6.4 percent of fatal accidents and 4.6 percent of non-fatal injury accidents. The corresponding cost to the people of New South Wales was estimated at 8 million dollars.

In contrast to Newcomb and Negri, who ranked poles second to guardrails in frequency of contact, Vaughan found - by a rather large margin - utility poles to be the object struck most often. This may be a function of different guardrail/utility pole placement policies in the two countries. Alternatively, there may be differences between the areas from which the data were collected; Newcomb and Negri obtained their data from New York State, but did not separate urban and rural areas, whereas over 80 percent of pole accidents analyzed by Vaughan happened within urban areas.

Other factors associated with pole accidents that deviated from the Australian national accident experience were:

- fatal and non-fatal injuries were sustained more predominately by young, male occupants,

- cars were overinvolved in pole accidents,

- pole accidents were overrepresented on straight road segments and underrepresented at intersections,

- approximately one driver in six was described by police as either smelling of alcohol or intoxicated, but no comparison could be made to the national experience (Perchonok [Reference 9] found that drinking drivers were overrepresented in accidents which occurred under passive, low-demand conditions. This, coupled with the previous result concerning the straight vs. intersection dimension, tends to indicate that drinking drivers may be more prevalent in pole accidents.)

- pole accidents were slightly overrepresented on wet roads,

- relative to the overall accident population, pole accidents were a late night-early morning phenomenon which was accentuated on the week-ends.

Vaughan also evaluated the utility company records as an alternative source of accident data. He found that the police had records of 2.5 times as many crashes. This is not surprising, as the utilities are more interested in damage to their property rather than accident statistics.

2.2 Proposed Countermeasures to the Utility Pole Problem

Countermeasures to the utility pole problem can be generally divided into three major categories: those that increase the conspicuity of the poles, those that lessen the severity of the collision, and those that remove the poles from the immediate roadside. Each of these types of countermeasures will be discussed individually in the following three sections.

2.2.1 Increasing the Pole's Visibility

Three similar techniques have been suggested in order to increase the visibility of a utility pole, including: painting the bottom portion with a reflective paint (Reference 7), installing reflective tape on the poles, and delineating the poles with paddle-markers placed close to them (Reference 10). The major advantage to these countermeasures is cost; they could be implemented inexpensively. However, their effectiveness is suspect, in that such a countermeasure assumes that an accident involved driver is capable of avoiding an off-road obstacle if he perceives it sooner; in all probability, this assumption is invalid. It is conceivable that marginal benefits may be realized by such techniques, because the road path may become more obvious, thus preventing some off-road excursions.

Utility companies have an additional objection concerning the placing of paddle-markers near poles; this is the possibility that a falling lineman may impale himself on the paddle-marker (Reference 10). Since the major benefit of paddle-markers would seem to be the delineation of the road path, it would appear that they could be just as effective if they were placed elsewhere, farther away from the utility pole.

2.2.2 Countermeasures to Lessen the Accident Severity

McAlpin (Reference 11) divides severity lessening countermeasures into three specific types: barriers, attenuators, and breakaway devices. The objective of the barriers, e.g. guardrails, is to divert the vehicle away from the more dangerous object, such as a utility pole. Additional benefits are gained in that some of the vehicle's kinetic energy will be absorbed during the impact with the barrier. This sort of energy absorption is the primary aim of an attenuating device. (Examples of attenuators are stategically placed plastic barrels filled with water, which rupture at contact, or drums with the top halves filled with sand.) Theoretically, in an accident involving attentuators, the resultant deceleration level will be decreased, lessening the chance of serious injury; this is in contrast to contact with a utility pole, in which total deceleration of the vehicle takes place over a very short time period.

Breakaway devices also decrease the impact severity of contact with a roadside obstacle, by having the obstacle "fail" or breakaway. Generally, this is accomplished by mounting the object on a shear or frangible base. However, this technique is not particularly adaptable to wooden utility poles; thus, an alternative method has been proposed by Wolfe, et al. (Reference 12), in which wooden utility poles are weakened by boring holes and routing a circumferential groove near the base. In addition, holes are drilled near the top, so that, in the event the pole is contacted and broken, the middle section will also break away from the top portion of the pole. Thus, the wires will not have to support the weight of the entire pole.

The major objection to most of these countermeasures is the massive financial expenditure required to protect motorists from all the utility poles which line the nation's roads. A reasonable compromise may be to install these devices at selected sites determined to be more dangerous than others, however, the identification of the more dangerous sites is not easily accomplished. For instance, consider the difficulty in assessing the amount of additional hazard a site must present before special attention is warranted.

The potential hazard of breakaway devices to pedestrians must also be considered. Two recent accidents in Boston, Massachusetts (Reference 25) - resulting in one death and two serious injuries - illustrate the possibility of this type of event. However, to put this in perspective, Vaughan found only four cases in his sample of 2,557 pole accidents which involved pedestrians (two of these were suspected to be coding errors).

Another problem with breakaway poles (and particularly with the idea of weakening existing installations by drilling is their ability to meet safety standards after having been weakened. This is a major concern to utility companies. For example, a northeastern power company in a heavy snow load area provided the following comment on the safety factor issue:

> "In general, in urban areas ... the loading stress on a typical pole must be no more than 1/2 of its maximum strength. Our service area has been classified as a heavy loading district. This requires that we design our structures so that they may withstand 1/2" radial thickness of ice on the conductors under a horizontal wind pressure of 4 lbs./sq. ft. (40 miles per hour).
>
> ... In urban or suburban areas we generally use poles approximately 35 feet in height, and space them every 200 feet. There are usually three phase wires, secondary wires, and perhaps two large telephone cables attached to the pole. The point of maximum stress on the pole from the horizontal wind force on the pole and wires is at the ground line. Our standard 35' poles have a circumference of approximately 29" at the ground line, and can withstand 49,400 ft.-lbs. of bending moment at this location. Under conditions of 1/2" of radial ice and a 40 MPH wind, the bending moment on the pole at the ground line will be 22,900 ft.-lbs. This figure is 46% of the maximum withstand strength of the pole and 93% of the maximum allowable ..."

Wolfe, et al. suggested the possibility of relaxing the design standard as a viable alternative, arguing that the safety factor currently used may be conservative.

The utility companies have questioned the sufficiency of the experimental set up used by Wolfe, et al. to test the remaining poles' ability to maintain the line after one pole has been broken away. Wolfe, et al. used a system of three poles*, whereas utility company representatives suggested that at least five poles - all weakened - were necessary to simulate the real world conditions. The concern here was to insure that no chain reaction of downed poles would occur after a pole was struck by a vehicle (or broken due to weather conditions). Furthermore, Wolfe, et al. recognized that the weakening of a power pole would decrease its service life because of its increased susceptability to rot. The affect of rot on a poles' resistance to normal stresses would have to be considered in relation to present and revised design standards.

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*It is unclear from this report whether the other two poles in the system had been weakened.

Obviously, the restrictions, due to design standard limitations, of this countermeasure will vary between areas; not all areas are designated as heavy loading districts. Wolfe, et al. also suggested that weakening of poles be confined to every other pole or to those which are particularly vulnerable to contact. As in the case of installing other protective breakaway devices, the latter approach is not easily accomplished.

2.2.3 Countermeasures to Remove Poles From the Roadside

It has been suggested in various sources that the roadside (or portions of it) be cleared of roadside obstacles; e.g., References 4, 7, 13, 26 and 30. A 30 foot (9 m) recovery zone is the presently recommended design practice (Reference 26). Under these conditions, it has been estimated that of vehicles exiting the roadway at 70 MPH (113 KPH) or less, 80 percent of them should regain control. Such a countermeasure would involve undergrounding power and telephone cables within the recommended 30 foot (9 m) zone. As this is an expensive proposition, implementation could be spread out over a fairly long period of time. Along these same lines, in new residential developments, efforts can be made to bury any incoming cables, or if necessary, erect power lines between the back lots of houses on parallel streets.*

There are disadvantages associated with the clear roadside option. For example, maintaining a clear roadside environment may not be physically possible in many urban/suburban areas (where the majority of pole accidents seem to occur); furthermore, the utility companies may be faced with many difficulties in attempting to negotiate new easements for the poles.

Power poles located along the roadside have a secondary function - supporting street lamps. A decrease in the lighting level, as a result of

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*In this case access problems for maintenance are a major consideration.

moving or eliminating poles, may create more economic loss than the reduction in pole accidents can save. Less rigid light posts can be substituted, but this will affect the cost of implementation.

Another criticism of these countermeasures is if a vehicle does not contact a utility pole, it might hit something else. To an extent, this is true, but considering that utility poles are one of the most dangerous roadside objects, vehicle occupants would, in general, benefit from contacting some other obstacle.

2.2.4 Other Countermeasures

During the course of the present study, other countermeasures to the utility pole problem have been suggested. Two of these are modifications to AASHTO's recommendation for 30 foot (9 m) clear zones on both sides of the road. Since this distance is not always available - because of either right of way limitations or physical obstructions - a compromise may be to move the poles back as far as possible; utility pole contact is still possible under these conditions, but the enlarged recovery area maximizes the probability of avoiding the collision entirely and the impact speed should be (marginally) lower. For the situation in which it is impossible to maintain even a partially clear roadside environment on both sides, an alternative may be to confine the utility poles to one side of the street.

The above methods essentially decrease the pole density in those portions of the roadside environment in which poles are most likely to be contacted. An additional approach to achieve this end, is to increase the average spacing between poles. The magnitude of the spacing is constrained by the weight and tension of the wires strung between the poles and the effects of adverse weather conditions, e.g. wind and ice.

It should be noted that all three of these methods can be combined with one another, thereby increasing the flexibility and benefits of each.

3. METHODOLOGY

3.1 Data Collection Plan

3.1.1 Overall Approach

The main objective of this study was to define and analyze the nature and extent of the accident problem associated with single-vehicle collisions with utility poles. Originally, the approach suggested was to (1) collect on-site inventories of all utility pole accidents in the chosen study areas to provide information on the nature of utility pole collisions, and (2) collect exposure data by undertaking an inventory of selected road segments to evaluate the extent of utility pole involvement. It was clear that the on-site data collection procedure, in conjunction with police and utility company data, would provide the necessary descriptive statistics on pole accidents, however, using road segments to obtain exposure presented several problems.

- The obvious problems of defining a road segment, i.e., where should it start, how long should it be, should it be lengthened/shortened to include/exclude one more accident, etc.

- Selection of criteria to discriminate between high and low accident segments is difficult; for example, should high and low accident groupings be based on the number of pole accidents, run-off-road accidents, or all accidents.

- Obtaining the accident statistics for each road segment could be time consuming. This would depend on how police files are organized (e.g., by date, location, nearest intersection, etc.).

In addition, although this approach would enable the likelihood of a pole accident occurring to be predicted as a function of parameters such as average daily travel (ADT), road type and characteristics, and pole density, it does not allow an assessment of pole accident frequency with respect to other types of accidents.

As a solution to these problems, it was decided that run-off-road accidents would be sampled concurrently with obtaining the utility pole accident data in six of the chosen study areas. The effort was limited to six areas because it (1) was economical, and (2) would be sufficient to place the utility pole accident problem into perspective. By using this approach, it was anticipated that the following additional information would be available.

- Pole accidents as a proportion of all single-vehicle run-off-road accidents. This is particularly important in the implementation of the results of the cost-effectiveness analysis of possible countermeasures; i.e., for a particular road type, given the number of run-off-road accidents, the expected number of pole accidents could be predicted.

- General characteristics of single vehicle, run-off-road accidents to compare to the particular characteristics of pole accidents.

- By looking at the pole accident rate, i.e., (number of pole accidents)/(number of single vehicle accidents), those parameters (pole spacing, offset, etc.) which significantly affect pole accident frequency (rather than the frequency of run-off-road accidents) can be determined.

Since there are considerably more run-off-road accidents than utility pole accidents, it was appropriate to sample only a fraction of the run-off-road accidents. As both the pole accident and the run-off-road samples are drawn from the same general population, collecting more run-off-road accidents than poles would gain very little in terms of the statistical analysis. Accordingly, for each of the areas in which run-off-road accidents were to be collected, a sampling fraction was estimated using the appropriate police agency's accident statistics which gave similar number of run-off-road accidents as single vehicle utility pole accidents.

3.1.2 Data Sources

It was decided that data covering the whole of 1975 would be collected and that the collection should be retrospective. Three potential sources were available: police accident reports, utility company records, and driver reports submitted to the appropriate state's Department of Motor Vehicles. It was decided that police reports would provide the most suitable data and the least bias of the three sources. For example, utility company records, in general, are based on repair reports such that they represent only those accidents in which pole damage was sustained. Such a sample would be biased towards more serious injury collisions. As regards driver records, reporting requirements (in terms of injury and/or amount of property damage) varies between states and the level, accuracy, and consistency of reporting is likely to be lower than for the other sources. Undoubtedly there will be some variation in the damage/injury reporting thresholds for different police agencies. However, the elimination of any bias toward serious injury through inclusion of property damage accidents is a more important consideration than the slight bias that will be incurred from a damage threshold. Additionally, using police reports that are filed with the express purpose of documenting the accident (rather than using records kept for an alternate purpose) should provide the most consistent data in both level and accuracy of reporting.

In order to fulfill the study's objectives, a wide variety of data had to be collected for each applicable accident. These data can be divided into three general categories; they are listed below together with examples of data elements for each:

- accident data, e.g., time of day, road and weather conditions, driver action and condition, etc.

- utility pole data , e.g., offset from roadway of struck pole, pole spacing in the vicinity of the accident, pole damage, cost-to-repair, etc.

- roadway data, e.g., road width and composition, shoulder widths and composition, vertical and horizontal alignments, ADT, etc.

The police reports would supply the information necessary to meet the accident data needs. The level of detail in these reports is sufficient to provide a general accident description and the prevailing environmental conditions. However, with the exception of a few of the more serious accidents, detailed utility pole and roadway data are not included on police reports; thus, the police reports needed to be supplemented with other data sources. Through conversations with personnel at various utility companies, it was determined that the companies generally could provide the average pole spacing for road segments containing a large number of utility poles, but the spacing in the immediate vicinity of a struck pole would not be available. Perhaps, more importantly, few of the utility companies' records included pole offset information. In general, it was found that utility companies would be able to provide cost-to-repair data for the study, but that other pole-related information would be most conveniently obtained by visiting the site of the accident.

It was also decided that roadway data could be efficiently collected at the scene at the same time the utility pole data were obtained rather than by contacting local highway departments. Their cooperation, however, was still necessary in obtaining the ADT figures for those roads on which applicable single vehicle accidents had occurred.*

3.1.3 Selection of Data Collection Areas

In order to insure that the data in this study were compatible with the rural data collected in conjunction with the "Methodology to Reduce the Hazardous Effects of Highway Features and Roadside Objects" (Reference 27), the same states were to be used, specifically Maine, Georgia, Tennessee, South Dakota, Wyoming, and California. For each of these states, the five largest cities were considered as potential data collection areas.

The three largest cities in each were generally selected to be data collection areas. However, in California, Los Angeles was eliminated because its large size (over 7 million residents) might tend to bias the study; similarly, San Francisco was discarded on the premise that it was geographically atypical. Later in the study, it was decided to drop San Jose as a data collection area as well. Contributing to this decision were the facts that in California, the utility companies had undertaken a campaign to bury overhead cables, and the expense of data collection in California was high, due, in part, to its distance from Buffalo; thus, the expense of collecting such a limited quantity of data could not be justified.

In addition to data from these states, it was decided to collect data locally in Western New York; i.e., the eight-county area surrounding Buffalo. It was felt that this would provide a useful data subset to compare the data from the other areas and serve as a training ground for the investigators

* Actually, in all states except New York and California, the state Departments of Transportation acted as "clearing houses" for the ADT data and, thus, there was no need to contact the local highway departments in those areas.

before sending them into the field. The third largest city in this area, Jamestown, was eliminated as it was estimated that there would be only 15 applicable utility pole accidents in 1975. Furthermore, it was decided to use all applicable accidents in the Erie and Niagara County areas, rather than to confine the data collection to the cities of Buffalo and Niagara Falls. Since Calspan is centrally located (see Figure 3-1) in this two-county area, the additional data collection could be accomplished economically and the more rural data could serve as a transition, by way of comparison, between the urban/suburban data collected in this study and the rural data of the "Highway Hazards" program.

Another exception to the general procedure of collecting data in three cities per state was made in Maine. There, five cities were selected as data collection areas, but were actually three urban-suburban areas, Lewiston and Auburn are contiguous to each other, as are Portland and South Portland.

Table 3-1 is a list of the data collection areas finally selected and other relevant facts about the locales.

Figure 3-2 is a map of the United States illustrating the scope of the data collection effort.

3.1.4 Establishment of Field Operations

Prior to starting data collection, a great deal of preliminary work was necessary. For each area, it had to be determined that cooperation could be obtained from the local police and utility companies. In addition, an overall plan for the data collection, the data collection procedures, and a training program for the field representatives had to be developed; police reports of applicable accidents within each area had to be obtained together with necessary equipment for investigation, i.e., measuring wheels, safety clothing, etc.

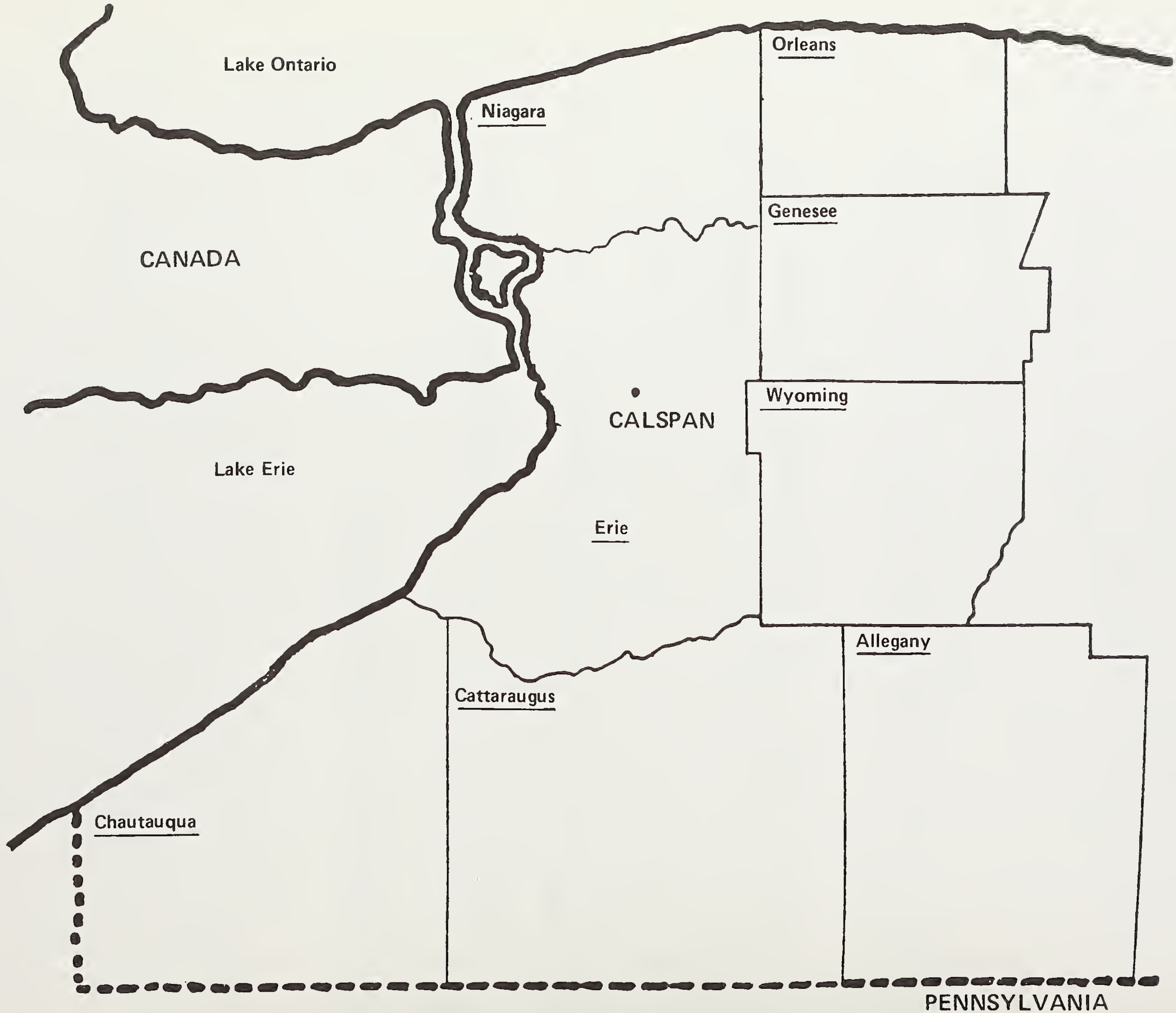

Figure 3-1 EIGHT COUNTY AREA SURROUNDING BUFFALO

TABLE 3-1

SUMMARY OF DATA COLLECTION AREA*

Area	Population	Population Density (people/mi.^{2})**	Utility Companies Within Area
Erie County, NY	1,113,491	1,052	New York Telephone, Niagara Mohawk, New York State Gas and Electric
Niagara County, NY	235,720	443	New York Telephone, Niagara Mohawk, New York State Gas and Electric
Oakland, CA	361,613	6,771	Pacific Telephone, Pacific Gas and Electric
San Diego, CA	696,566	2,200	Pacific Telephone, San Diego Gas and Electric
Atlanta, GA	497,024	3,783	Southern Bell, Georgia Power
Columbus, GA	154,098	2,231	Southern Bell, Georgia Power
Macon, GA	122,423	2,498	Southern Bell, Georgia Power
Memphis, TN	623,755	2,868	South Central Bell, Memphis Light, Gas, and Water
Nashville, TN	448,003	882	South Central Bell, Nashville Electric Services
Knoxville, TN	174,587	2,267	South Central Bell, Knoxville Utilities Board
Portland-S. Portland, ME	88,383	Unk.	New England Bell, Central Maine Power
Lewiston-Auburn, ME	65,930	Unk.	New England Bell, Central Maine Power
Bangor, ME	33,168	967	New England Bell, Bangor Hydroelectric
Sioux Falls, SD	72,488	2,900	Northwestern Bell, Northern States Power
Rapid City, SD	43,836	2,657	Northwestern Bell, Black Hills Power and Light
Aberdeen, SD	26,476	4,728	Northwestern Bell, Northwestern Public Service
Cheyenne, WY	40,863	3,589	Mountain Bell, Cheyenne Light, Fuel, and Gas
Casper, WY	39,361	4,800	Mountain Bell, Pacific Power and Light
Laramie, WY	23,143	Unk.	Mountain Bell, Pacific Power and Light

*1970 Figures

**1 person/mi.^{2} = .38 persons/km^2

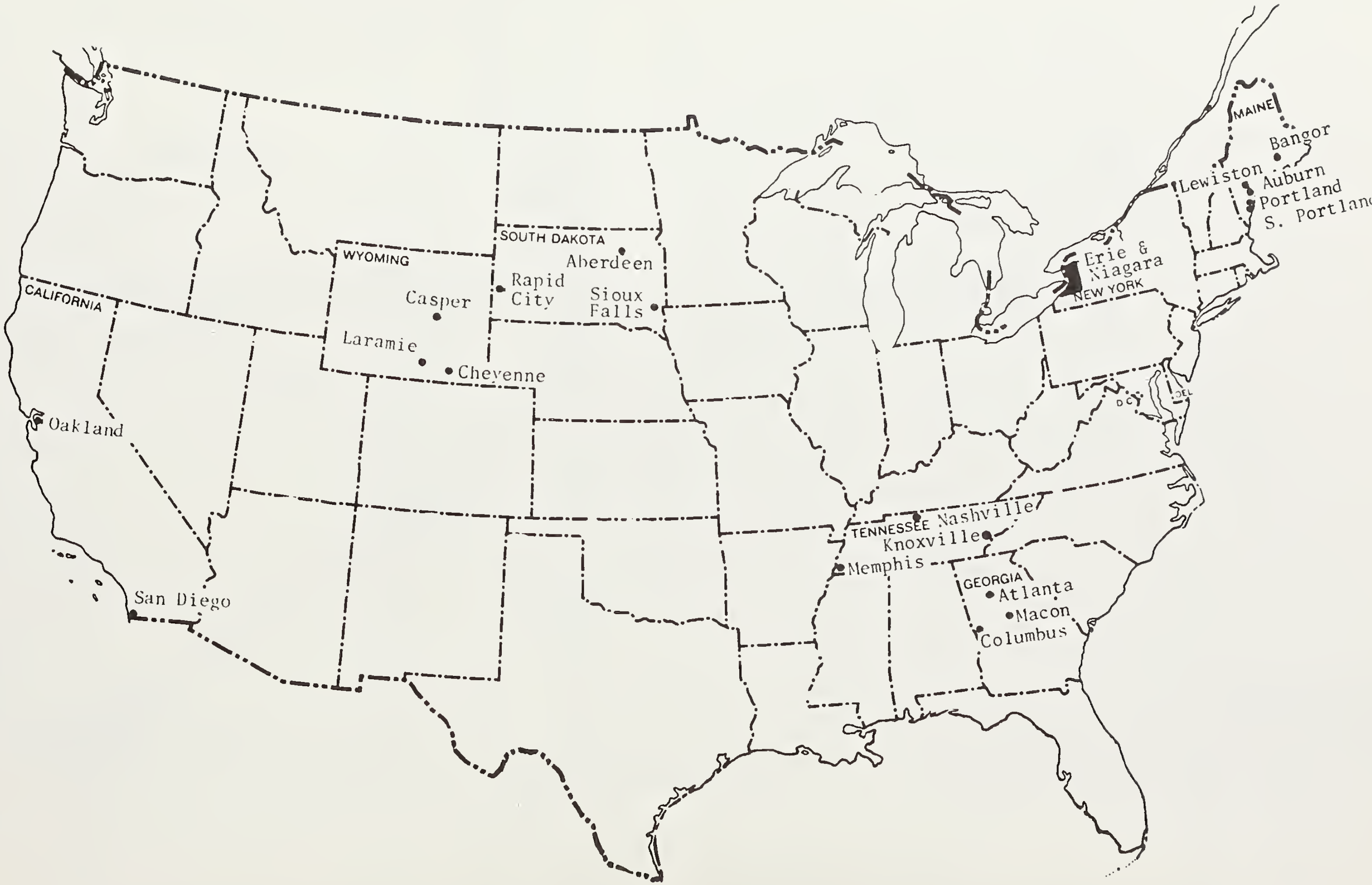

Figure 3-2 ACCIDENT DATA COLLECTION SITES

Police agencies in all areas other than Western New York were contacted to ask their cooperation in providing accident reports of applicable accidents. In many places, it was agreed that a Calspan representative would be given access to the police accident files to search for the applicable accident reports, and make appropriate copies. As an alternative, other police departments agreed to supply copies of applicable accident reports, which required their own personnel to search the files. When this involved a significant amount of labor, arrangements were made to reimburse the police for their expense.

In Western New York, however, the accident reports were already being obtained on a routine basis. Exceptions to this were the police agencies for the Cities of Buffalo and Niagara Falls; because accidents are not presently sampled in these jurisdictions on a continuing basis, formal requests for cooperation with the study were made.

Concurrent with setting up the accident data collection effort, contact was made with the appropriate telephone and power companies. Most of the companies were amenable to cooperating, but they generally could not make any formal commitment to provide the cost-to-repair data without the approval of the company's upper management and/or its legal department. Accordingly, formal letters of request were mailed to the appropriate personnel.

The letters to the power companies were then followed by another round of telephone conversations in which most agreed to cooperate. In situations where the company was still reticent to provide the repair costs - generally because they felt that the study's results might not be in their best interests - the appropriate power company personnel were further contacted by a representative of the Federal Highway Administration. These procedures gained the cooperation of the power companies in all the data collection areas.

In obtaining the cooperation of the telephone companies, initial contact was made by telephone with individual Bell Telephone Companies. A number of these companies referred our request to their parent company, American Telephone and Telegraph (AT&T). As a result, additional information outlining the objectives of the study was forwarded to AT&T who then agreed to endorse the study.

Rather than hire and train teams in each area, the data collection plan developed utilized six field representatives trained in Buffalo, who subsequently traveled to the data collection areas. It was felt that data collected in this manner would contain less investigator-dependent variability; training time would be reduced, the necessity for spot checks in the field would be greatly reduced; and the field data collection procedures could be (and were) refined by the investigators to a very efficient level. An exception was made in both California data collection areas. There, local personnel were hired and trained in order to avoid the expense of sending and supporting two or four people in California for an extended period of time. A training program for the field representatives was developed and a data collection manual was written in conjunction with this training program; these are discussed in Sections 3.2.2 and 3.2.3.

Copies of the applicable accident reports were collected just prior to the beginning of the field data collection phase in each specific area. In the relatively small data collection areas, i.e., Maine, South Dakota, and Wyoming, in which access to the accident files had been granted by the local police departments, the field representatives visited the police agencies personally, searched the files, and pulled and copied the appropriate reports. Other agencies in small data collection areas supplied employees to do the search of the files.

The procedure for selecting the run-off-road accidents should be noted. Originally, it had been planned to collect only a 20% sample in the six areas (Erie and Niagara Counties, Columbus and Macon, Georgia, Knoxville and Nashville, Tennessee, and San Diego, California); however, it was found in the first data collection area--Knoxville--that the volume of run-off-road accidents generated by the 20% sample fell short of the number estimated. Therefore, it was decided to use a 40% sample of the run-off-road accidents. Since the rightmost digit of the license plate can be shown to behave as a uniformly distributed random variable, the 40% sample was selected by including only those accidents in which the involved vehicle's rightmost license plate digit corresponded to any one of four preselected (and presumably random) numbers. In San Diego, a run-off-road sample had not been planned originally, but due to the quality of the police reports, a decision was made to utilize a 20% sample of run-off- road accidents. Because of the preponderance of license plates containing no digits, it was decided to base this sample on the last digit of the police report number. Table 3-2 is a list of the numbers used for the respective states.

TABLE 3-2

SUMMARY, BY STATE, OF RIGHTMOST DIGIT OF LICENSE PLATE FOR APPLICABLE RUN-OFF-ROAD ACCIDENTS

State	Digits
New York	1, 3, 6, 9
Georgia	2, 4, 5, 9
Tennessee	5, 6, 7*, 9*
California**	4, 6

*Not used in Knoxville

**Digits refer to rightmost digit of police report number

Each investigator was provided with:

- a Rolatape Measure Master, Model 30MM, measuring wheel*,
- a Lufkin HW50 50 foot tape measure,
- a poncho,

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*Optical range finders were considered for measuring the scene data, but models with the appropriate range, i.e., 15 to 1500 feet (5-450 m) were not only difficult to obtain, but the accuracy at both ends of their working range was suspect.

- a mesh, blaze orange safety vest,
- 5/32" Allen key (the set screw securing the measuring wheel to its axle had a habit of coming loose)
- maps of the relevant area provided by the local Chambers of Commerce,
- clipboards, pencils, etc.

In addition, one Keystone Pocket-matic 101 camera (and film) was purchased for each data collection team.

3.1.5 Field Data Collection Logistics

It was decided that the most economical way to conduct the inventory within the data collection areas, was to have the field representatives work as two-man teams. An attempt was made to have only one team visit any one area; in this way, the time necessary to become oriented to the data collection area, its traffic patterns, etc., was minimized.

Prior to going into the field in a particular data collection area, the investigators advised the local police of their planned activity. They also marked the accident locations on maps of the area; in this way, itineraries could be laid out daily, thus minimizing driving time between accident sites. Each field representative generally inventoried twenty to thirty accident sites per day.

Data collection in the Erie and Niagara Counties area was conducted throughout the duration of the data collection phase. Early in the study, this data collection aided in determining relevant data elements and in developing the final version of the supplemental data collection form. Throughout the remainder, data collection activities in Erie and Niagara Counties were conducted as an alternative to sending the field representatives to a new area in the middle of the week.

The scope of the data collection effort was greater than the total number of cases that underwent statistical analysis. Much of this stemmed from the fact that the existence of utility pole contact could not always be determined from the police report; the terms "light pole", "utility pole", and "telephone pole" were often synonymous. Thus, the investigators had to visit the scene in order to decide whether the case was a utility pole accident, an applicable run-off-road accident, or should be discarded. Other potentially applicable cases had to be rejected occasionally as a result of the inability to locate the accident site from the police description or recent construction changing the scene. Table 3-4 presents the magnitude of the data collection effort for each data collection area. It should be noted that additional cases were categorized as non-applicable during the coding of the data. These are summarized in Appendix 1.

3.1.6 Ancillary ("Armchair") Data Collection Procedures

The term ancillary data is used here to refer to the cost-to-repair and ADT information. All of these data were obtained by contacting the appropriate personnel in the utility companies and local highway departments/ state DOT's.

In requesting cost-to-repair information from utility companies, it transpired that the data could be provided by one of two alternatives, depending on the structure of their files. Either a list of accidents by date, location, and cost-to-repair was prepared by the utility company of all accidents requiring repairs which could then be checked against the police reports, or a list of utility pole accidents by date and location compiled by Calspan from police reports of the appropriate area was forwarded to the utility company to be checked against their records.

TABLE 3-4

SUMMARY OF ACCIDENTS INVESTIGATED

Area	Number of Pole Accidents Investigated	Number of Run-Off-Road Accidents Investigated	NA	Total
Macon	119	60	77	256
Columbus	140	152	81	373
Nashville	433	564	466	1,463
San Diego	175	249	62	486
Oakland	158	-	60	218
Knoxville	198	89	86	373
Memphis	791	-	509	1,300
Erie and Niagara Counties	699	1,072	525	2,296
Atlanta	1,025	-	24	1,049
Portland, Maine	41	-	21	62
South Portland	22	-	11	33
Lewiston	54	-	9	63
Auburn	33	-	13	46
Bangor	40	-	7	47
Casper	13	-	13	26
Cheyenne	4	-	11	15
Laramie	1	-	13	14
Sioux Falls	19	-	17	36
Rapid City	17	-	31	48
Aberdeen	9	-	23	32
TOTAL	3,991	2,186	2,059	8,236

Some of the ADT data were collected in the same manner described above; lists of intersections near which applicable pole and run-off-the-road accidents had been investigated were sent to the cooperating highway agency. There the ADT figures were entered and the lists were returned to Calspan. This form of collection was confined to the small data collection areas such as Wyoming and South Dakota.

In most other areas, traffic flow maps, or traffic survey maps, were obtained, and data coding personnel subsequently located the accident site on the map and determined the nearest applicable ADT figure. In Erie and Niagara Counties, it was more convenient to visit the respective county highway departments because of the way in which the information was stored; i.e., Erie County used an index card file; in Niagara County, there was only one traffic survey map available which was located in the highway department office.

Regarding the ADT information, it should be noted that there were few local roads within the urban/suburban areas for which these data could be found; presumably, this is because no counts have been made on them.

3.2 Field Data Collection

3.2.1 Supplemental Data Collection Form

Data collection activities had been initiated in the Erie and Niagara Counties area prior to the start of the major data collection effort. A preliminary version of the supplemental data collection form was developed and field tested. An extremely rough version of the data coding form was created at this time; its primary intent was to determine if, 1) there were any ambiguities in the data collected in the field, 2) any important data elements had been inadvertently omitted, and 3) any superfluous data were being collected. A copy of the final supplemental form is provided in Appendix 2.

The data elements which were collected on the data collection form are listed in Table 3-5. A more detailed description of the individual variables are contained in the data collection manual discussed in the next section.

3.2.2 Data Collection Manual

To facilitate training of the field representatives and to insure uniformity in the data collected, a data collection manual was written. A copy of the manual can be found in Appendix 2. The manual provides a definition of each data element and, when necessary, the prescribed method for measuring it.

3.2.3 Field Investigator Training

At the beginning of the major portion of the data collection phase, a three-day training session for the field investigators was held at Calspan. The manual was reviewed in a classroom-type training session during the first day and special situations regarding measurement of the pole spacings were diagrammed and discussed. This was followed by a group session inventorying pole accident sites. The investigators then inventoried pole accidents which had already been inventoried by the experienced accident investigators. In this way, errors in an individual's data collection technique could be discovered and corrected. Problems encountered during these accident site visits were also discussed.

3.3 Data Processing

3.3.1 Data Coding Form

The preliminary data coding form developed in conjunction with the supplemental data collection form underwent several revisions prior to reaching its final form (see Appendix 3). The coding form was designed to

TABLE 3-5

FIELD DATA ELEMENTS

- Struck Pole Idenfitication Number
- Pole Offset
- Pole Spacings, Near Side
- Shoulder Width, Near Side
- Road Width
- Shoulder Width, Far Side
- Pole Spacings, Far Side
- Specification of North
- Path of Vehicle
- Road Curve
- Road Type
- Curb Height
- Spillway Depth
- Ditch Depth
- Other Off-Road Height or Depth
- Accident Type
- Number of Through Lanes
- Number of Inside Auxiliary Lanes
- Number of Outside Auxiliary Lanes
- Road Surface Type
- Shoulder Surface Type
- Streetlamp Attached to Struck Pole
- Posted Speed Limit
- Traffic Control
- Intersection
- Type of Pole
- Pole Damaged
- Pole Circumference
- Median Width

increase the efficiency of the coding and keypunching phases. This was accomplished by making as many data elements as possible self-coding, i.e., the value to be coded can be ascertained without using tables located elsewhere. This was not possible with all variables, e.g., Objects Struck, Primary Area of Damage, etc. The coding form was also laid out to permit keypunching directly from the coding sheets. In order to avoid differences in the interpretation of the data elements by coding personnel, a codebook was written. The codebook contained more detailed information for those variables which were not self-explanatory. A copy of it is provided in Appendix 3.

3.3.2 Data Conversion

Prior to the analysis phase, the data needed to be converted to a form suitable for the computer program that was to be used. This program - capable of generating four dimensional frequency distributions - placed restrictions on the variables being analyzed; specifically, they needed to be in INTEGER*2 format*, with a range from one to twenty. (This latter limitation applied only to analysis variables - variables which are included in the frequency tabulations.)

A transformation program (see Appendix 3) was written that appropriately grouped and changed those variables equal to zero or having negative values into a more suitable form. Certain continuous data elements, e.g., pole spacing, were converted into two variables on the analysis data file; one variable was grouped and the second retained the raw value. Obviously, only the former could be used when creating frequency distributions, but the other could be used to determine means** or to recategorize the variable of interest.

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*INTEGER*2 format means that each value was represented on the data tape by a 2 byte integer word.

**A feature of the analysis program is its capability to provide the sum of a given variable with each cell of the resultant frequency distribution. This summed variable does not have to have a range between one and twenty.

The data file that was output from the conversion program contained one accident record and an occupant record for each person reported in the involved vehicle. Each accident record was comprised of 82 variables; occupant records contained four data elements. A listing of the variables is given in Appendix 3.

3.4 Data Control Procedures

3.4.1 Spot Checks

Spot checks of all the field investigators were made very early during the data collection phase by randomly selecting several completed reports from each investigator. As this was undertaken primarily to improve the quality of the data, and not as a "catch-as-catch-can" exercise, the field representative whose work was being assessed, accompanied the "checker". Not only did this lessen the amount of time required to locate the accident sites, but errors could be discussed at the scene. In general, the quality of the data collected was found to be extremely high.

Only one spot check per investigator was made by the above method. Once assured that the data were being collected correctly, it was decided to delegate further spot-checking responsibilities to the various team leaders. These were carried out periodically; no decrease in quality was evident.

3.4.2 Coding Review

In the course of the study, a discontinuity between the data collection and data coding phase developed.* This, in retrospect, was a boon to the study, in that the time was utilized to review the data that already

*Primarily, this was a result of the extremely inclement winter experienced in the Buffalo area, which delayed the completion of data collection in Erie and Niagara Counties.

had been coded and correct any errors that were detected. Coding procedures had evolved throughout the coding task; additionally, slight variations among the coders were also suspected. The review was carried out on a case-by-case basis; special emphasis was placed on the cases which were coded early in the process, as errors were most likely to occur then.

3.4.3 Edit Checks

A set of validity and consistency checks were developed for the utility pole data. The validity checks insured that each data element was coded with a legal code or had a reasonable value, e.g. no median widths of 400 feet should occur. The consistency checks, on the other hand, examined the codes of two or more data elements, and insured that they did not contradict each other. For instance, if it were found that snow covered roads contributed to an accident occurring in July, one would suspect a coding error.

In order to facilitate the editing process, a computer program was written; a listing of the program is given in Appendix 3. The error listing generated by this program was subsequently returned to the data coding personnel, who reviewed each case and made any necessary amendments.

The cases requiring corrections were input into the edit program a second time and, if necessary, corrected again. This process continued until all the cases had successfully "survived" the editing process; as it turned out, no case needed more than four iterations.

3.5 Data Analysis Procedures

The data analysis phase was intended to answer two major questions concerning utility pole accidents:

- in what way do utility pole accidents differ from run-off-road accidents, and
- what factors affect the severity of utility pole accidents?

In order to answer the first of the two questions, univariate distributions of relevant variables were generated using the analysis program mentioned in Section 3.3.2. The analysis program was developed at Calspan for dealing with multivariate categorical data arranged in a hierarchical fashion. It can produce joint frequency distributions of up to four dimensions and, if so desired, calculate the sum and sum of squares of a fifth variable for each cell in the frequency distribution; furthermore, the program has a mechanism to filter out those cases which are not of interest. The original version of the analysis program was altered in this study, so that the run-off-road sample could be properly weighted. This was accomplished by increasing the appropriate cell frequencies by 5 in 20% sample areas and 2.5 in 40% areas. Prior to the output routines, each cell frequency was made integer by truncation. Because of the truncation, slight variations in the total frequencies will be evident in analyses using run-off-road data; the error in the total number of cases can be no greater than the number of cells in the analysis.

Initially, univariate distributions for run-off-road accidents and utility pole accidents occurring in run-off-road areas were examined for differences. However, no statistical procedures were used in making this determination; because of the large sample sizes involved, almost all χ^2 or analyses of variance turned out to be significant, but had very low degrees of statistical association (Reference 14). Instead, these distributions were examined for trends. These trends, combined with engineering intuitions, suggested bivariate distributions which were then generated and analyzed.

In order to assess the relative importance of the various significant factors leading to utility pole contact, stepwise multiple regression techniques were applied using the SAS computer package (Reference 15). An additional computer program was required to create the SAS data set from the data file used for the analysis program. In order to account for the sampling of the run-off-road accidents, multiple records were written onto the data file for run-off-road accidents. This was relatively straightforward in 20% sampling areas, for which five output records could be written; it was somewhat more difficult to output the 2 1/2 records necessary to properly weight 40% sample areas. To circumvent this problem, two and three records were written alternately for each case.

The analysis of the severity factors utilized data from all collection areas. Bivariate distributions of potentially relevant variables and severest occupant injury were generated by the analysis program and examined for significant trends.

3.6 Countermeasures Evaluation Procedures

Implementation decisions regarding technologically and legally feasible countermeasures should be based on a cost-benefit analysis. Essentially, this analysis involves comparing a countermeasure's estimated costs to its projected savings; Table 3-6 presents examples of potential cost and saving sources. Obviously, all of the sources are not relevant to every countermeasure (in fact, some are mutually exclusive).

TABLE 3-6 - SOURCES OF POTENTIAL COSTS AND BENEFITS FOR UTILITY POLE RELATED COUNTERMEASURES

Potential Costs Sources	Potential Benefits Sources
Implementation Costs	Decreased Societal Costs of Personal Injury
Increased Maintenance Costs	Decreased Utility Company Property Damage
Additional Costs to Provide Adequate Street Lighting	Decreased Vehicle Damage Costs
Cost of Inadequate Street Lighting	Decreased Maintenance Costs

If the benefits of a proposed countermeasure outweigh its expected costs, then its introduction is warranted.

Prior to undertaking a cost-benefit analysis, one must decide which factors to include; in other words, to whom should the countermeasure be cost-beneficial? In relation to the utility pole accident problem, there are two points of view to consider: society as a whole and the utility companies. Ideally, one would want to demonstrate that a countermeasure is financially advantageous to the utility companies, i.e., the cost of implementation could be recovered through a reduction in repair costs and other associated benefits.*

Since a large portion of the repair costs are recovered through insurance and because of the magnitude of countermeasure implementation costs

*For example, if utility lines were buried underground, a utility's economic loss as a result of downed power lines after an ice storm would be a thing of the past.

relative to repair costs, it is unlikely that a countermeasure can be shown to be cost-effective solely from the utility companies' point of view. However, the introduction of societal factors into the cost-benefit analysis creates additional problems:

- who should bear the financial burden of installing countermeasures proven to be cost-effective to society, and
- estimated societal costs, such as personal injury, are subject to wide variations

The issues surrounding the placement of a dollar value on injuries incurred in motor vehicle accidents will be discussed in Section 3.6.1. However it should be noted that the variations in the injury costs do not detract from the utility of the cost-benefit analysis; rather, when improvements are indicated, their benefits should be sufficiently large to absorb these variations. The question concerning the financial responsibility of the countermeasure's introduction is quite obviously beyond the scope of this study. However, the authors feel that it must be dealt with before any countermeasure is deemed cost-beneficial.

3.6.1 Injury Costs

As was noted, societal costs of injuries sustained in automobile collisions are subject to large variations. Miller, et al. (Reference 16) provided an example of the magnitude of this variation based on the results of three 1972 reports. The authors cite a study by the NHTSA (Reference 17) which placed a value of $200,700 on each fatality. The Ad Hoc committee on the Cumulative Regulatory Effects on the Costs of Automotive Transportation (RECAT) found the societal cost of an automobile fatality to be $140,000 (Reference 18); the National Safety Council (NSC), on the other hand, estimated the cost to society to be only $21,800 (Reference 19).* As one can see, these variations are rather extreme, i.e., on the order of 9 to 1.

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*This value is based on NSC workman's compensation costs from on-the-job motor vehicle injuries; it includes permanent total disabilities as well as fatalities.

One obvious source of the discrepancy in the cost estimates stems from differences in the cost components of societal cost. The components which the NHTSA utilized in their respective estimates are presented in Table 3-7.

TABLE 3-7 - COMPONENTS OF SOCIETAL COST ESTIMATES

NHTSA	NSC
Production/Consumption (Market, home, family, and community)	Wage losses
Medical (Hospital, physician, coroner, rehabilitation)	Medical and hospital fees
Funeral	Insurance administration and claim settlement costs
Legal and court	Property damage
Insurance administration	Money value of time and others directly or indirectly involved
Accident investigation	
Losses to others	
Vehicle damage	
Traffic delay	

The major variation in the two definitions seems to lie in the Production/ Consumption component. The NSC included only the amount of all future wage earnings at the victim's present salary; in contrast, NHTSA's method applied an increase of 3% per year (for productivity gains) discounted at 7% per year to the mean full-time income of the appropriate age group. Furthermore, the NHTSA added in the societal benefit of volunteer work, home maintenance, household tasks, child rearing, etc. (in 1975 [Reference 20] this amounted to an additional $63,545 in the cost of a fatal accident). The above reasons are not sufficient, by themselves, to explain the entire variation in the estimates. Differences in age and income between the accident population and those receiving workman's compensation, for instance, may also be relevant. The other factors, not included in the NSC estimate, also contribute to the discrepancy in cost estimates but are not of the magnitude of the "wage loss differences".

Miller, et al. reported another interesting finding relative to the costs of injuries sustained in motor vehicle accidents. If one were to compare the three broad general categories of highway safety - fatal, non-fatal, and property damage only - on the basis of their cost to society, a different set of rankings would result from each of the three sources (NHTSA, RECAT, and NSC) providing societal cost estimates of injury! This is presented in Table 3-8.

TABLE 3-8 - COMPARISON OF SOCIETAL COST ESTIMATES
(adopted from Miller, et al.)

	NHTSA		RECAT		NSC	
Components	Cost $\$ \times 10^9$	Rank	Cost $\$ \times 10^9$	Rank	Cost $\$ \times 10^9$	Rank
Fatal Injuries	11.0	2	7.7	1	2.4	3
Non-Fatal Injuries	27.7	1	6.1	2	3.6	2
Property Damage	7.2	3	4.9	3	4.6	1
TOTAL	45.9		18.7		10.6*	

*Excludes insurance administration costs estimated to be $\$5.2 \times 10^9$

It would seem, then, that one is forced to arbitrarily select a source of injury costs for the cost-benefit analysis. For the purposes of this study, the 1975 costs as determined by the NHTSA will be utilized. The major justifications for this choice are:

- this reference provides the highest estimates of societal injury costs; if a countermeasure does not prove to be cost-beneficial under these circumstances, it can be disregarded rather confidently
- the NHTSA figures are broken down by injury severity; in this case the Abbreviated Injury Scale or AIS is used (Reference 21)

Since the data collection phase of the present study measured injury severity in terms of K-A-B-C-D, each AIS code will have to be transformed into the K-A-B-C-D scale. The transformation and associated societal cost for each injury level is shown in Table 3-9.

TABLE 3-9 - K-A-B-C-D TO AIS
TRANSFORMATION AND RESULTANT SOCIETAL COSTS

Injury Severity	Includes AIS Codes:	Societal Cost per Injury
K	6	$287,175
A	3, 4, or 5	30,335
B	2	4,350
C	1	2,190
D or O	-	520

The cost of an "A" severity injury was computed by weighting the societal cost estimate of AIS 3, 4, and 5 injuries by their respective probabilities of occurrance. The NHTSA results were based on 4,000 AIS 5, 20,000 AIS 4, and 80,000 AIS 3 injuries.

3.6.2 Property Damage Costs

Included in the above injury costs is an estimate of the vehicle repair costs, also broken down by injury severity. The data that these estimates were based upon were collected from the claim files of 20 insurance agencies; it is unclear whether the vehicle repair costs were separated from other claim costs, such as reimbursement for property damage. It will be assumed, however, that only vehicle cost-to-repair is included.

No estimate of property damage appears to be available in the NHTSA report. In the case of utility pole accidents, this value has been obtained through the utility companies. Unfortunately, it was beyond the scope of the present study to collect cost-to-repair data in the run-off-the-road accident sample.

4. RESULTS

As has already been described in the Data Collection Plan, single vehicle, run-off-road accidents were collected in selected areas concurrently with single vehicle, utility pole accidents. Consequently, the utility pole accidents and run-off-road accidents in those areas should both be a subset of the single vehicle accidents, so that by comparing the two data sets, any differences peculiar to utility pole accidents should emerge. To be explicit, there are three data sets of interest; (i) utility pole accidents for all areas studied, (ii) utility pole accidents for the areas in which run-off-road accidents were sampled, and (iii) run-off-road accidents.

4.1 Overview of the Utility Pole Accident Problem

4.1.1 The Extent of the Utility Pole Accident Problem

In analyzing utility pole accidents, the first requirement is to put the problem into perspective with respect to other types of accidents. Referring to Accidents Facts 1976 (Reference 1),* single vehicle accidents accounted for 36.3 percent of the fatal accidents and 18.5 percent of all accidents. Looking specifically at urban areas, the corresponding figures were 26.0 percent and 10.4 percent respectively. The obvious question to ask is what percentage of the single vehicle accidents are utility pole collisions? (This breakdown is not provided in the national statistics.) Using the data from the present study, Table 4-1 gives the distribution of single vehicle accidents by first object struck ranked by frequency - this table is constructed by combining the run-off-road accident data, corrected for sampling fraction, with the utility pole accident data for the same study areas.

As a source of impact, utility poles are by far the most frequent. They accounted for 21.1 percent of the objects struck in single vehicle accidents, compared to 13.5 percent for impacts with a fence or guardrail, the next most frequent object struck. Combining this figure with the national figure

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*The figures cited are based on 1974 data.

TABLE 4-1 - FIRST OBJECT STRUCK IN
SINGLE VEHICLE ACCIDENTS RANKED BY FREQUENCY

First Object Struck	Number of Accidents	Percentage of Total
Utility Pole	1291	21.1
Fence, Guardrail	825	13.5
Sign, Mailbox, Parking Meter, Guy Wire	728	11.9
Culvert, Ditch, Embankment	714	11.7
Tree	682	11.1
Light Signal Pole	466	7.6
Fire Hydrant	223	3.6
Building	215	3.5
Ground (generally rollover)	187	3.1
Wall	175	2.9
Shrubbery	120	2.0
Bridge	116	1.9
None	79	1.3
Other	303	4.9
TOTAL	6124	100.0

for single vehicle accidents suggests that 2.2 percent of all accidents in urban areas involve impacts with utility poles.

Obviously, the proportion of utility pole accidents as a function of single vehicle accidents can be expected to vary from area to area. For example, one would expect the historical development of an urban area to affect pole placement practices, which would in turn affect pole accident frequency. Table 4-2 contrasts pole accident frequency to the number of single vehicle accidents for those areas in which run-off-road accidents were collected. The proportion of utility pole accidents ranges from a high of 44.8 percent in Macon, Georgia to a low of 17.5 percent in San Diego, Calfornia. The latter figure most likely results from low density housing development together with a policy of undergrounding cables in new developments. Being able to account for this type of variation is an important part of this analysis. If the variation in the proportion of utility pole accidents between the areas studied can be explained by a given set of parameters, the results of the study can be extrapolated to any area of the country.

4.1.2 The Severity of Utility Pole Accidents

The previous figures suggest that utility poles are the most frequent object struck in single vehicle, *urban* accidents. However, this is of little consequence unless the relative severity associated with these and other fixed object collisions is known. It is well documented that single vehicle accidents have a high proportion of fatal and serious injuries. For example, the figures already quoted from *Accident Facts 1976* show that 10.4 percent of all urban accidents are single vehicle accidents but that they account for 26.0 percent of all fatalities. Since the present study was limited to single vehicle accidents, data for the overall accident population were not collected so that it is not possible to compute directly comparable figures. However, a comparison can be made of the relative severities. Using the figures from *Accident Facts*, the relative severity for single vehicle accidents (number of fatal single vehicle accidents/number of single vehicle accidents) in urban areas is 0.3 percent. Table 4-3 gives details of the

TABLE 4-2 - RELATIVE FREQUENCY OF UTILITY POLE ACCIDENTS COMPARED TO SINGLE VEHICLE ACCIDENTS BY STUDY AREAS

	Columbus, Georgia	Macon, Georgia	San Diego, California	Erie and Niagara, New York	Knoxville, Tennessee	Nashville, Tennessee	TOTAL
Number of Pole Accidents	109	103	145	632	179	322	1,490
Number of Single Vehicle Accidents	354	230	830	2,889	514	1,329	6,146
Relative Proportions	30.8%	44.8%	17.5%	21.9%	34.8%	24.2%	24.2%

TABLE 4-3 - SEVERITY OF UTILITY POLE AND RUN-OFF-ROAD ACCIDENTS

Police Injury Code	Utility Poles*		Run-off-Road		Combined	
	#	%	#	%	#	%
O-D	664	44.6	2886	62.2	3550	57.9
C	117	7.9	287	6.2	404	6.6
B	330	22.1	556	12.0	886	14.5
A	220	14.8	364	7.8	584	9.5
K	12	0.8	19	0.4	31	0.5
Severity Unknown	51	3.4	181	3.9	232	3.8
Unknown	96	6.4	347	7.5	443	7.2
TOTAL	1490	(100.0)	4640	(100.0)	6130	(100.0)

Utility Pole Accidents for those areas where run-off-road accidents were collected present sample classified by most severe occupant injury. Combining the utility pole accidents with the run-off-road accidents, it can be seen that there were 31 accidents involving fatal injury which represents 0.5 percent of all single vehicle accidents. Hence, the data from the present study suggest a slightly higher fatality rate although the number of fatalities that this figure is based on is small. Despite the small number of fatalities, it is interesting that in looking at the utility pole accident sample, the fatality rate is higher than for the run-off-road sample, i.e., 0.8 versus 0.4. That utility pole accidents are more severe than run-off-road accidents is also confirmed by looking at other injury levels. The proportion of no injuries is considerably lower, 44.6 percent for utility pole accidents compared to 62.2 percent for all run-off-road accidents and the proportion of injuries higher; at the C level 7.9 percent versus 6.2 percent, at the B level 22.1 percent versus 12.0 percent, and at the A level 14.8 percent versus 7.8 percent.

Having put the utility pole accident problem into perspective, the next step is to expand the various areas of interest in an attempt to find out why utility pole accidents occur and what affects their severity. Section 4.2 looks at the general characteristics of utility pole accidents and discusses how they vary from other run-off-road accidents. Section 4.3 then analyzes factors which affect utility pole accident frequency and Section 4.4, factors which affect utility pole accident severity.

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*The fatality rate is also dependent on the number of no injury accidents, the proportion of which will vary from state to state depending on the reporting criterion for property damage accidents. Fatalities as a proportion of all injuries could be a more reliable figure.

4.2 General Characteristics of Utility Pole Accidents

To explore the differences between utility pole and run-off-road accidents, univariates for utility pole accidents* (for the areas in which run-off-road accidents were sampled) were compared to the corresponding univariates for run-off-road accidents. To aid in the process of determining those variables which distinguish utility pole from run-off-road accidents, an attempt has been made to order the univariates into major headings which broadly describe the accident generation process and accident severity. They are as follows:

1. Time of Accident
2. Vehicle Descriptors
3. Environmental Conditions
4. Occupant Information
5. Driver Information
6. General Roadway Characteristics
7. Roadway Departure Characteristics
8. Collision Characteristics
9. Characteristics of Objects Struck
10. Utility Pole Placement Characteristics.

By examining the variation of parameters within each of these categories, it becomes clear where utility pole and run-off-road accident characteristics differ. Because of the large number of univariates, it would be laborious to present and discuss each table in turn. Accordingly, by way of summary, Table 4-4 lists each univariate analysis found in Appendix 4 with comments on any differences found between the two samples.

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*Univariates for the three data sets - run-off-road accidents, utility pole accidents, and utility pole accidents in run-off-road areas - are presented in Appendix 4.

TABLE 4-4 - SUMMARY OF COMPARISON OF
UNIVARIATES FOR UTILITY POLE AND RUN-OFF-ROAD ACCIDENTS

Univariate	Comment
TIME	
Month of Year	Small differences ~1%
Day of Week	" " ~1%
Hour of Day	" " ~3% - 50% of ROR* & UP accidents occur between 10PM-5AM
VEHICLE	
Model Year of Vehicle	" " ~1%
Vehicle Type	" " ~1-2% - Vehicle type unknown in 60% of cases
ENVIRONMENTAL CONDITIONS	
Light Conditions	" " ~1-2% - 60% of ROR & UP accidents occur at night
Road Conditions	" " ~1-2% - 60% of ROR & UP accidents occur on dry roads
Weather Conditions	" " ~1-2%
OCCUPANT INFORMATION	
Seated Position	" " ~1%
Restraint Use	" " ~2% - Restraint use low, 12-14% of occupants were known to be wearing seat belts
Occupant Ejection	" " ~1% - Ejection rate for UP and ROR about 1.0%
Occupant Injury	No Injury lower for UP accidents, 46.3% vs. 64.2% C Injury higher for UP accidents, 8.9% vs. 7.2% B " " " " " , 21.6% vs. 11.4% A " " " " " , 13.3% vs. 7.3% Fatal Injury higher for UP accidents, 0.6% vs. 0.4%
Severest Occupant Injury	No Injury lower for UP accidents, 44.6% vs. 62.2% C Injury higher for UP accidents, 7.9% vs. 6.2% B " " " " " , 22.1% vs. 12.0% A " " " " " , 14.8% vs. 7.8% Fatal Injury higher for UP accidents, 0.8% vs. 0.4%
Number of Occupants	Small differences ~2% - Average occupancy UP accidents 1.55, ROR accidents 1.57.

*ROR - Run-Off-Road Accidents
UP - Utility Pole Accidents

TABLE 4-4 (Continued)

Univariate	Comment
DRIVER INFORMATION	
Age	Small differences ~2-3%
Sex	Small differences ~1%
Traffic Violations	UP accidents had 3.8% fewer violations
Driver Condition	UP accidents had 3.0% more accidents involving driver falling asleep.
Drinking Involvement	UP accidents had 2.3% more drinking involvement than ROR accidents. The relatively small differences suggest that once vehicle leaves the road, the likelihood of avoidance is independent of driver condition.
Driver Action	----
GENERAL ROADWAY CHARACTERISTICS	
Road Type	Fewer UP accidents on Expressway (0.5% vs. 7.1%) and Local roads (30% vs. 35.7%).
Posted Speed Limit	UP accidents higher in 30-40 MPH (48-64 KPH) limits (71.4% vs. 58.7%) indicating that these are the roads with utility poles.
ADT	UP accidents overrepresented on roads with 6,000-10,000 and 11,000-15,000 ADT's.
Road Width	For widths < 24 feet (7 m), UP accident frequency was lower indicative of local type roads. UP accident frequency also lower for widths > 50 feet (15 m) indicative of Expressways.
Shoulder Width - Near Side	Small differences ~ 1% except for "no shoulder" where UP accidents were more frequent (54.9% vs. 47.6%).
Shoulder Width - Far Side	Small differences ~ 1% apart from "no shoulder" where UP accidents were more frequent (56.8% vs. 48.7%).
Median Width	Small differences ~ 1% apart from roads without medians where UP accidents were more frequent (93.2% vs. 87.9%).
Number of Through Lanes - Near Side	UP accidents slightly higher on single lane roads, 77.0% vs. 73.7%, but effect is small.
Number of Through Lanes - Far Side	----

TABLE 4-4 (Continued)

Univariate	Comment
GENERAL ROADWAY CHARACTERISTICS (Cont.)	
Number of Inside Auxiliary Lanes -	
Near Side	Small differences ~0.7% (Indicates that UP accidents occurred less frequently at intersections.)
Far Side	" " ~0.4%
Number of Outside Auxiliary Lanes -	
Near Side	" " ~2.4%
Far Side	" " ~2.5%
Intersection Type	Up accidents less frequent than ROR accidents at intersections, 12.6% vs. 16.1%.
Turn Leg	Small differences ~ 1%
Traffic Control	" " ~ 1%
Road Surface	" " ~ 0.7%
Shoulder Surface	UP accidents occurred less frequently on dirt and asphalt, and more frequently on concrete - this is probably indicative of road type.
DEPARTURE CHARACTERISTICS	
Side of Road Exited	Higher proportion of vehicles left right side in UP than in ROR accidents, 69.3% vs. 64.0% - occurred because to strike utility poles, angle of departure must be low; this is more likely in right than left departures. For both UP and ROR accidents, more vehicles departed right than left side
Road Path	Higher proportion of vehicles exited straight roads in UP accidents (low departure angle) 69.8% vs. 59.5%. For both UP and ROR accidents, more vehicles exited left than right curves.
Road Grade	Higher proportion of UP accidents occurred on level, 52.3% vs. 40.0%. Sign of grade not determined so that effect of speed cannot be assessed.
Travel Lane	Higher proportion of vehicles in UP accidents departed from near side lane, 57.0% vs. 48.1% - resulted from lower departure angle with higher probability of striking Utility Poles situated near the road.

TABLE 4-4 (Continued)

Univariate	Comment
COLLISION CHARACTERISTICS	
Travel Speed	Speeds for UP accidents marginally higher - likely because UP accidents were more severe - might expect higher travel speed although this is also a function of offset.
Area of Damage	Higher proportion of frontals in UP than ROR accidents, 67.7% vs. 49.3%. More damage to right front and right side than left front and left side for both UP and ROR accidents.
Direction of Force	Pattern similar to area of damage. More frontals in UP than ROR accidents. Right side impacts more frequent than left side impacts for both UP and ROR accidents.
Towed	More UP accident vehicles towed, 73.2% vs. 58.2%, reflects their more severe nature.
CHARACTERISTICS OF OBJECTS STRUCK	
Number of Objects Struck	Slightly higher number of single hits for UP accidents, 76.4% vs. 71.2%--most likely reflected higher severity of UP collisions.
Type of First Object Struck	Utility poles most frequently struck (21.1%) followed by Fence/Guardrail (13.5%), Sign/Mailbox/Parking Meter (11.9%), Culvert/Ditch/Embankment (11.7%), Tree (11.1%).
Rollover	Vehicles involved in UP accidents have fewer Rollovers, 3.2% vs. 10.0%--majority of energy dissipated in pole impacts, insufficient energy left for vehicle to roll-over.
UTILITY POLE PLACEMENT CHARACTERISTICS	
Pole Spacing - Near Side	43.3% of ROR accidents were on roads with 0 or 1 pole* Average pole spacing on roads where there were poles was 145 feet (44 m) for UP accidents and 180 feet (55 m) for ROR accidents.
Pole Spacing - Far Side	45.6% of ROR accidents were on roads with 0 or 1 pole, compared to 28.3% for UP accidents. Average pole spacing was 173 feet (53 m) for UP accidents and 171 feet (52 m) for ROR accidents.

*Within 600 feet (53 m) of either side of the accident site.

TABLE 4-4 (Continued)

Univariate	Comment
UTILITY POLE PLACEMENT CHARACTERISTICS	
Distance of Pole from Road Edge	Mean offset for struck poles was 5.5 feet (1.7 m) compared to mean final rest position of 7.33 feet (2.2 m) (usually the object struck) for ROR accidents in general.
Pole Circumference	---
Pole Type	97.4% of struck poles were wood.
Streetlamp Attached	33.6% of all struck poles had street lamps attached.
Pole Mortality	14% of all poles were undamaged; 33% sustained minor damage; nearly 11% of all damaged poles were knockdowns.
Cost to Repair	Average cost to repair = $171.

As is perhaps to be expected, parameters under the headings 4.2.1 through 4.2.5 showed little difference between the utility pole accident sample and the run-off-road accident sample (with the obvious exception of occupant injury) i.e., parameters describing the general accident population, such as hour of day, day of week, month of year, model year of vehicle, vehicle type, light/road/weather conditions, driver age/sex/drinking involvement/condition, occupancy, etc. This lack of variation serves to confirm that utility pole and run-off-road accidents are both subsets of the same accident set. Intuitively, one would expect the differences between utility pole and run-off-road accidents to show up in parameters which affect or describe vehicle departure attitudes and roadside environment rather than simply the probability of the vehicle leaving the road, i.e., the accident types are distinguished by events which occur after the vehicle has left the road. For example, one could expect the distribution of departure speeds to be different because departure speed will affect departure angle which, in turn, should affect the likelihood of a vehicle striking a utility pole . This is confirmed in Table 4-4 in that the major differences occur under the headings of departure characteristics, collision characteristics, characteristics of objects struck, and utility pole placement characteristics. A discussion of the pertinent results follows by major subject heading. Where appropriate, additional bivariate analyses have been given to expand the discussion; the raw data for these analyses can be found in Appendix 5.

4.2.1 Time of Accident

The differences between the distributions of the related variables for utility pole and run-off-road accidents were small. For both samples, accident frequency was slightly higher in winter months (November through March) than in the summer months; by day of week, weekend days (Friday through Sunday) had higher frequencies with Saturday being the highest; by hour of day, nearly 50% of the accidents occurred between 10 PM and 5 AM, with particularly high frequencies between 10 PM and midnight.

4.2.2 Vehicle Descriptors

Differences between utility pole and run-off-road accidents were small. Unfortunately, the make of vehicle was often reported without the model, so that it was not possible to determine the type of vehicle in approximately 60% of the accident sample.

4.2.3 Environmental Conditions

Differences between utility pole and run-off-road accidents were small. For both utility pole and run-off-road accidents, almost 60% of the accidents occurred after dark. The frequency of accidents coded "Dark with Street Lighting" was higher for utility poles, which is not surprising in that 33% of utility poles inventoried had lights attached. By road condition, about 60% of utility pole and run-off-road accidents occurred on dry roads, 25% on wet and 12% on ice/snow covered roads.

To determine whether there was any cross-correlation between road and light conditions, a bivariate analysis was run. The results are given in Table 4-5. It can be seen that there was a higher proportion of utility pole accidents at dawn irrespective of road conditions and at dusk on wet roads. Looking at all accidents which occurred in the dark, there appeared to be little difference in the proportion of utility pole accidents for dark versus light on either wet or dry roads. On roads with ice/snow/slush/etc., the proportion of utility pole accidents was less than for other road conditions, with a slightly higher proportion at night.

4.2.4 Occupant Information

Seated position, restraint use, ejection, and occupancy all showed only small differences between utility pole and run-off-road accidents. However, there was a considerable difference in injury severity. Looking at occupant injury for utility pole accidents, the proportion of no injury was considerably lower, 40.3% versus 64.2%, and the proportion of injury higher, at the C level, 8.9% versus 7.2%, at the B level, 21.6% versus 11.4%, at the A level, 13.3% versus 7.3%, and for fatalities, 0.6% versus 0.4%.

TABLE 4-5 - PROPORTIONS OF UTILITY POLE COLLISIONS IN SINGLE VEHICLE ACCIDENTS - LIGHT VERSUS ROAD CONDITIONS

	Dry	Wet	Ice	Snow	Slush	Misc. Winter Conditions	All Winter Conditions Combined
Daylight	0.25	0.247	0.154*	0.174	0.412*	0.16	0.19
Dawn	0.429*	0.417*	--	--	--	--	--
Dusk	0.245*	0.45*	--	--	--	--	0.10*
Dark - Lights	0.339	0.349	0.222*	--			--
Dark - No Lights	0.173	0.153*	0.333*	0.333*			0.143*
Dark - Lights Unknown	0.213	0.203	0.50*	0.237	0.682		0.226
Dark - Total	0.248	0.244	0.313*	0.238	0.682		0.198

*Note sample size is small.

Data for this table are given in Tables 1a and b - Appendix 5.

4.2.5 Driver Information

Driver age and sex and driver action showed only small differences between utility pole and run-off-road accidents. For example, the mean age of drivers involved in utility pole accidents was 28.8 years compared to 29.1 years for run-off-road accidents. Drivers involved in utility pole accidents had 3.8% fewer moving violations. Driver condition showed that, for utility pole accidents, situations where the driver fell asleep were overrepresented - 6.2% vs. 3.2%; this is likely explained by the fact that when a driver falls asleep, his vehicle will drift off the road edge rather than turn abruptly with a consequently higher likelihood of striking a utility pole (see page 58).

Interestingly, drinking involvement showed only slightly higher involvement in utility pole accidents than in run-off-road accidents, which suggests that once the vehicle has left the road, driver condition has little effect on the subsequent outcome of the accident, i.e., if unimpaired drivers were able to avoid utility poles during off-road excursions, impaired drivers would, as a result, be overrepresented in utility pole accidents.

To see if there was an age/drinking involvement effect, utility pole accidents as a proportion of single vehicle accidents were tabulated by driver age and drinking involvement - Table 4-6 (compiled from Tables 2a and b - Appendix 5). The overall figures confirm that there is little effect. However, when drinking was involved, young drivers were overrepresented. That is, the proportion of utility pole accidents was higher for young drivers, particularly the 26-35 age group.

TABLE 4-6 - PROPORTION OF UTILITY POLE COLLISIONS IN SINGLE VEHICLE ACCIDENTS - DRIVER AGE VERSUS DRINKING INVOLVEMENT

Drinking Involvement	Driver Age (years)						
	16-18	19-25	26-35	36-45	46-55	56-65	66-75
Non Drinkers	0.226	0.168	0.233	0.257	0.211	0.184	0.213
Drinkers*	0.300	0.246	0.347	0.207	0.212	0.237	0.66**
All Drivers	0.232	0.252	0.270	0.237	0.232	0.198	0.274

*Drinkers - includes, Had Been Drinking, HBD - Contributed, Cited for Drinking
**Small sample size

4.2.6 General Roadway Characteristics

Utility pole accidents were underrepresented on Expressway (0.5% vs. 7.1%) and Local (30.0% vs. 35.7%) roads, and overrepresented on Arterial (31.6% vs. 26.5%) and Collector roads (33.4% vs. 26.8%). This is most likely the result of a higher pole density for Arterial and Collector roads.

Utility pole accidents were overrepresented on roads with 30-40 MPH (48-64 KPH) speed limits (71.4% vs. 38.7%) indicating that these are roads which carry a high pole density. Similarly with road widths, utility pole accidents were underrepresented for widths less than 24 feet (7 m) and greater than 50 feet (15 m), which is probably indicative of road type, i.e., local and expressway type roads. Perhaps surprisingly, ADT showed only small differences apart from the ranges 6,000-10,000 and 11,000-15,000, which both showed about a 3% overrepresentation for utility pole accidents; this again is probably indicative of road type. Shoulder width, both near and far side, showed only small differences apart from roads without shoulders where utility pole accidents were overrepresented 54.9% vs. 47.6%. This overrepresentation is likely linked to departure angle, in that vehicles exiting at a shallow angle (which is the case without a shoulder) are more likely to strike poles. Median Width and Number of Roadway Lanes both showed small differences although utility pole accidents were slightly overrepresented on roads without medians (93.2% vs. 87.9%) and on two lane roads (77.0% vs. 73.7%). This could well be the same effect in that one could expect a strong correlation between no median and two lane roads.

Very few utility pole or run-off-road accidents occurred where there were auxiliary turning lanes and the difference between the samples was small. This suggests that very few run-off-road or utility pole accidents occurred at intersections, a fact confirmed by the univariate of intersection which showed that only about 25% of single vehicle accidents involved intersections and in 40% of these, the intersection was incidental to the accident.

Finally, road surface showed no difference between the two samples, and shoulder surface - for those accident sites with shoulders - only minor differences with an underrepresentation on dirt (3.2%) and asphalt (3.4%) and a corresponding overrepresentation on concrete (7.1%); this is most likely an indicator of frequency of shoulder type material rather than a parameter that can be linked to departure characteristics.

4.2.7 Departure Characteristics

The parameters considered, up until now, have been general accident descriptors and, with the exception of occupant injury, would not be expected to show a great deal of variation between utility pole and run-off-road accidents. This is because until the vehicle actually starts to depart the roadway, there should be little to distinguish the likelihood of either event occurring. However, once the vehicle has started to depart the road, the probability of striking a utility pole or other roadside obstacle will be a function of both the departure characteristics and the immediate roadside environment.

Looking first at side of road exited, vehicles leaving the right hand side of the road were overrepresented in utility pole accidents, 69.3% vs. 64.0%. This occurs because vehicles which leave the right hand side of the road have less room laterally (than those departing to the left) to develop any appreciable departure angle; in departing at a shallow angle, a vehicle has a higher likelihood of striking a utility pole.* This same characteristic leads to an overrepresentation in utility pole accidents of vehicles leaving straight roads (69.8% vs. 59.5%) and to the higher proportion of departures from the near side lane (57.0% vs. 48.1%). Interestingly enough, there also seemed to be a grade effect in that a higher proportion of utility pole accidents appeared to occur on the level (65.4% vs. 57.0%). However, the sign of the grade was not recorded, which makes it difficult to provide a logical explanation for this trend.

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*Later in this section (page 89), the concept of an effective utility pole contact zone for a given line of poles will be introduced. The width of this zone is shown to be inversely proportional to the sine of the departure angle; thus, within the range of possible departure angles - 0 to 90 degrees, the width is inversely proportional to the angle itself. Since the probability of pole contact is obviously higher for longer effective contact zones, it follows that utility pole contact is more likely for shallow departure angles and less likely for higher departure angles.

4.2.8 Collision Characteristics

Parameters in this category relate the vehicle to the collision. Looking at vehicle speed, although the differences between cells are quite small, the cumulative percentage showed that speeds for vehicles involved in utility pole accidents were higher than for run-off-road accidents in general. Since these are travel speeds estimated by the police rather than impact speeds, there is no *a priori* reason for them to be higher for utility pole accidents. A likely explanation for the difference is that with increased travel speed, departure angle is decreased with an associated higher likelihood of striking a utility pole. A higher proportion of vehicles involved in utility pole accidents were towed from the scene, which is a clear indication of the generally higher severity of utility pole accidents. The area of damage shows that vehicles involved in utility pole collisions were overrepresented in frontal impacts, 67.7% vs. 49.3%; this is to be expected since utility poles have such a narrow profile, it is very much a hit or miss situation. There were also fewer instances of "Not Reported if Towed" for utility pole accidents (14.1% vs. 26.4%) which again, is most likely an indication of higher severity. Note that for both utility pole and run-off-road accidents, right side damage was more frequent than left side damage, which is consistent with the higher frequency of cars departing the right side of the road. This damage pattern is confirmed by looking at the direction of principal force. Utility pole accidents were overrepresented in 12 o'clock impacts (69.3% vs. 50.4%) and in impacts to the right front (1 or 2 o'clock) (20.5% vs. 14.3%). Both utility pole accidents and run-off-road accidents had more impacts to the right side (1-5 o'clock) than to the left (7-11 o'clock).

4.2.9 Characteristics of Object Struck

Having established which parameters affect departure and how the collision characteristics vary between utility pole and run-off-road accidents, it is appropriate to look at the characteristics of the object(s) struck. Looking first at the number of objects struck, utility pole accidents had a slightly higher number of single hits (76.4% vs. 71.2%). This could be linked to the fact that there was a higher proportion of frontal impacts; under this condition there is less chance of a glancing type impact which, in turn, allows the vehicle to travel on to additional impacts.

To look at relative frequency of object struck, the utility pole and run-off-road samples have been combined. Utility poles were by far the most frequent object struck, 21.1% vs. 13.5% for fences and guardrails, the second most frequent object struck. Perhaps a more appropriate comparison is with the next most frequent rigid narrow object struck, i.e., trees, which accounted for 11.6% of all objects struck. Obviously, in considering the relative frequency of types of object struck, severity must also be considered for both the first impact and subsequent impacts, i.e., although a particular impact may not in itself be severe, the impact may contribute to a subsequent impact, e.g., rollover, with a higher severity. These considerations are discussed fully in the section on injury severity.

Looking at vehicle rollover, utility pole accidents had fewer rollovers (3.2% vs. 10.0%) than run-off-road accidents, which can be explained by the fact that the majority of the vehicle's kinetic energy is dissipated in the impact with the pole such that the residual energy is insufficient to produce rollover.

4.2.10 Utility Pole Placement Characteristics

This section includes all parameters associated directly with utility poles and explores their effect on utility pole accident frequency.

Obviously, one would expect pole density to be related to utility pole accident frequency. The results certainly confirm this in that 43.3% of run-off-road accidents occurred where there were less than 2 poles.* Also, the average pole spacing (near side) was less for utility pole accidents, 145 feet (44 m), than for run-off-road accidents, 180 feet (55 m), (calculated for run-off-road accidents where there were two or more poles). Looking at pole spacing on the far (opposite) side of the road exited, 45.6% of run-off-road accidents occurred on roads with no poles or a single pole on the far side compared to 28.3% for utility pole accidents; average pole spacing was 173 feet (53 m) for utility pole accidents compared to 171 feet (52 m) for run-off-road accidents.

*Pole spacing was measured by counting the number of poles, within 600 feet (183 m) of either side of the struck utility pole (or the final rest position in a run-off-road accident), so that situations where there were less than 2 poles were also known.

Looking at the distance of poles from the road edge, 50.0% of all utility pole accidents occurred with an offset of 4 feet (1.2 m) or less, with a mean offset of 5.5 feet (1.7 m). Although pole offset was not measured for run-off-road accidents and would obviously not be present for at least 43% of the accidents, final rest position (which was the object struck in the majority of cases) provided a good indication of the offset of the objects that were struck. Then for the run-off-road accidents, mean offset was 7.3 feet (2.2 m) with 50% of the vehicles coming to rest within 10 feet (3.0 m) of the roadway. It is certainly not surprising then that utility poles figured highly in urban single vehicle accidents, since 74% of all struck poles were within 10 feet of the road edge.

Since most utility poles were wood, pole type and circumference indicated predominant type rather than the most frequent type hit.

It is also useful to know that in 33.6% of all utility pole accidents, the struck pole had a streetlamp attached, since to suggest, for example, that undergrounding utility cables would alleviate the problem, would leave one third of the street lights unsupported!

To summarize this section, the univariate analyses provide a very general look at utility pole accidents as they compare to run-off-road accidents and serve to identify parameters which produce variations between the two accident types. The next step in the analysis is to explore these variations in greater detail to try and determine precisely how utility pole accidents differ from run-off-road accidents. At this point, the analysis can be conveniently divided into two main areas (i) Factors which affect utility pole accident frequency and (ii) Factors which affect utility pole accident severity.

4.3 Factors Which Affect Utility Pole Accident Frequency

In looking at factors which affect utility pole accident frequency, the emphasis is on parameters which affect vehicle departure attitude or describe utility pole placement characteristics rather than collision characteristics, i.e., variables such as area of damage, number of objects struck, cost to repair, etc. need not be considered. The comparison of univariates, summarized in Table 4-4, showed that there were significant variations in utility pole versus run-off-road accident frequency for the following parameters:

Road Type	Side of Road Exited
Average Daily Traffic (ADT)	Road Path
Road Width	Road Grade
Speed Limit	Travel Lane
Shoulder Width	Travel Speed
Number of Lanes	Pole Spacing
Intersection Type	Pole Offset

These parameters fall under the three main headings of General Roadway Characteristics, Departure Characteristics, and Utility Pole Placement Characteristics. It is not surprising that the differences between utility pole and run-off-road accidents showed up in these categories since they basically characterize the road the vehicle is on, its attitude as it departs, and the position of the poles once it has departed.

4.3.1 General Roadway Characteristics

In exploring the effect of roadway characteristics on utility pole accident frequency, it is important not only to look at the relation between utility pole accident frequency and particular parameters, but also the relationships between the parameters themselves. For example, it could well lead to erroneous conclusions if two parameters are included that are in themselves strongly correlated.

Effect of Road Type, Road Width, Speed Limit, and ADT

It is extremely likely that there is a cross-correlation between some of these parameters. Accordingly, bivariate analyses of road type, speed limit, road width, and ADT have been run; the data is given in Tables 3 to 6 of Appendix 5.

In looking at road type by speed limit, Table 4-7, which gives figures for all single vehicle accidents (i.e., run-off-road and utility pole accidents combined), shows that there is a link between the two parameters; 77.4% of all single vehicle accidents on local roads occurred with speed limits of 30 MPH (48 KPH) or less compared to 43.5% for collector roads and 22.0% for arterial roads. A reverse trend appears at the higher limits of 50 and 55 MPH (80 and 88 KPH), where 35.9% of all arterial single vehicle accidents occurred on roads with these limits compared to 15.1% for collector roads and 5.9% for local roads. To see what effect there is, specifically on utility pole accidents, Table 4-8 gives the proportion of utility pole accidents as a function of single vehicle accidents by road type and speed limit. It can be seen that the main effect, irrespective of road type, is an overrepresentation of utility pole accidents at the lower speed limits. An obvious explanation of the trend is that these are the roads most likely to have utility poles located along them (See page 79).

Tables 4-9 and 4-10 look at the effect of road width on road type. Table 4-9, which gives the percentage of single vehicle accidents by road width for each road type, suggests that there is a strong link between the two elements. For example, 25.6% of the single vehicle accidents on local roads were on roads of width less than 20 feet (6 m), whereas the corresponding figures for collector and local roads were only 10.0% and 2.9%, respectively. Similarly, the accumulative percentage shows that over 75% of local road accidents were on roads of width less than 30 feet (9 m), whereas, 65% of the arterial single vehicle accidents were on roads of width greater than 30 feet (9 m), i.e., local roads were

TABLE 4-7 - ROAD TYPE VERSUS SPEED LIMIT -

RUN-OFF-ROAD AND UTILITY POLE ACCIDENT SAMPLE COMBINED

Speed Limit (MPH)	Road Type					
	Arterial		Collector		Local	
	#	%	#	%	#	%
15*	--				13	0.6
20	--				31	1.5
25	14	0.8	53	3.1	297	14.7
30	359	21.2	688	40.4	1227	60.6
35	234	13.8	387	22.7	233	11.5
40	308	18.2	222	13.0	76	03.8
45	167	9.9	96	5.6	28	1.4
50	112	6.6	38	2.2	22	1.1
55	496	29.3	219	12.9	97	4.8
TOTAL	1690	100.0	1703	100.0	2024	100.0

*1 MPH = 1.61 KPH

TABLE 4-8 - ROAD TYPE VERSUS SPEED LIMIT -

UTILITY POLE ACCIDENTS AS A PROPORTION OF SINGLE VEHICLE ACCIDENTS*

Speed Limit (MPH)	Road Type			
	Arterial	Collector	Local	Overall
15**	--	--	.077	.077
20	--	--	.290	.290
25	.286	.340	.175	.203
30	.318	.343	.224	.275
35	.308	.323	.197	.285
40	.351	.302	.211	.315
45	.251	--	.107	.186
50	.313	.079	.091	.233
55	.179	.146	.330	.188
OVERALL	.275	.288	.216	.257

*Compiled from Table 3 - Appendix 5

**1 MPH = 1.61 KPH

TABLE 4-9 - ROAD TYPE VERSUS ROAD WIDTH -

RUN-OFF-ROAD AND UTILITY POLE ACCIDENT SAMPLES COMBINED

Road Width (ft.)	Arterial		Collector		Local	
	#	%	#	%	#	%
0 - 19*	49	12.9	174	10.1	531	25.6
20 - 29	533	31.9	823	48.1	1038	50.0
30 - 39	269	16.1	346	20.3	313	15.1
40 - 49	332	19.9	190	11.1	106	5.1
50 - 59	202	12.1	52	3.0	44	2.1
60 - 69	113	6.7	48	2.8	31	1.5
70 - 79	63	3.7	45	2.6	7	0.3
≥ 80	111	6.6	31	1.8	5	0.2
TOTAL	1672	100.0	1709	100.0	2075	100.0
Mean Road Width	64.0 feet		31.4 feet		26.2 feet	

*1 foot = 0.305 meters

TABLE 4-10 - ROAD TYPE VERSUS ROAD WIDTH

UTILITY POLE ACCIDENTS AS A PROPORTION OF SINGLE VEHICLE ACCIDENTS*

Road Width (ft.)	Arterial	Collector	Local	Overall
0 - 19**	.143	.213	.181	.187
20 - 29	.231	.262	.213	.234
30 - 39	.379	.379	.284	.347
40 - 49	.386	.321	.226	.339
50 - 59	.248	.327	.159	.248
60 - 69	.274	.271	.065	.240
70 - 79	.175	.133	--	.148
≥ 80	.099	.194	--	.116
OVERALL	.277	.285	.212	.255

*Compiled from Table 4 - Appendix 5

**1 foot = 0.305 meters

the narrowest, arterials the widest with collectors in between. In fact, looking at mean road width, it becomes obvious that it could be used as a surrogate of road type. Table 4-10 gives the proportions of utility pole accidents in single vehicle accidents by road type and width. It is interesting that for all these road types, utility pole accidents were overrepresented on roads of width 30 to 50 feet (9 to 15 m), which is most likely the result of a predominance of utility poles.

Tables 4-11 and 4-12 look at the effect of ADT on road type. Table 4-11 gives the percentage of single vehicle accidents by ADT for each road type. Again, as for road width, ADT can be used as an indicator of road type. That is, for arterial roads 60% of the single vehicle accidents occurred on roads with ADT's 6-20 thousand, for collector roads 90% of accidents occurred on roads with ADT's 0-15 thousand, and for local roads 70% of accidents occurred on roads with ADT's 0-5 thousand. This ranking is reflected in the mean ADT figures, 13.4 thousand for arterials, 6.9 thousand for collectors, and 5.15 thousand for local roads. Table 4-12 gives the proportion of utility pole accidents in single vehicle accidents by ADT and road type. There do not appear to be any obvious trends. However, it should be noted that the number of accidents for which ADT was not known was large (56%), and therefore the use of ADT as a predictor variable is limited because it severely restricts the size of the data base.

From the preceding analyses, the most useful variables appear to be road width, speed limit, and with the noted limitation, ADT. An obvious question to ask is how are these variables related. Intuitively, one would expect, for example, road width and speed limit to be correlated, i.e., roads with higher speed limits are wider. To test this, mean road widths, calculated using the combined utility pole and run-off-road accident samples (Tables 6a and b - Appendix 5) have been tabulated against speed limit in Table 4-13. Fitting a

TABLE 4-11 - ROAD TYPE VERSUS ADT -

RUN-OFF-ROAD AND UTILITY POLE ACCIDENT SAMPLES COMBINED

ADT (in thousands)	Arterial		Collector		Local	
	#	%	#	%	#	%
0 - 5	238	20.0	387	50.1	336	70.4
6 - 10	309	26.0	210	27.2	87	5.4
11 - 15	204	17.2	98	12.7	11	0.7
16 - 20	200	16.8	46	6.0	13	0.8
21 - 25	108	9.1	9	1.2	11	0.7
26 - 30	71	6.0	10	1.3	7	0.4
31 - 35	33	2.8	7	0.9	--	--
36 - 40	11	0.9	--	--	10	0.6
> 40	14	1.2	5	0.6	2	0.1
TOTAL	1188	100.0	772	100.0	477	100.0
Unknown	510		969		1626	
Mean ADT*	13.4 K		6.9 K		5.15 K	

*Calculated from Table 5 - Appendix 5

TABLE 4-12 - ROAD TYPE VERSUS ADT -

UTILITY POLE ACCIDENTS AS A PROPORTION OF SINGLE VEHICLE ACCIDENTS**

ADT (in thousands)	Arterial	Collector	Local	Overall
0 - 5	.239	.258	.232	.245
6 - 10	.337	.286	.172	.295
11 - 15	.338	.418	.545*	.371
16 - 20	.225	.348	.007*	.239
21 - 25	.306	.444*	.091*	.297
26 - 30	.268	.300*	--	.250
31 - 35	.242*	.286*	--	.250
35 - 40	.818*	--	--	.429*
> 40	.143*	--	.100*	.190*
OVERALL	.291	.293	.216	.277

*Indicates a sample size of less than 40
**Compiled from Table 5 - Appendix 5

TABLE 4-13 - MEAN ROAD WIDTH BY SPEED LIMIT -
UTILITY POLE AND RUN-OFF-ROAD ACCIDENT SAMPLES COMBINED

Speed Limit (MPH)	15*	20	25	30	35	40	45	50	55
Mean Road Width - (feet)	17.2*	21.5	37.2	30.5	36.7	35.1	40.8	39.3	35.9

Road width = 0.42 (speed limit) + 16.35   r = 0.78

*1 MPH = 1.61 KPH
1 foot = 0.305 meters

TABLE 4-14 - ROAD WIDTH VERSUS SPEED LIMIT -
UTILITY POLE ACCIDENTS AS A PROPORTION OF SINGLE VEHICLE ACCIDENTS*

Road Width (ft.)	Speed Limit (MPH) 15**	20	25	30	35	40	45	50	55	Overall
0 - 19**	.200	.105	.105	.206	.104	.214	.120	.074	.211	.179
20 - 29	.286	.261	.208	.236	.320	.252	.168	.205	.172	.270
30 - 39	--	--	.217	.362	.491	.467	.227	.200	.143	.3[illegible]
40 - 49	--	--	.175	.328	.352	.607	.318	.632	.263	.334
50 - 59	--	--	.158	.194	.333	.542	.095	.125	.030	.210
60 - 69	--	--	.286	.129	.360	.313	.219	--	.143	.214
70 - 79	--	--	--	.267	.135	.043	--	.083	.091	.122
≥ 80	--	--	--	.500	.120	.230	.330	.077	--	.066
OVERALL	.236	.209	.180	.270	.280	.314	.186	.185	.146	.239

[box] Utility pole accidents overrepresented within speed limit
[oval] Utility pole accidents overrepresented within road width

*Compiled from Table 6 - Appendix 5

**1 MPH = 1.61 KPH
1 foot = 0.305 meters

regression line through the data points shows that there is a significant correlation ($p \leq 0.2$). To explore the effect that this correlation has on utility pole accidents, the proportion of utility pole accidents in single vehicle accidents has been calculated for road width as a function of speed limit - Table 4-14. Note that figures that are circled are cells where utility pole accidents were overrepresented compared to the overall road width figure. For example, for roads with a speed limit of 35 MPH (56 KPH) and width of 20-29 feet (6-9 m), the figure of .320 shows that utility pole accidents were overrepresented, compared to the overall road width figure of .230 and the overall speed limit figure of .280. This suggests that although there was a correlation between speed limit and road width, both variables contributed to the overrepresentation; this was true for all cells in Table 4-14 which are both circled and boxed. The cross-correlation between the two parameters is clear in that overrepresentation of utility poles occurred for roads with speed limits of 30-40 MPH (48-64 KPH) and widths 30-50 feet (9-15 m).

Pursuing the argument further, one would expect ADT to be correlated with road width and speed limit, i.e., roads which are wider and have a higher speed limit have a larger capacity and are likely to carry a higher daily traffic. To test this, mean ADT's have been calculated using the combined utility pole and run-off-road accident samples within road width and speed limit; these are given in Table 4-15. A linear regression of ADT versus road width showed a significant correlation as did the regression of ADT versus speed limit. Thus, all these variables appeared to be highly correlated. Their interaction was explored further with a two-way multiple regression analysis of ADT on road width and speed limit. It can be seen that both road width and speed limit contributed significantly to ADT, with road width providing the stronger measure. It is reasonable to conclude from this analysis that road width and speed limit are, in general, sufficient to characterize the road system.

TABLE 4-15 - MEAN ADT'S (X 1000) FOR ROAD WIDTH VERSUS SPEED LIMIT - UTILITY POLE AND RUN-OFF-ROAD ACCIDENT SAMPLES

Road Width (ft.)	Speed Limit (MPH) 25*	30	35	40	45	50	55	Overall
5 - 19*	8.88	6.40	3.11	3.47	1.50	2.59	3.18	3.69
20 - 29	2.39	8.45	6.04	7.32	7.07	11.87	7.77	7.50
30 - 39	3.96	12.49	10.54	13.01	9.90	21.50	26.14	12.64
40 - 49	3.68	13.98	13.01	20.63	16.43	16.55	18.06	13.38
50 - 59	7.11	17.41	12.23	22.42	29.05	31.91	18.83	19.37
60 - 69	19.33	18.25	18 97	18.04	22.85	11.00	34.13	19.68
70 - 79	9.00	16.88	18.66	22.00	10.00	40.75	37.44	27.32
≥ 80	--	32.20	17.07	25.33	27.14	30.32	41.85	32.30
OVERALL	5.17	12.67	10.34	13.59	14.74	20.60	16.56	

Linear Regression

ADT = 0.34 Road Width - 0.45 $r = .98$

ADT = 0.38 Speed Limit - 2.17 $r = .86$

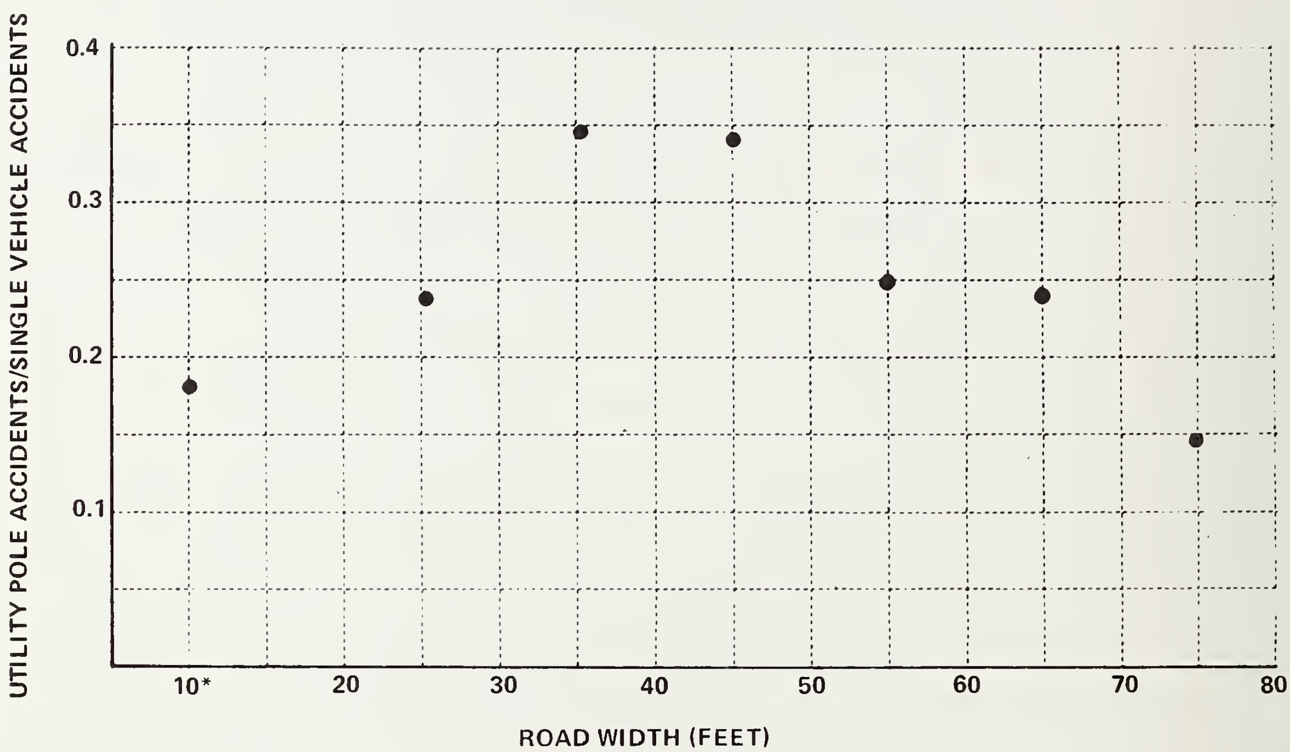
ADT = 0.2921 (Road Width) + 0.3801 (Speed Limit) - 13.52

$B_2 = 0.6611$ $B_3 = 0.474$ $R^2 = 0.6031$ $R = 0.78$

$r_{12} = 0.6611$ $r_{13} = 0.4074$ $r_{23} = 0$

*1 MPH = 1.61 KPH
1 foot = 0.305 meters

It was established in Table 4-14 that utility pole accidents are overrepresented on roads of width 30-60 feet (9-18 m) with speed limits of 30-40 MPH (48-64 KPH). This effect is illustrated in Figures 4-1a and b, which show road width and speed limit plotted against the proportion of utility pole accidents in single vehicle accidents. An obvious question to ask--particularly when looking at road width--is whether there was an actual width effect or were utility poles overrepresented on roads of 30-50 feet (9-15 m) because these were the roads with utility poles located along them. To sort out this problem, Table 4-16 gives the proportion of utility pole accidents as a function of single vehicle accidents for road width and pole spacing (compiled from figures given in Table 7 - Appendix 5). Note also that the percentage of run-off-road accidents which occurred where there were no poles is given together with the percentage of utility pole accidents, both broken down by road width. It can be seen from the table that for roads of width greater than 30 feet (9 m), there was definitely a pole density effect, i.e., roads with a high percentage of no pole accidents had lower utility pole accident rates. However, this does not hold for roads of less than 30 feet (9 m). These categories [0-19 feet (0-6 m) and 20-29 feet (6-9 m)] had the two lowest proportions of no pole accidents and also relatively low utility pole accident rates. Note also that these roads are important in terms of utility pole accident frequency, in that 50.5% of all utility pole accidents occurred on them. Thus, although these roads have a high pole density, there was obviously some other factor operating to keep the utility pole accident rate down. A likely consideration is travel speed; Table 4-7 showed that roads of width less than 30 feet (9 m) were, in general, "local" roads (77.4% of which had speed limits of 30 MPH (48 KPH) or less), so that travel speed will be low. This is confirmed by the data of Table 6 - Appendix 5, which tabulates utility pole and run-off-road accidents by road width and speed limit; calculating the median speed limit for widths 0-19 feet (0-6 m) and 20-29 feet (6-9 m) showed them both to be less than 30 MPH (48 KPH). Table 4-14 also suggests that there is a speed effect, in that the proportion of utility pole accidents in single vehicle accidents was low for low speed limits. Thus, one can conclude that roads of width less than



*1 FOOT = 0.305 METERS

Figure 4-1 (a) PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS VERSUS ROAD WIDTH

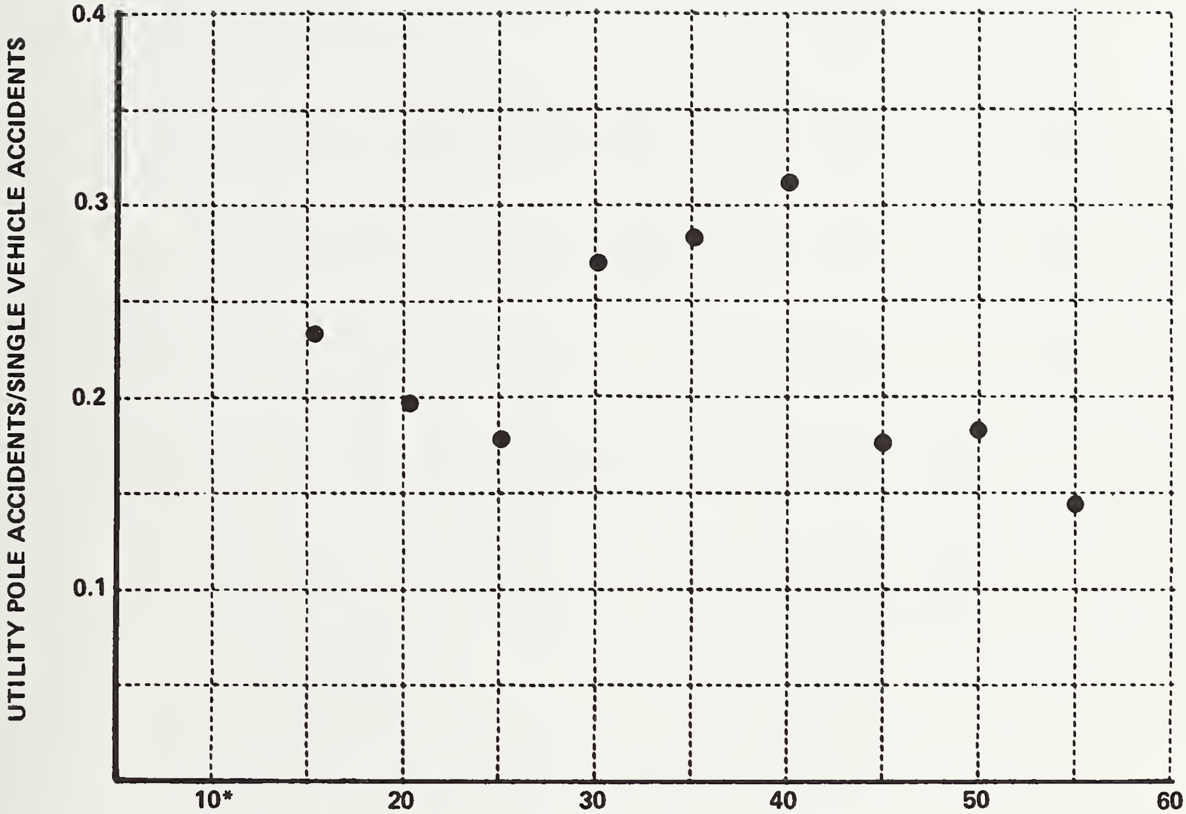


Figure 4-1 (b) PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS VERSUS SPEED LIMIT

TABLE 4-16 - ROAD WIDTH VERSUS POLE SPACING -

PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS**

Road Width (ft.)	Pole Spacing (ft.)											
	51-100†	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	>500	Overall	% 0 Poles	% UP Accidents
0 - 19†	.52*	.305	.249	.270	.20	.138*	.143	.077*	--	.043*	.180	.200	.146
20 - 29	.44	.431	.251	.220	.198	.161	.206	.063*	.091*	.029*	.234	.202	.419
30 - 39	.64	.516	.413	.444	.056*	.182	--	--	--	.167*	.342	.247	.158
40 - 49	.645	.576	.413	.313*	.444*	.30	.115	--	--	--	.346	.267	.108
50 - 59	.75*	.479	.273	.182	--	--	--	.167*	--	--	.211	.377	.058
60 - 69	.125	.614	.289	.333*	.50*	--	--	--	--	--	.224	.397	.036
70 - 79	--	.318*	.368	.364*	--	--	--	--	--	--	.123	.542	.026
≥ 80	.09	.375	.375	.231*	--	--	--	--	--	--	.069	.707	.048
OVERALL	.519	.459	.293	.256	.179	.181	.151	.100	.030	.044	.357	.266	1.00

*Small sample sizes

**Data compiled from Table 7 - Appendix 5

† 1 foot = 0.305 meters

30 feet (9 m) had a low utility pole accident rate, despite a high pole density, because their travel speed is low.

Effect of Travel Speed

Although it is reasonable to assume that travel speed is low on low speed limit roads, the relationship between speed limit and travel speed was checked by plotting mean travel speed against speed limit - Figure 4-2. Note that the data for run-off-road accidents and utility pole accidents have been plotted separately (derived from the data given in Table 8 - Appendix 5). Both accident samples show that there was a strong correlation between the two parameters (r = 0.80 for utility poles and r = 0.85 for run off road accidents). Interestingly enough, there does not appear to be much difference in the travel speeds estimated for utility pole accidents and other run-off-road accidents; it could be argued that because the effective stiffness of vehicles in collisions with narrow objects is less and the depth of penetration consequently larger than would be the case for wider objects, impact speeds might be overestimated. To see how travel speed and utility pole accident frequency were related, Table 4-17 gives the proportion of utility pole accidents in single vehicle accidents versus travel speed; these figures are plotted in Figure 4-3.

TABLE 4-17 - TRAVEL SPEED VERSUS PROPORTION OF UTILITY POLE ACCIDENTS ON SINGLE VEHICLE ACCIDENTS

Travel Speed (MPH)	0-9*	10-19	20-29	30-39	40-49	50-59	60-69	70-74
UP/ROR	.139	.162	.236	.249	.153	.226	.262	.417

*1 MPH = 1.61 KPH

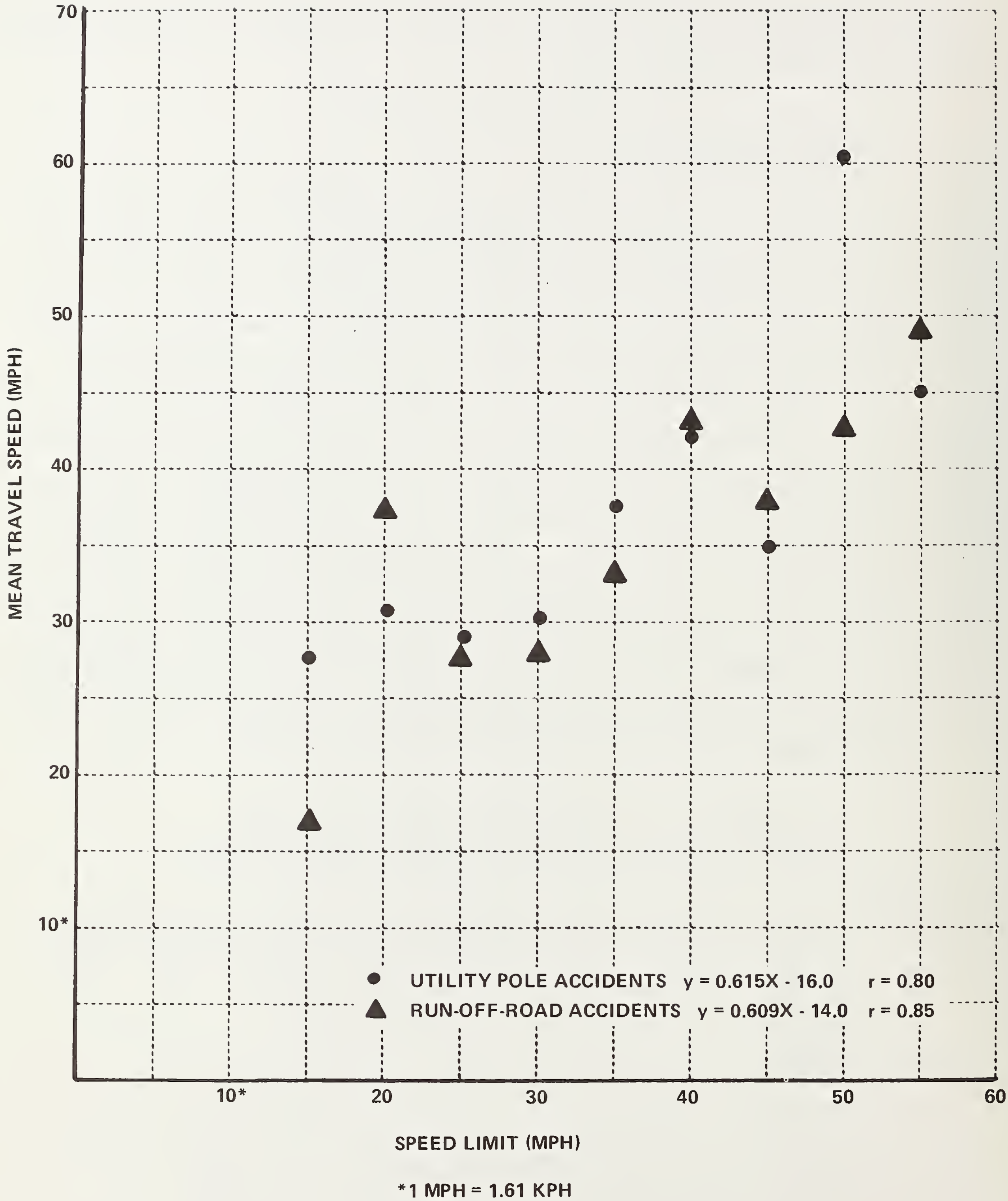


Figure 4-2 TRAVEL SPEED VERSUS SPEED LIMIT

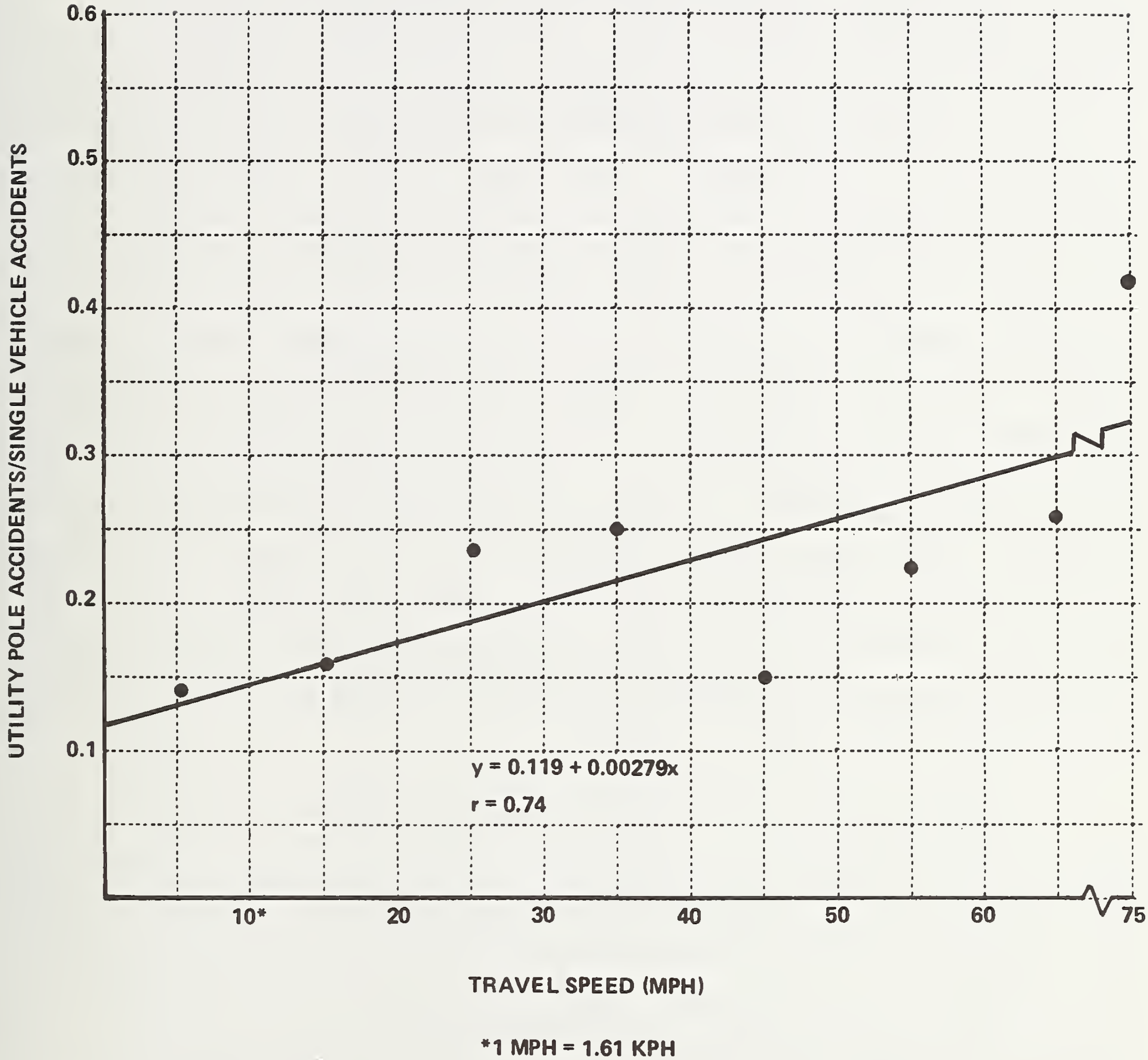


Figure 4-3 PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS VERSUS TRAVEL SPEED

The data suggest that as travel speed increases the proportion of utility pole accidents increases. This can be explained by a decreasing departure angle with increasing speed, with a corresponding increase in the probability of pole contact, i.e., a vehicle exiting at a very shallow angle will have a trajectory which will expose it to more utility poles than the trajectory of a car which exited at a much greater angle. Although the cor-correlation coefficient for this plot is significant ($p \leq .05$), suggesting a fairly strong relation, it should be noted that in 72% of the cases, travel speed was unknown. This must obviously cast some uncertainty on the relationship between travel speed and utility pole frequency. However, since it has already been established that travel speed and speed limit are strongly correlated, the relation should be able to be confirmed by looking at speed limit. Figure 4-1(b) showed a tendency for utility pole frequency to increase with speed limit, apart from a decrease for speed limits of 45 MPH (72 KPH) and greater. This latter effect was probably due to variations in pole density, i.e., there were fewer poles located on these roads than on lower speed limit roads, with a consequently lower probability of pole contact. To check this, utility pole and run-off-road accidents have been tabulated by speed limit and pole density - Tables 9a and b, Appendix 5.

Using these figures, the proportion of utility pole accidents in single vehicle accidents were calculated as a function of speed limit and pole density - Table 4-18. Although it appears that the utility pole accident rates were lower in the higher speed limit categories because these roads had fewer poles on them (i.e., a high proportion of accidents with no poles present), there was little indication of a speed effect in any of the pole spacing categories. In general, the breakdown by pole spacing showed that utility pole accident rates were higher for 30, 35, and 40 MPH (48, 56, and 64 KPH) roads with lower rates for roads with lower or higher speed limits than these.

TABLE 4-18 - PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS TABULATED BY SPEED LIMIT AND POLE DENSITY**

Speed Limit (MPH)	Pole Spacing (ft.) 1-50†	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	Overall	% 0 Poles	% Utility Pole Accidents
15†	--	--	.33	--	--	--	--	--	--	--	.236	.309	.010
20	--	.50*	.71*	.33*	--	--	--	--	--	--	.205	.614	.006
25	--	.412*	.49	.146	.20*	.167*		--	--	--	.169	.35	.049
30	--	.556	.48	.289	.277	.083	.167	--	--	--	.271	.290	.447
35	--	.490*	.488	.308	.263	.348*	.118*	--	--	--	.278	.172	.170
40	--	.429*	.462	.310	.273	.20*	.250*	--	--	--	.314	.106	.137
45	--	.167*	.355	.230	.250*	.125*	.50*	--	--	--	.178	.206	.040
50	--	1.00*	.464*	.270*	.250*	.211*	--	--	--	--	.183	.367	.029
55	--	.22*	.291	.265	.129	.179	.194	--	--	--	.146	.351	.112
OVERALL	.083	.527	.456	.285	.246	.172	.170	.155	.114	.031	.354		1.00

*Indicates sample size of less than 30 accidents.
**Compiled from Table 9 - Appendix 5
†1 foot = 0.305 meters
1 MPH = 1.61 KPH

Effect of Number of Roadway Lanes and Median Width

Looking at median width and number of roadway lanes in the univariate analysis, utility pole accidents were overrepresented on roads without medians and on two lane roads. It was commented at the time that this could well be the same effect. Table 4-19(a) gives the number of traveled lanes, for utility pole and run-off-road accidents combined, on roads with and without medians. Approximately 80% of accidents on roads without medians were on two lane roads which confirms that the two effects are one and the same, i.e., roads without medians had, in general, two lanes. However, it is worth noting that on two lane roads with medians, the utility pole frequency was above average although the number of accidents was small, i.e., the existence/nonexistence of medians obviously did not figure prominently in the overall utility pole problem. The table also shows that utility pole accident frequency is reduced as the number of lanes increases, most likely because of a decrease in pole density on these roads.

TABLE 4-19 - NUMBER OF LANES FOR ROADS WITH AND WITHOUT MEDIANS*

a) Frequency of Utility Pole and Run-Off-Road Accidents

Number of Lanes	1	2	3	4	5	6	8
With Median	--	48	2	506	1	97	4
Without Median	172	4423	250	705	18	14	2
TOTAL	172	4471	252	1211	19	111	6

b) Proportion of Utility Pole Accidents in Single Vehicle Accidents

Number of Lanes	1	2	3	4	5	6	Overall
With Median	--	.354	--	.520	--	.021	.155
Without Median	.070	.255	.192	.306	.110	.286	.254
OVERALL	.070	.256	.192	.242	.110	.057	.243

*Compiled from Table 10 - Appendix 5

Effect of Shoulder Width

Shoulder width by definition will have a direct bearing on pole offset. That is, offset was defined as the distance from the road edge to the pole and will, therefore, include the shoulder width. This means that roads with shoulders will have larger offsets than roads without. Figure 4-4 shows shoulder width plotted against pole offset for utility pole accidents in run-off-road areas; the data for the plot is given in Table 11 - Appendix 5. Not surprisingly, there was a very strong correlation (r = 0.92) unless shoulder width is subtracted from offset, in which case, the correlation disappears. Thus, in looking at the effects on utility pole frequency, it is reasonable to discard shoulder width and look at pole offset directly.

4.3.2 Departure Characteristics

The univariates showed that utility pole accidents, when compared to run-off-road accidents in general, had more departures to the right hand side of the road, and a higher proportion of vehicles exiting from straight roads and traveling in the lane nearest the object struck. All of these trends are related to departure angle in that they are situations in which one would expect a lower than average departure angle. This would mean that the likelihood of striking a pole would be higher since in departing at a lower angle, a vehicle is exposed to more utility poles. Table 4-20 looks at the combined effects of road surface condition and road path; road path is also broken down into intersection/no intersection because it was felt that departure characteristics would be less important in intersection situations. The table shows that utility pole accidents were overrepresented on straight roads for each of the three surface conditions. However, in looking at the effect of road surface on straight road departures, the utility pole accident frequency was less for wet, snow, or ice than for dry roads. This is explained by the fact that in these situations the vehicle is more likely to be skidding than tracking, so that the departure angle will likely be increased. The departure angle effect is again seen in comparing departure for right and left curves. Utility pole accidents were overrepresented on left curves compared to right curves in dry conditions

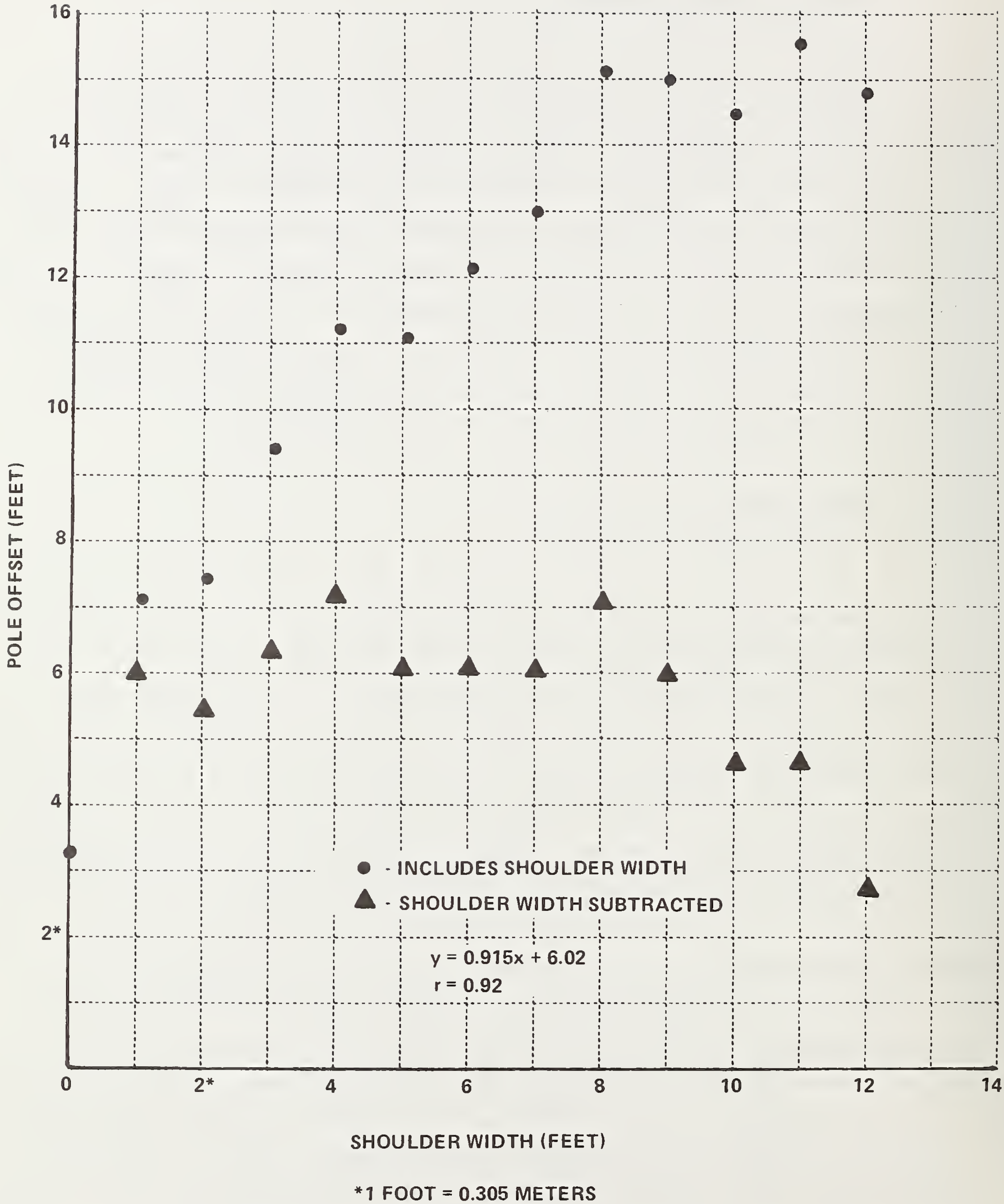


Figure 4-4 UTILITY POLE OFFSET PLOTTED AS A FUNCTION OF SHOULDER WIDTH

but the reverse was true in adverse weather conditions, i.e., the proportion of utility pole accidents went down in bad weather for left curve departures but up for right curve departures. As in the straight road situation, the decrease on left curves can be explained by the vehicle skidding rather than tracking. However, the increase in utility pole accidents on right curves is more difficult to explain, particularly as the relative frequency of single vehicle accidents was not increased in this situation (see Table 12 - Appendix 5).

TABLE 4-20 - PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS BY ROAD PATH AND ROAD SURFACE*

	Road Surface			
Road Path	Dry	Wet	Snow/ Ice	Overall
No Intersection				
Straight	.330	.270	.218	.303
Curve Right	.144	.195	.205	.162
Curve Left	.227	.151	.148	.197
Intersection				
Straight	.388	.329	.344	.374
Curve Right	.128	.245	.111	.174
Curve Left	.275	.286	.143	.268
OVERALL	.300	.243	.215	.278

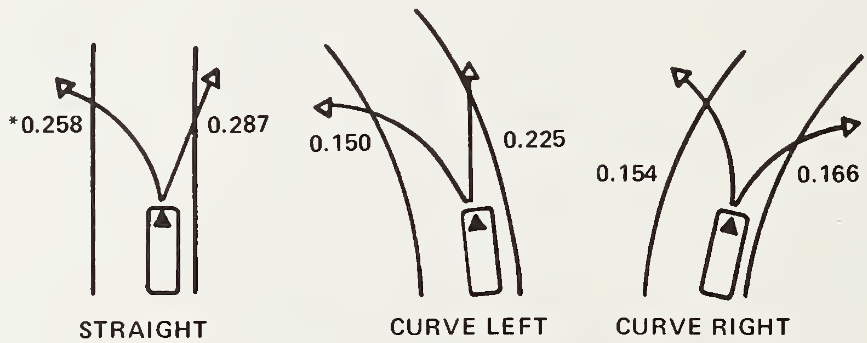
*Calculated from data given in Table 12 - Appendix 5

TABLE 4-21 - PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS BY ROAD PATH AND SIDE EXITED*

	Road Path			
	Straight	Curve Right	Curve Left	Overall
Side Exited				
Right	.287	.166	.225	.258
Left	.258	.154	.150	.216

*Data for this table are given in Table 13 - Appendix 5

Table 4-21 looks at the effect of side of road exited on road path. Irrespective of whether the accident occurred on a straight or curve, utility pole accident frequency was higher for right side than left side departures. This is to be expected, in that the departure angle will be less for a vehicle departing to the right in all three path configurations; this can be seen in Figure 4-5.



*PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS

Figure 4-5 DEPARTURE ANGLE BY ROAD CONFIGURATION

The fact that these variations in the proportion of utility pole accidents are departure angle effects is further confirmed by ranking the road path and side exited configurations in ascending order of utility pole involvement, i.e., curve left-left side, curve right-left side, curve right-right side, curve left-right side, straight-left side, and straight-right side. This is the same order that one would logically place them in terms of decreasing departure angle.

It is clear then that departure angle had a considerable effect on the probability of striking a utility pole. However, the analysis of departure characteristics has limited utility in that, although it aids in understanding the underlying problems, it is not an area to which countermeasure analysis can be readily applied.

4.3.3 Pole Placement Characteristics

Table 4-2 - presented in the introduction - showed that there was a significant variation in the proportion of utility pole accidents in single vehicle accidents among the areas of collection; the proportions are given again in Table 4-22 below.

TABLE 4-22 - PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS BY DATA COLLECTION AREA

	Macon	Knoxville	Columbus	Nashville	Erie and Niagara Counties	San Diego
Utility Pole/ Single Vehicle Accidents	.448	.348	.308	.244	.219	1.75

Assuming that the characteristics of the driving population were approximately the same for each area, it is reasonable to postulate that this surprisingly large variation among areas must be the result of different roadway and pole placement characteristics. Obviously, one would expect pole placement characteristics to provide the larger effect.

Pole placement characteristics include pole spacing, pole offset, and the number of poles the spacing is based on. The latter element is particularly useful in that it tells us something about the frequency of areas where there were no poles. This is important in trying to explain inter-area variations, because one would expect the overall utility pole frequency for an area to be a function of the relative density of utility poles in that area. To test this hypothesis, the proportion of utility pole accidents in single vehicle accidents has been plotted as a function of the percentage of run-off-road accidents that occurred where there were no utility poles - Figure 4-6. The data for this figure are given in Table 14 - Appendix 5. Note there is one data point for each data collection area. In addition to the six data points, the curve must also go through the point (1,0) since when the proportion of single vehicle accidents occurring where there are no poles reaches 1.0, the proportion of utility pole accidents must be zero. The curve is obviously not linear and, intuitively, one would expect a logarithmic function (particularly as accidents in any given area are likely to be Poisson distributed). Fitting a curve of the form $y = a + b \ln x$ showed a very strong correlation ($r = 0.96$) and suggests that the majority of the between area variation was explained by the relative pole density of each area, i.e., areas which had a large number of poles had a higher pole accident frequency.

Interestingly enough, "pole spacing" complements this parameter because by looking at pole spacing, areas where there were no utility poles are specifically excluded, i.e., for a spacing to be calculated, there must have been at least two poles within 600 feet either side of the accident site. Figure 4-7 shows the proportion of utility pole accidents in run-off-road accidents plotted as a function of pole spacing. (Note that these proportions are obtained from Table 54 - Appendix 4.) As in the case of the number of poles variable, a logarithic function produced the best fit and showed a very strong correlation ($r = 0.99$). Not surprisingly, one can conclude that as pole spacing increases, utility pole accident frequency decreases.

As a side issue, pole spacing can also be used to obtain an estimate of mean departure angle. Unfortunately, as has already been seen, because the data was collected retrospectively from police records, it was not possible to obtain departure angle. However, using the simple model shown in Figure 4-7,

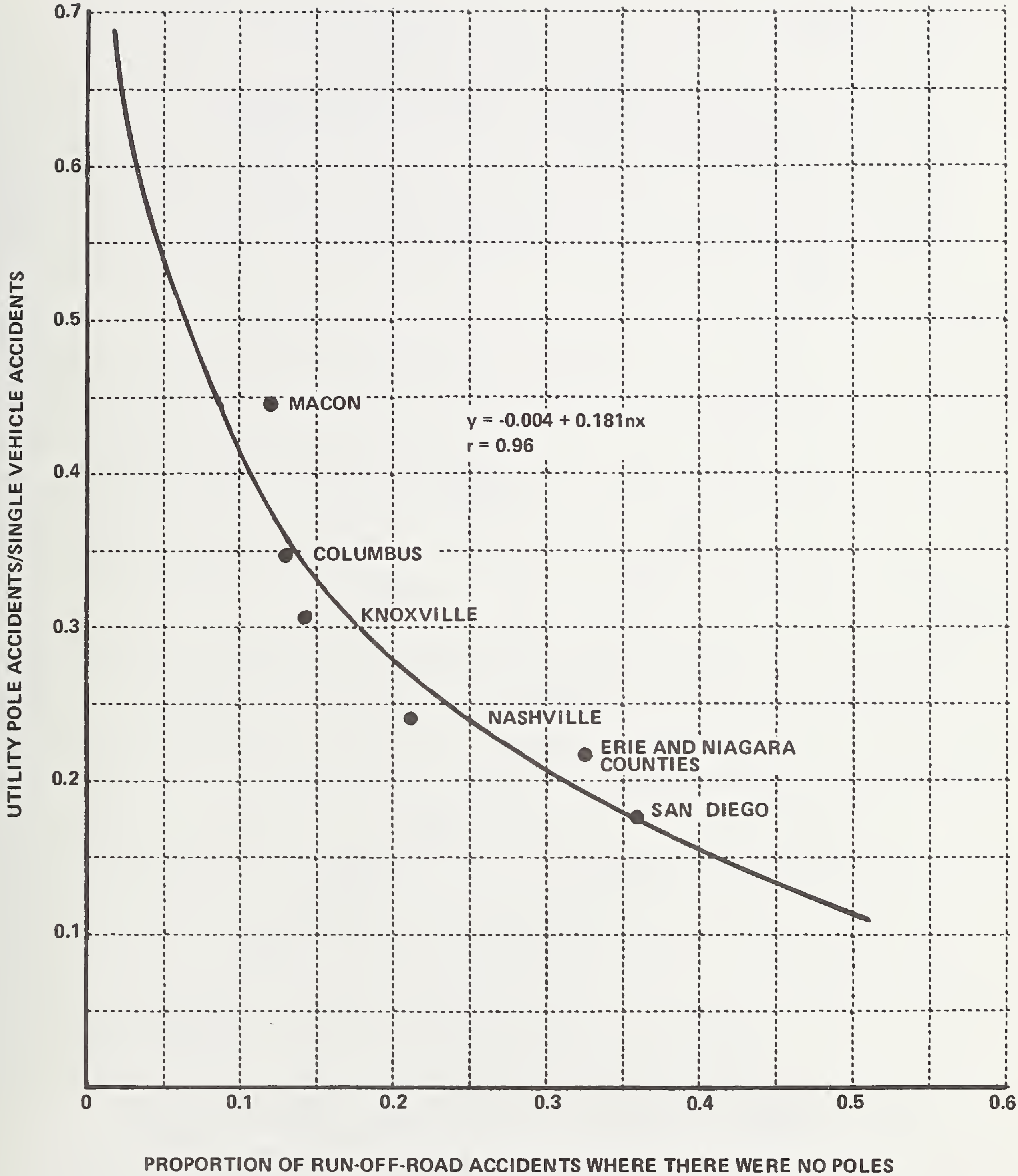


Figure 4-6 PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS VERSUS PROPORTION OF RUN-OFF-ROAD ACCIDENTS WHERE THERE WERE NO POLES

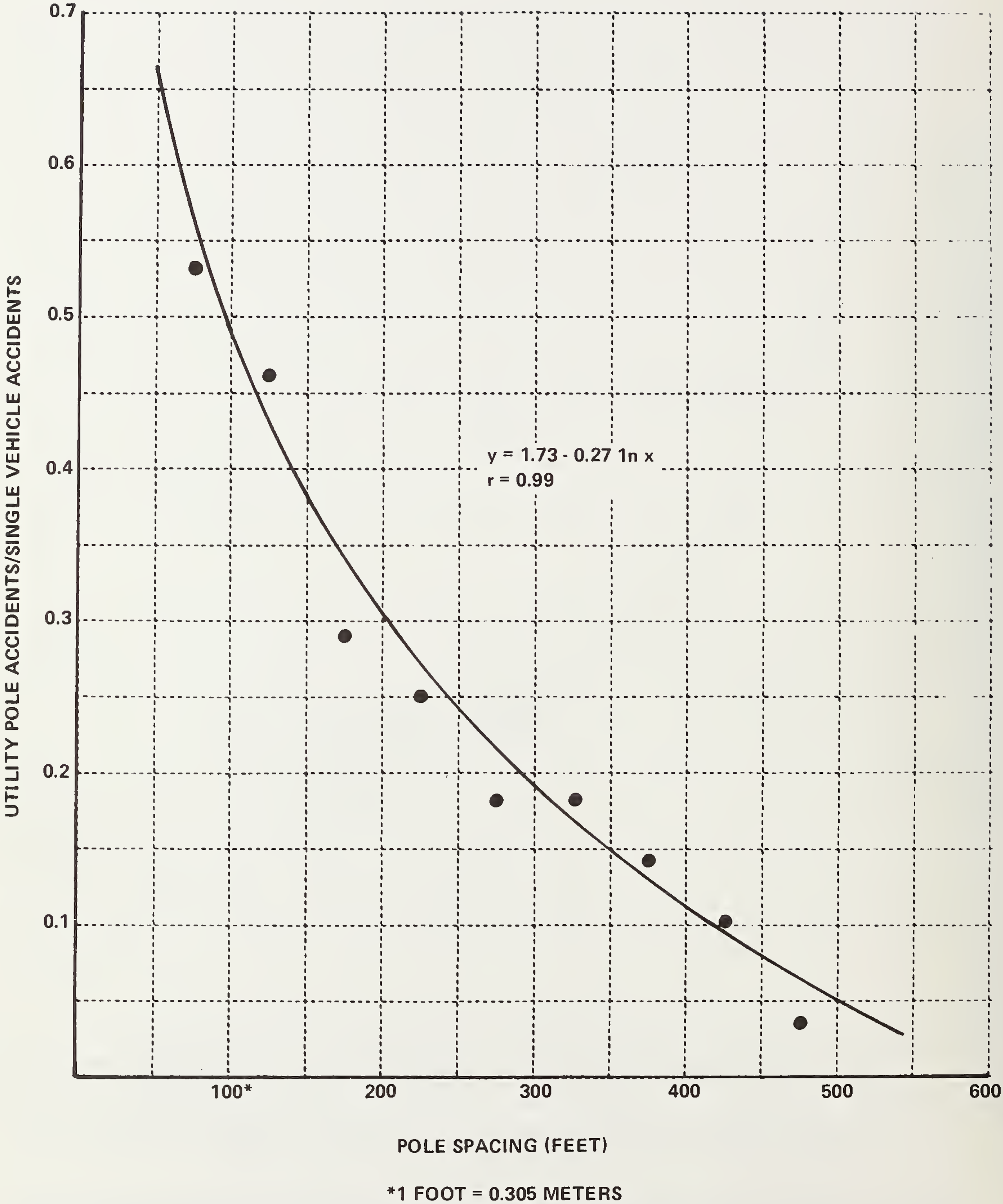


Figure 4-7 PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS VERSUS POLE SPACING

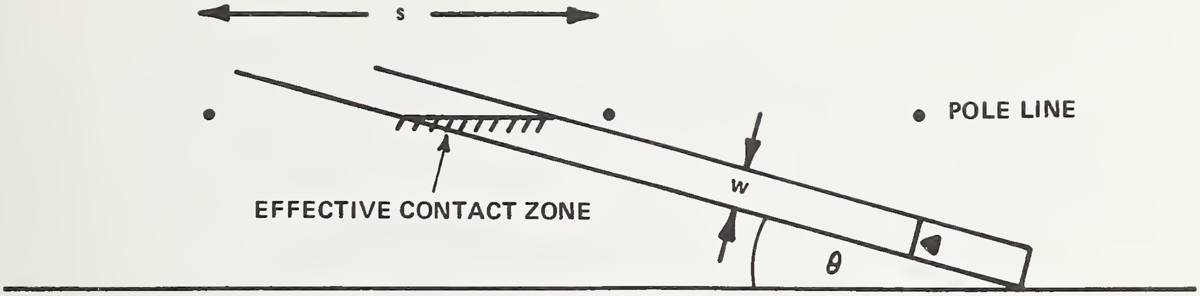


Figure 4-8 MODEL FOR ESTIMATING DEPARTURE ANGLE FROM POLE SPACING

the departure angle may be calculated as follows:

Vehicle of width w

Vehicle leaves road at angle θ

Effective contact zone with respect to pole line = w/sin θ

Average pole spacing = s

Probability of a pole contact given a run-off-road accident $P = \frac{w}{s \sin \theta}$

Then using the probability of a pole accident as obtained from the accident data, i.e., proportion of utility pole accidents in run-off-road accidents, a departure angle can be estimated for each pole spacing category. These estimates are given in Table 4-23 and have been calculated assuming an average car width of 6 feet (183 cm). It can be seen that the values obtained were surprisingly constant, although there is no a priori reason why departure angle should vary with pole spacing. Assuming that departure angle is constant--and the results certainly suggested this to be the case--then intuitively, one would expect utility pole contact to decrease with increased spacing, i.e., the vehicle has to travel further before contact so that there is a higher probability of striking another object or being redirected to the road.

Using a similar argument, it could be expected that pole offset would also have an effect on utility pole accident frequency. Figure 4-9 shows the proportion of utility pole accidents in single vehicle accidents plotted against lateral offset at vehicle rest (usually the utility pole for

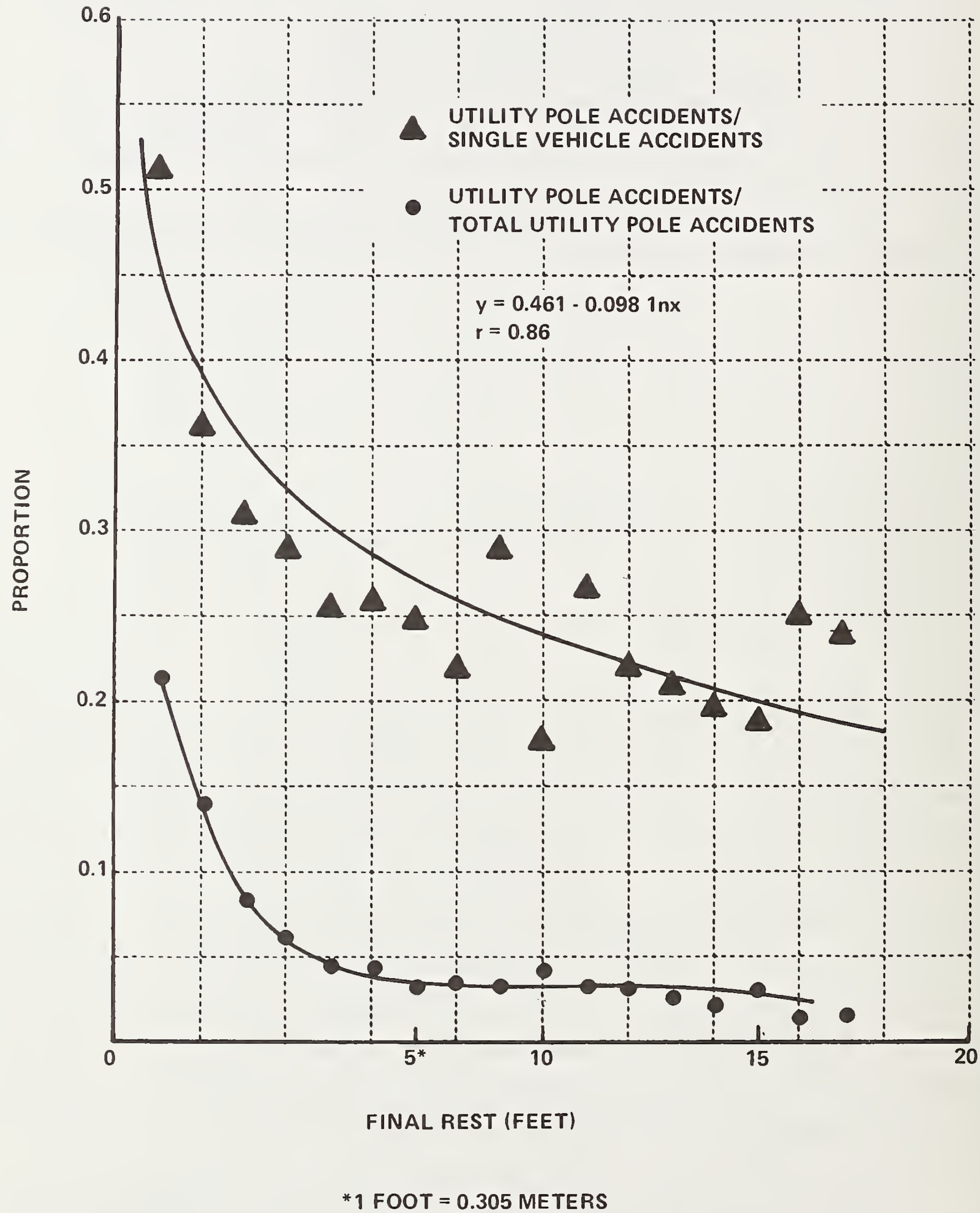


Figure 4-9 PROPORTION OF UTILITY POLE ACCIDENTS IN SINGLE VEHICLE ACCIDENTS VERSUS FINAL REST POSITION

TABLE 4-23 - ESTIMATED DEPARTURE ANGLE AS A FUNCTION OF POLE SPACING

Pole Spacing (ft.)	Utility Pole Accidents / Single Vehicle Accidents	Estimated Departure Angle in Degrees
50 - 100*	0.53	8.68
100 - 150	0.46	5.98
150 - 200	0.29	6.79
200 - 250	0.25	6.12
250 - 300	0.18	6.96
300 - 350	0.18	5.10
350 - 400	0.14	6.56
400 - 450	0.10	8.10

*1 foot = 0.305 meters

utility pole accidents and the object struck for run-off-road accidents). Utility pole accident frequency as a function of pole offset has also been plotted for comparison purposes. It can be seen that the two curves follow each other closely, such that the proportion of utility pole accidents is high at low offsets which is where the utility poles are located. Once the mean offset [5.5 feet (0.7 m)] is reached, the utility pole accident frequency starts to flatten out, although there is still a slight downward trend for their proportion in single vehicle accidents. Unfortunately, using final rest position for run-off-road accidents means that what was measured is the proportion of vehicles that traveled to rest as far as a given offset rather than the proportion of vehicles involved in accidents with poles at that offset, i.e., those that escaped contact with a pole and traveled further are missing. This means that the pole offset effect is likely to be overestimated, particularly at small offsets.

4.3.4 Assessing the Relative Importance of Parameters in Predicting Utility Pole Accident Frequency

A number of relationships that existed between utility pole accident frequency and different parameters describing the road and environment have been identified. The final stage of the analysis is to try and assess the relative importance of these parameters in predicting utility pole accident frequency. To do this, a stepwise multiple regression analysis program (15) was used. Before discussing the results, it is useful to look at the matrix of correlation coefficients generated for the various parameters considered (Table 4-24). Note that this is a straight correlation matrix and does not represent the partial correlation of one parameter with respect to another. Table 4-25 ranks the independent variables by strength of correlation with the dependent variable, i.e., the probability of a utility pole accident occurring given a single vehicle accident; this is a dichotomous variable where 1.0 represents a utility pole accident and 0.0 a run-off-road accident.

Not surprisingly, number of poles and pole spacing are the two variables which show the strongest correlation with the dependent variable. Note that these correlations are not as strong as those in the earlier analyses, because the actual accidents are used as data points, whereas previously, mean values have been used, which produces significant smoothing of the data. The next most significant parameter is ADT. Looking at Table 4-24 suggests why, in that ADT and pole spacing show a high degree of correlation. Other parameters which exhibit strong cross-correlation* are number of poles with pole spacing, ADT with road width and median width, road width with median width and number of lanes, shoulder width with speed limit, median width and shoulder width, speed limit with median width and travel speed, travel lane with number of lanes and side exited, road path with travel speed.

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* In order to obtain as clear a picture as possible, a conservative criterion for what constituted a "strong cross-correlation" was selected as $r \geq 0.2$.

TABLE 4-24 - CORRELATION MATRIX FOR PARAMETERS RELEVANT TO UTILITY POLE ACCIDENT FREQUENCY

	Accident Type	ADT	Road Width	Shoulder Width	Speed Limit	Median Width	Number Of Lanes	Inter-section	Side Exited	Road Path	Road Grade	Travel Lane	Travel Speed	Spacing	Offset	Number Of Poles
Accident Type		-.123 2781	-.057 6028	-.075 6012	-.089 5929	-.087 6129	-.043 6126	.042 6108	-.042 5859	-.075 5979	-.080 4458	-.047 4724	.028 1722	-.224 4080	.056 6137	.524 6137
ADT			.474 2733	.128 2700	.202 2676	.369 2775	.507 2775	-.053 2770	-.144 2697	.014 2736	.103 1995	.010 2115	.124 939	-.120 1878	.165 2781	-.310 2781
Road Width				.056 5922	.174 5826	.703 6020	.756 6024	.024 5999	-.159 5752	-.052 5870	.028 4394	.118 4631	.111 1677	-.113 4011	.085 6028	-.179 6028
Shoulder Width					.568 5808	.204 6004	.001 6001	-.114 5983	.009 5739	.133 5854	.002 4430	-.015 4625	.353 1623	.156 4010	-.099 6012	-.022 6012
Speed Limit						.249 5922	.126 5920	-.132 5900	.020 5667	.083 5792	-.037 4288	.046 4562	.486 1710	.180 3934	-.231 5929	-.047 5929
Median Width							.405 6119	-.049 6100	-.144 5851	.044 5972	.021 4451	-.006 4717	.183 1722	-.006 4077	.084 6129	-.172 6129
Number Of Lanes								.034 6097	-.156 5848	-.096 5969	.018 4454	.200 4722	.066 1715	-.085 4075	.105 6126	-.105 6126
Inter-section									-.027 5840	-.093 5950	.009 4451	-.010 4717	-.125 1712	-.052 4072	.046 6108	.058 6108
Side Exited										-.031 5742	.034 4278	.792 4717	.031 1664	-.025 3912	-.071 5859	-.007 5859
Road Path											.130 4369	-.057 4675	.291 1678	.120 3982	.090 5979	-.067 5979
Road Grade												.019 3601	-.058 651	.083 3281	.254 4458	-.063 4458
Travel Lane													.114 1287	-.047 3315	-.008 4724	-.024 4724
Travel Speed														.152 969	.172 1722	-.036 1722
Spacing															-.002 4080	-.563 4080
Offset																.043 6137
Number Of Poles																

*Correlation coefficient

**Sample size upon which the correlation coefficient was based.

TABLE 4-25 - RANK OF THE INDEPENDENT VARIABLES BY STRENGTH OF CORRELATION WITH DEPENDENT VARIABLE (PROBABILITY OF A UTILITY POLE ACCIDENT)

Variable Name	R	
Number of Poles	0.524	
Pole Spacing	-0.224	
ADT	-0.123	
Speed Limit	-0.089	
Median Width	-0.087	
Road Grade	-0.080	
Road Path	-0.075	
Shoulder Width	-0.075	
Road Width	-0.057	
Offset	0.056	
Travel Lane	-0.047	
Intersection	0.042	
Side Exited	-0.0422	
Travel Speed	0.0282	Not Significant ($p < .02$)
Number of Lanes	-0.0043	

Knowing which variables show strong correlation helps considerably in structuring the regression analysis. All the results that follow were obtained using the stepwise regression program for the SAS computer package. This program computes a sequence of multiple linear regression equations in a stepwise manner. At each step, one variable is added to the regression equation and the variable brought in is the one which contributes most (of those not yet included) to the regression sum of squares. At each stage any variable which is already included in the model but whose existing sum of squares contribution has declined to a non-significant level (in this case, $p \leq .5$) is eliminated. Selection stops when all variables are non-significant, i.e., the variation that they explain is insufficient to warrant inclusion. A difficulty which becomes more marked as the number of independent variables is increased is the selection of parameters to be included in the analysis. To quote Davis and Goldsmith (Reference 22), "Any attempt to determine the 'best' regression model for a given set of data requires a priori definition of what is meant by 'best'". In the present context, emphasis was placed on maximizing the number of data points but at the same time, taking care to insure that no potentially significant parameters were excluded. For example, if travel speed were included, the number of data points would have been restricted to 1,722; whereas by using speed limit, the number of data points was 5,929. A similar problem arose with regard to ADT.

In order to maintain the maximum number of data points, it was reasonable to suggest that these two variables be omitted from the analysis. However before doing this, regression analyses were run to check that they were not important variables. Another problem which arose in terms of limiting the number of data points was inclusion of the pole spacing variable. To obtain pole spacing, there had to be at least two poles in close proximity to the accident site, so that including this variable automatically eliminated accidents where there were no poles or only a single pole present. However, the correlation matrix established that there was a high correlation between pole spacing and number of poles. This is not surprising considering the data collection technique used to obtain spacing was to average the spacing 600 feet either side of the struck pole (i.e., measure the distance between the two extreme poles and divide by one less than the total number of poles). To establish whether pole spacing could be discarded, separate runs were made with and without the variable. Thus, 6 initial runs were made--3 with pole spacing included and 3 without--as follows: (i) with all variables included, (ii) with travel speed deleted and (iii) with travel speed and ADT deleted. Table 4-26 summarizes the results by giving the order in which variables were entered together with the value of R^2 which is the proportion of variation explained.

It can be seen that including travel speed severely restricts the number of data points as does ADT. Comparing corresponding runs with and without pole spacing included, the order with which variables were entered was very similar. However not surprisingly, there was a considerable difference in the order of variables between the runs with travel speed and those with it

TABLE 4-26 - PRELIMINARY STEPWISE REGRESSION RUNS

	Pole Spacing Included						Pole Spacing Excluded					
	All Variables Included *		Travel Speed Deleted		Travel Speed and ADT Deleted		All Variables Included		Travel Speed Deleted		Travel Speed and ADT Deleted	
Step Number	Variable Entered	R^2	Variable Entered	R^2	Variable Entered	R^2	Variable Entered	R^2	Variable Entered	R^2	Variable Entered	R^2
1	Number of Poles	.165	Number of Poles	.206	Number of Poles	.179	Number of Poles	.258	Number of Poles	.259	Number of Poles	.256
2	Road Grade	.186	Speed Limit	.226	Shoulder Width	.193	Road Grade	.279	Offset	.274	Shoulder Width	.264
3	Median Width	.214	Offset	.232	Offset	.198	Median Width	.292	Speed Limit	.279	Offset	.268
4	Travel Speed	.231	Road Path	.238	Road Grade	.204	Travel Speed	.305	Road Path	.284	Road Grade	.273
5	Speed Limit	.279	Pole Spacing	.241	Road Path	.206	Speed Limit	.327	Travel Lane	.286	Road Path	.275
6	Travel Lane	.296	Travel Lane	.243	Intersection	.207	Shoulder Width	.344			Road Width	.276
7	Road Path	.321	Shoulder Width	.245	Travel Lane	.208	Road Path	.357			Number of Lanes	.277
8	Shoulder Width	.346	Road Grade	.247	---		Travel Lane	.370			Median Width	.279
9	Pole Spacing	.357	---		---		Road Width	.381				
10	Intersection	.367	--- ---		--- ---		Number of Lanes	.395				
Number of Data Points**	248		1172		2510		331		1502		3353	

*ADT, Road Width, Shoulder Width, Speed Limit, Median Width, Number of Lanes, Intersection, Side Exited, Road Path, Road Grade, Travel Lanes, Pole Spacing, Pole Offset, Number of Lanes

**Total possible 6137 accident cases

deleted, although the difference between the runs with ADT and those without was not as marked. More importantly, travel speed did not appear to be a major variable, in that although it was entered at Step 4, it contributed only an additional 1.7% (spacing included) and 1.3% (spacing excluded) to the variation explained. The lack of importance of ADT was even more marked in that it never entered the regression. Thus, it was reasonable to exclude travel speed and ADT from the model in order to significantly increase the number of data points. These runs are shown in Table 4-26, Run 3 with pole spacing included, Run 6 with it deleted. Comparing these runs, the order in which variables are entered is identical until Step 6. However, at this point, the increase in r^2 from including further variables is extremely small. Since pole spacing was not entered in the regression analysis, it is reasonable to exclude the parameter from further analysis. Thus, the most relevant analysis is Run 6, which has travel speed, ADT, and pole spacing deleted. Looking again at the order with which variables were entered, shoulder width went in at Step 2. However, it has already been established that shoulder width is highly correlated with offset from Figure 4-4, plus the correlation matrix shows that it is also strongly correlated with speed limit. The existence of these cross-correlations justified omitting shoulder width on the basis that it might be obscurring effects of speed limit and offset. Hence, the regression was rerun with the variables travel speed, ADT, pole spacing, and shoulder width deleted; the results are given in Table 4-27.

At each step of the regression, the constant and coefficients of the regression equation are given together with the ninety-five percent confidence interval, i.e., it is 95% certain that the regression coefficient lies within the margin of error quoted. This test is equivalent to testing the significance of the partial correlation coefficient for this particular variable at the end of the preceding step or using an F ratio test on the (additional sum of squares explained by the variable)/(residual sum of squares) (Reference 23). Although any one of these three tests establishes whether a regression coefficient is significantly different from zero, they give no indication of the importance of a particular variable; this can be determined from the increase in the square of the multiple correlation coefficient. The value of the multiple correlation coefficient, together with the increase in its square, is given at each step.

TABLE 4-27 - STEPWISE REGRESSION WITH TRAVEL SPEED, ADT, POLE SPACING, AND SHOULDER WIDTH DELETED - 3,371 DATA POINTS

Step Number	Variable Entered	Coefficients of Regression Equation Including Margin of Error									R^2
		Constant	Number of Poles	Offset	Road Grade	Road Path	Speed Limit	Road Width	Number of Lanes	Median Width	
1	Number of Poles	-0.055	0.0689 $\pm$.002	--	--	--	--	--	--	--	0.257
2	Offset	-0.105	0.0686 $\pm$.002	0.0075 $\pm$.0014	--	--	--	--	--	--	0.263
3	Road Grade	-0.030	0.0682 $\pm$.002	0.0093 $\pm$.0014	-0.059 $\pm$ .013	--	--	--	--	--	0.268
4	Road Path	0.0093	0.0676 $\pm$.002	0.0094 $\pm$.0014	-0.054 $\pm$ .013	-0.027 $\pm$ .008	--	--	--	--	0.270
5	Speed Limit	0.103	0.0672 $\pm$.002	0.0077 $\pm$.0015	-0.053 $\pm$ .013	-0.026 $\pm$ .008	-0.0022 $\pm$ .0007	--	--	--	0.273
6	Road Width	0.088	0.0677 $\pm$.002	0.0067 $\pm$.0015	-0.053 $\pm$ .013	-0.023 $\pm$ .008	-0.0026 $\pm$ .0007	0.001 $\pm$.0004	--	--	0.274
7	Number of Lanes	0.107	0.0681 $\pm$.002	0.0067 $\pm$.0015	-0.052 $\pm$ .013	-0.024 $\pm$ .008	-0.0025 $\pm$ .0007	0.0023 $\pm$.0007	-0.026 $\pm$ .012	--	0.275
8	Median Width	0.075	0.0678 $\pm$.002	0.0070 $\pm$.0016	-0.052 $\pm$ .013	-0.022 $\pm$ .008	-0.0021 $\pm$ .0007	0.0045 $\pm$.001	-0.045 $\pm$ .013	-0.005 $\pm$ .0015	0.277

*95% confidence interval

As in the preliminary runs, "number of poles" was the first variable entered, explaining 26.1% of the variance. Offset was then entered at Step 2 (replacing shoulder width in the previous run) and explained a further 0.7% of the variance. Road grade was entered at Step 3, road path at Step 4, and speed limit at Step 5, each explaining an additional 0.5, 0.3, and 0.3 percent of the variance, respectively. The remaining 3 steps each contributed about another 0.1% to the variation explained when the variables road width, number of lanes, and median width were added to the model.

It is clear from this regression analysis that the overriding factor in predicting utility pole accidents is "number of poles". Note that this variable not only identifies that a line of poles exists but also indicates their average spacing since poles that were within 600 feet of either side of the struck pole (or the rest position of the vehicle in run-off-road accidents) were counted. Although the variation explained was relatively small, it is encouraging that offset is entered as Step 2, in that it complements the "number of poles" parameter from the point of view of providing a more complete definition as to the location of the utility pole. The proportion of variation explained might have been improved had the actual pole offset been measured in non-pole accidents rather than final rest position of the vehicle. This would obviously provide a more definitive measure of the effect of offset on the probability of a utility pole accident.

The remaining parameters that were entered, described the road type (i.e., road grade) or were related to the vehicle departure angle, i.e., road path and speed limit. This suggests that if better measures of departure attitude were available (for example, angle and speed), a higher proportion of the variation would be explained.

4.4 Factors Which Affect Utility Pole Accident Severity

It was seen in the introduction that utility pole accidents were, in general, more severe than run-off-road accidents. In trying to suggest possible countermeasures, it is important to understand why they were more severe. However, before expanding the discussion of severity, it is pertinent to examine the injury reporting codes upon which the data are based.

4.4.1 Injury Reporting Codes and Accident Reporting Criteria

Throughout this Section, accident severity is estimated whenever possible by the distribution of severest occupant injury rather than occupant injury. This has been done to avoid difficulties which occur because of variations in police reporting procedures in the different data collection areas; for example, some areas are required to report all occupants of the involved vehicle regardless of injury, whereas, others have only to report the driver plus any other injured occupants. Obviously, this produces a bias in the injury distributions between areas, such that accidents occurring in areas where the driver and injured occupants only are reported would appear to be more serious, i.e., there would be a larger proportion of injured occupants. Table 4-28 lists the data collection areas by occupant reporting criteria.

TABLE 4-28- OCCUPANT REPORTING CRITERIA, BY DATA COLLECTION AREAS

All Occupants	Driver and Injured Occupants, Only
Erie County, New York	San Diego, California
Niagara County, New York	Oakland, California
Portland, Maine	Memphis, Tennessee
South Portland, Maine	Nashville, Tennessee
Lewiston, Maine	Knoxville, Tennessee
Auburn, Maine	Macon, Georgia
Bangor, Maine	Columbus, Georgia
Sioux Falls, South Dakota	Cheyenne, Wyoming
Rapid City, South Dakota	Casper, Wyoming
Aberdeen, South Dakota	Laramie, Wyoming
Atlanta, Georgia	

Furthermore, given that the probability of injury is lower when using a seat belt, one would expect to observe an apparent difference in seat belt usage rates among the areas, resulting from variations in occupant reporting procedures, i.e., restraint usage in areas which report all occupants should be higher due to a greater number of restrained and uninjured occupants who were reported (but who would not have been reported in a "driver and injured occupant area"). This effect, however, is not evident in Table 4-29, which gives the distribution of restraint usage by data collection area for pole and run-off-road accidents. This is possibly due to the large quantity of unknown information. Note that, overall, 87% of the reported occupants were unrestrained!

Since the above table indicates that restraint usage, despite variations across data collection areas, was extremely low, it is reasonable to assume that the effect of restraint use on overall severity was low and no corrections need be applied in combining the data for different areas.

Another problem with using severest occupant injury occurs from variations in police interpretation of the different levels of severity. This is illustrated in Table 4-30.

Considering, for the moment, the first three data collection areas in this table, the proportions of property damage (category O/D) and fatal injury are similar but the proportion of A, B, and C injuries are subject to wide variations. This can, most likely, be attributed to differences in interpretation of the injury severity codes* rather than differences in the actual severities. To avoid problems that could arise from variations in severity codings, accident severities as used in this analysis are restricted to the proportions of no injury (or alternatively, injury) and fatal accidents.

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*The Erie and Niagara Counties data were converted during data processing into the K-A-B-C code from an injury description code used throughout the State of New York. A table for this conversion can be found in Reference 28.

TABLE 4-29 - RESTRAINT USE BY AREA

Restraint Use	Area										
	Cheyenne	Casper	Laramie	Sioux Falls †	Rapid City †	Aberdeen †	Portland †	South Portland †	Lewiston †	Auburn †	Bangor †
No				14	15	4	43	16	72	43	20
Yes				1			2	3	2	4	17
Unknown	2	10	1	5	15	5	1		2	2	5
Total	2	10	1	20	15	9	46	19	76	49	42
% No Rest.	*	*	*	93.3	*	*	95.6	84.2	97.3	91.5	54.1

Restraint Use	Area									
	Eric & Niagara †	Nashville	Memphis	Knoxville	Atlanta	Macon	Columbus	San Diego	Oakland	Total
No	2331	939	399	92	2	13	224	197	2	4411
Yes	354	144	54	11			36	58		686
Unknown	1581	581	462	481	1032	266	134	692	107	5384
Total	4266	1664	915	584	1034	279	394	947	109	10481
% No Rest.	86.8	86.7	88.1	89.3	*	*	86.2	77.3	*	86.5

*Result would be meaningless due to large number of unknowns.

† All occupants reported in this area.

TABLE 4- 30 - SEVEREST OCCUPANT INJURY BY AREA (UTILITY POLE ACCIDENTS)

Injury	Erie and Niagara Counties		Nashville		San Diego		Macon		Columbus		Knoxville	
O/D	274	(45.4)*	131	(45.3)	61	(45.5)	56	(56.6)	60	(55.6)	82	(51.3)
C	81	(13.4)	17	(5.9)	9	(6.7)	0	(0.0)	0	(0.0)	10	(6.3)
B	165	(27.3)	39	(13.5)	46	(34.3)	20	(20.2)	39	(36.1)	21	(13.1)
A	51	(8.4)	97	(33.6)	17	(12.7)	5	(5.1)	6	(5.6)	44	(27.5)
K	6	(1.0)	3	(1.0)	1	(0.7)	2	(2.0)	0	(0.0)	0	(0.0)
Injured, Severity Unknown	27	(4.5)	2	(0.7)	0	(0.0)	16	(16.2)	3	(2.8)	3	(1.9)
Unknown	28	-	33	-	11	-	4	-	1	-	19	-
TOTAL	632	(100.0)	322	(100.0)	145	(100.0)	103	(100.0)	109	(100.0)	179	(100.0)

*Percentage of Total less Unknown in parentheses

In comparing the distribution of accident severities between areas, it is evident from Table 4-30 that the proportions of no injury accidents varied significantly. This is likely explained by variations in the reporting criterion among police agencies. For example, in Maine the police are to be notified when accident damage exceeds $200, in Georgia when it exceeds $25, and in Tennessee, there is no requirement to notify the police, so that the range is considerable. Table 4-31 summarizes the police notification criteria for the various data collection areas.

TABLE 4-31 - POLICE NOTIFICATION CRITERIA

State	Must Notify Police if Fatality or Bodily Injury	Property Damage Threshold Necessary to Notify Police
California	Yes	Not required
Georgia	Yes	$25 (in accident)
Maine	Yes	$200 (in accident)
New York	Yes	Not required
South Dakota	Yes	$250 (in accident)
Tennessee	No*	Not required
Wyoming	Yes	$250 (to any one party)

Compiled from: American Automobile Association, 1974 Digest of Motor Laws.
*But must submit driver report.

Also contributing to the variation in the proportion of no injury accidents among the areas is the different emphasis given by police agencies to accident reporting; for example, in a large metropolitan area, the primary concern of the police at an accident scene would be the restoration of the traffic flow, which will likely lead to less emphasis on accident reporting with a consequently lower measure of reporting "marginal cases". Unfortunately, one cannot compensate for these biases and, while they do not impose any severe restriction on the utility of the data, any conclusions drawn from accidents between areas must be interpreted accordingly.

4.4.2 Relative Severity of Objects Struck

While it was shown in Table 4-3 that utility pole accidents were more severe than run-off-road accidents in general, this does not necessarily establish that they were the most severe type of object hit. To examine relative severity, Table 4-32 gives the distribution of accident severity by first object struck for both utility pole accidents and run-off-road accidents in order of their relative frequency from Table 4-1. Table 4-33 gives the relative proportions of no injury, injury and fatal injury accidents for each object. Note that in calculating the relative proportions, the subtotal of Table 4-32 was used, such that the categories "injured, Degree Unknown" and "Unknown If Injured" were excluded.

Looking at the proportion of no injury, utility poles had the lowest figure (49.5 percent) with the exception of vehicles striking the ground (47.4 percent), which generally involved rollover type accidents. Slightly less severe were culverts/ditches/embankments (55.5 percent no injury accidents), trees (57.0 percent), and bridges (59.1 percent). It can be seen that the proportion of no injuries continues to increase as the rigidity of the object struck decreases. However, surprisingly, collisions with light or signal poles had a relatively high proportion of no injuries.

Examining the fatality rate for the various objects struck, collisions with bridges (1.7 percent) had the highest rate followed by trees (1.2 percent) and ground contacts (1.1 percent). Utility pole accidents ranked fourth with a rate of 0.8 percent. The only other roadside objects which had non-zero fatality rates were culverts/ditches/embankments, fire hydrants, and signs/mailboxes/ parking meters/guy wires (0.7, 0.6, and 0.3 percent, respectively).

Neither ground, culverts/ditches/embankments, nor signs/mailboxes/ parking meters/guy wires are obstacles that one would naturally associate with severe injury. However, Table 4-34 shows that rollover was the predominant injury mechanism for these types of impacts, in that 96.3 percent of accidents in which the ground was struck involved rollover, and 20.2 percent of the

TABLE 4-32 - ACCIDENT SEVERITY BY FIRST OBJECT STRUCK

First Object Struck	Severest Occupant Injury							
	O/D	C	B	A	K	Subtotal	Severity Unknown	Unknown	Total
Utility Pole	577	99	289	192	9	1166	44	81	1291
Fence, Guardrail	569	46	85	39	1	740	20	63	823
Sign, Parking Meter, Mail Box, Guy Wire	535	36	63	30	3	668	7	53	727
Culvert, Ditch, Embankment	374	68	142	85	5	674	26	15	715
Tree	341	38	115	97	7	598	47	36	681
Light, Signal Pole	288	28	22	27		365	45	55	465
Fire Hydrant	147	10	14	7	1	179	4	41	224
Building	130	2	20	11		163	12	40	215
Ground (Generally rollover)	83	22	36	32	2	175	10	1	186
Wall	94	15	17	21		147	2	25	174
Shrubbery	93	2	0	5		100	6	14	120
Bridge	68	11	27	7	2	115			115
None	67	2	10	0		79			79
Other	181	22	44	30		277	8	18	303

TABLE 4-33 - PROPORTION OF NO INJURY, INJURY, AND FATAL ACCIDENTS, BY FIRST OBJECT STRUCK

First Object Struck	% No Injury	% Injury	% Fatal
Utility Pole	49.5	49.7	0.8
Fence, Guardrail	76.9	23.0	0.1
Sign, Parking Meter, Mail Box, Guy Wire	80.1	19.5	0.4
Culvert, Ditch, Embankment	55.5	43.8	0.7
Tree	57.0	41.8	1.2
Light, Signal Pole	78.9	21.1	0.0
Fire Hydrant	82.1	17.3	0.6
Building	79.8	20.2	0.0
Ground (Generally rollover)	47.4	51.4	1.1
Wall	63.9	36.1	0.0
Shrubbery	93.0	7.0	0.0
Bridge	59.1	39.1	1.7
None	84.8	15.2	0.0
Other	65.3	34.7	0.0

TABLE 4-34 - ROLLOVER FREQUENCY

AS A FUNCTION OF FIRST OBJECT STRUCK

First Object Struck	No Rollover	Rollover	Unknown	Total	% Rollover
Utility Pole	1251	32	8	1291	2.5
Fence, Guardrail	787	33	5	825	4.0
Sign, Parking Meter, Mail Box Guy Wire	666	56	7	729	7.8
Culvert, Ditch, Embankment	560	142	12	714	20.2
Tree	656	27	0	683	4.0
Light, Signal Pole	448	10	8	466	2.2
Fire Hydrant	222	2	0	224	0.9
Building	210	3	2	215	1.4
Ground	7	180	0	187	96.3
Wall	168	7	0	175	4.0
Shrubbery	118	2	0	120	1.7
Bridge	109	7	0	116	6.0
None	80	0	0	80	0.0
Other	284	15	5	304	5.0

culverts/ditches/embankments contacts. The rollover frequency was lower (7.8 percent) for impacts with signs/mailboxes/parking meters/guy wires but still well above the median. Although it is well known that rollover accidents are, in general, relatively severe, it is as well to confirm this using the present data; accordingly, Table 4-35 compares the injury distributions in rollover and non-rollover accidents.

Referring to Table 4-34, it is interesting to note that rollover frequency is reduced as the rigidity of the struck obstacle increases; that is, more and more of the vehicle's kinetic energy is dissipated in impact with the object, leaving progressively less energy for rollover.

Another factor which could have contributed to the above average severity of impacts with the ground, ditches/culverts/embankments and signs/parking meters/mailboxes/guy wires was the possibility of the vehicle impacting a second object. Table 4-36 looks at the characteristics of the second object struck for these object categories. For ground contact in 91.9 percent of the cases there was no second object struck which, combined with Table 4-32, confirms that the injury mechanism was rollover. Rollover was also the predominant injury mechanism for contacts with culverts/ditches/embankments in that a large proportion, i.e., 73.0 percent, involved no further contact and in 20.4 percent of the accidents, rollover occurred. However, this was not the case for impacts with signs/parking meters/mailboxes/guy wires, in that the rollover rate was quite low (7.8%) and impacts with secondary objects high (57.2%); this suggests that the second impact contributed significantly to the accident severity.

By way of summary the most severe impacts are those involving rollover followed by impacts with utility poles, trees, and bridges, in that order. However, it is important to realize that in looking at the combined effects of frequency and severity, utility poles were by far the most frequent source of injury of any object struck.

TABLE 4-35 - INJURY SEVERITY OF ROLLOVER AND NON-ROLLOVER ACCIDENTS

Accident Type	Severest Occupant Injury									
	O/D	C	B	A	K	Subtotal	Severity Unknown	Unknown If Injured	Total	% No Injury	% Fatal
Rollover	201	79	137	107	16	540	12	12	564	37.2	3.0
Non-Rollover	4131	454	1007	875	28	6495	227	574	7296	63.6	0.4
Unknown	24	4	9	4	-	41	-	14	55	58.5	0.0

TABLE 4-36 - DISTRIBUTION OF
SECOND OBJECT STRUCK BY FIRST OBJECT STRUCK

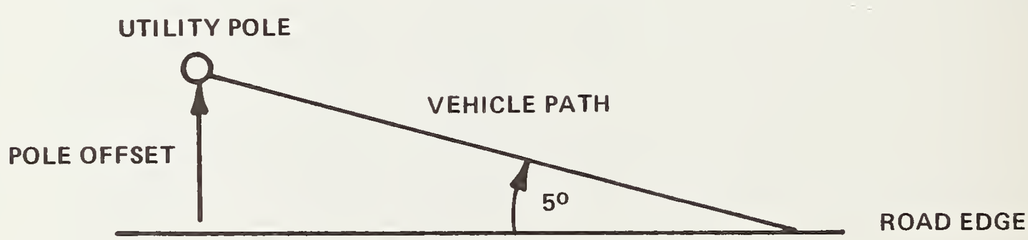
Second Object Struck	First Object Struck						
	Culvert, Ditch, Embankment		Sign, Parking Meter, Mail-Box, Guy Wire		Ground		Total
	#	%	#	%	#	%	
Utility Pole	22	3.1	49	6.8	3	1.6	74
Fence, Guardrail	12	1.7	24	3.3	2	1.1	38
Sign, Parking Meter, Mailbox, Guy Wire	16	2.2	115	15.9	1	0.5	132
Culvert, Ditch Embankment	25	3.5	58	8.0	2	1.1	85
Tree	30	4.2	48	6.6	2	1.1	80
Light, Signal Pole	-	-	2	0.3	-	-	2
Fire Hydrant	2	0.3	3	0.4	-	-	5
Building	7	1.0	2	0.3	-	-	9
Ground	54	7.6	28	3.9	-	-	82
Wall	-	-	15	2.1	-	-	15
Shrubbery	1	0.1	23	3.2	3	1.6	27
Bridge	2	0.3	10	1.4	-	-	12
None	520	73.0	310	42.8	170	91.9	1000
Other	21	2.9	38	5.2	2	1.1	61
TOTAL	712	100.0	725	100.0	185	100.0	1622

4.4.3 Parameters Related to Utility Pole Accident Severity

Having established the relative severity of utility pole accidents with respect to other roadside objects, the next step is to examine parameters which are likely to produce variations in severity so that possible countermeasures which reduce severity can be proposed and/or evaluated. The potential factors that will be assessed are: distance traveled to impact, pole circumference, and impact speed. It should be noted that the following analysis will make use of the sample of pole accidents from all twenty data collection areas.

An obvious method of affecting the distance traveled to impact is to vary the pole offset. The proportions of no injury, injury, and fatal accidents are presented in Table 4-37 as a function of the pole offset. It can be seen from this table that there is little association between the two variables. In fact, a regression analysis on the rates of no injury and injury accidents* resulted in values of r equal to 0.19 and 0.09, respectively.

The fact that the pole offset did not contribute significantly to the accident severity is not surprising, since, as in the following illustration, increased pole offset does not display a large effect on the impact velocity. Consider a case in which a vehicle traveling at 45 MPH (72 KPH) departs the road at a 5° angle**; a schematic of this situation can be found below:



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*A third analysis using the proportion of fatal accidents for the dependent variable would be superfluous, since it is a linear combination of the other two measures.

**This is the low end of the range of estimates in Table 4-23 and slightly below the more typical departure angle of 15° found in the Highway Hazards Project (Reference 27); the lower value was used to maximize the length of the vehicle's trajectory.

TABLE 4-37 - PROPORTION OF NO INJURY, INJURY, AND FATAL ACCIDENTS BY POLE OFFSET

Pole Offset (ft.)	% No Injury	% Injury	% Fatal	N*
0**	52.9	47.1	0.0	51
1	50.2	48.9	0.9	1126
2	45.9	53.7	0.4	460
3	54.1	45.5	0.5	222
4	47.4	52.6	0.0	156
5	51.5	48.5	0.0	97
6	53.6	46.4	0.0	84
7	52.1	47.9	0.0	71
8	61.5	35.4	3.1	65
9	51.4	47.2	1.4	72
10	48.7	51.3	0.0	76
11	50.9	47.2	1.9	53
12	38.0	60.0	2.0	50
13	51.0	49.0	0.0	49
14	61.0	38.9	0.0	36
15	52.2	47.8	0.0	46
16	50.0	50.0	0.0	22
17	42.3	53.8	3.8	26
≥ 18	45.6	50.9	3.5	114
Unknown	41.7	57.1	1.2	84
TOTAL	49.6	49.6	0.8	2960

*Excludes Injured, Degree Unknown and Unknown if Injured.
**1 foot = 0.305 meters

The distance traveled by the involved vehicle is given by: - pole offset/Sine (5°). Furthermore, assuming engine braking, i.e., a deceleration of .1g (Reference 29), the impact velocity with a pole of known offset can be calculated as follows:

$$V^2_{impact} = V^2_{departure} + 2\ a\ s$$

where a = vehicle acceleration, and

s = distance traveled

such that: $V_{impact} = \sqrt{4356 - 73.90 \text{ (pole offset in feet)}}$ ft./sec.

or $V_{impact} = \sqrt{405.22 - 22.49 \text{ (pole offset in meters)}}$ m/sec.

Table 4-38 tabulates the calculated impact speeds for various values of pole offset for this example.

It is obvious, then, that the pole offset does not greatly affect the impact velocity. As demonstrated in Table 4-38, poles would have to be moved back at least twenty-five feet to obtain a 10 MPH (16 KPH) decrease in the impact velocity; obviously a larger decrease would occur if a higher level of vehicle braking were used, however, this is not surported by the data. It should be noted that the above discussion is only concerned with the impact severity; no inferences are being made about the probability of pole contact.

TABLE 4-38 - IMPACT VELOCITY FOR A VEHICLE TRAVELING 45 MPH (72 KPH) WITH A 5° DEPARTURE ANGLE

Pole Offset (ft.)	Length of Trajectory (ft)	Impact Velocity (MPH)
0*	0*	45.00*
1	11.5	44.81
2	22.9	44.23
3	34.4	43.84
4	45.9	43.45
5	57.4	43.05
6	68.8	42.65
7	80.3	42.24
8	91.8	41.83
9	103.3	41.42
10	114.7	41.01
15	172.1	38.85
20	229.5	36.58
25	286.8	34.15
35	401.6	28.68
50	573.7	17.53

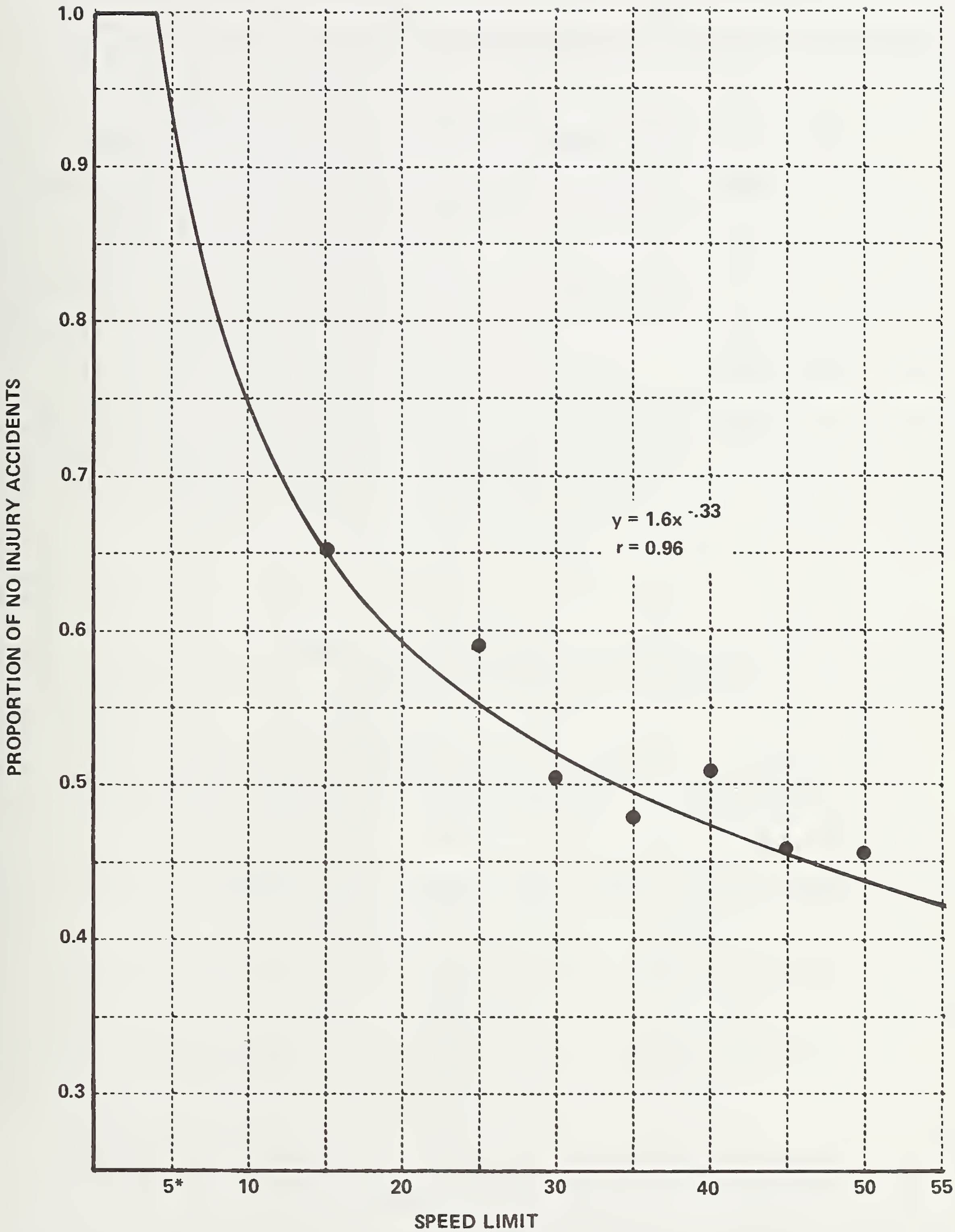
*1 foot = 0.305 meters
1 MPH = 1.61 KPH

Increasing the average pole spacing in order to increase the average length of a vehicle's off-road trajectory prior to pole contact will also have little effect on the resultant impact speed. This is also demonstrated in Table 4-38, in which the computed impact velocities are shown as a function of trajectory length. Intuitively, then, one would expect the benefits, if any, of pole offset and spacing to be realized in the frequency of pole contact.

A factor which one would expect to contribute to accident severity is that of impact speed. It was found previously in this Section that much of the data concerning estimates of impact speed were unknown; however, it was also demonstrated, using the data available, that the speed limit at the accident site correlated highly with the estimated impact velocity. Thus, in order to examine the effect of impact speed on the accident severity the speed limit will be used to approximate the actual speed.

Figure 4-10 is a plot of the proportion of no injury accidents against speed limit. The actual injury distributions can be found in Table 15 of Appendix 5; note that the proportions used in Figure 4-10 exclude "Injured, Severity Unknown" and "Unknown If Injured" categories. The data points were subsequently fit to a power curve function, which accounted for 92 percent of the variance ($r = 0.96$).

The power function was selected over an exponential model because it provided for an injury threshold; extrapolating the present data, an impact speed in excess of 4.15 MPH (6.68 KPH) is a prerequisite for any occupant injury. An exponential curve is constrained to pass through the point (0,1), which prevents the introduction of a threshold. Still, a least squares fit of an exponential model produced an r of 0.94. A linear model was the least



*1 MPH = 1.61 KPH

Figure 4-10 PROBABILITY OF NO INJURY AS A FUNCTION OF "IMPACT SPEED" attractive choice, despite accounting for 87 percent of the variance (r = 0.93); this model also predicted the occurrence of injury in 29 percent of all 0 MPH "impacts".

Previously, it was suggested that the rigidity of the object struck was an important factor in defining the resultant severity. Within pole accidents, one could expect accident severity to vary as a function of a pole's rigidity. While no direct measurement of pole rigidity is available, the pole circumference was recorded during the visit to the accident site. This data element should directly relate to the pole strength, in that both circumference and shear resistance are functions of the radius*. Since there was no way to determine the circumference after the pole had been replaced, the analysis had to be confined to poles for which the accident report indicated that no knockdown had occurred, or poles for which the utility companies had no repair records.

Table 4-39 provides the proportion of no injury, injury, and fatal pole accidents for different pole circumferences; a complete tabulation of the injury distributions can be found in Table 16, Appendix 5.

TABLE 4-39 - PROPORTION OF NO INJURY, INJURY, AND FATAL POLE ACCIDENTS BY POLE CIRCUMFERENCE (EXCLUDING KNOCKDOWNS)

Pole Circumference (in.)	% No Injury	% Injury	% Fatal	N
≤ 30*	58.5	39.8	1.7	354
31 - 35	49.8	49.7	0.5	614
36 - 40	48.2	51.2	0.5	734
41 - 45	48.4	49.9	1.7	345
≥ 46	48.7	50.3	1.0	193
TOTAL	50.4	48.7	0.9	2240

*1 in. = 2.54 cm

*More specifically, resistance to shear of a cylinder is directly proportional to its cross-sectional area.

A plot of the no injury accident rate is given in Figure 4-11. Note that a circumference of less than 31 inches (79 cm) is plotted at 25 inches (64 cm); similarly, a circumference of greater than 45 inches (114 cm) is plotted at 50 inches (127 cm). It appears from the figure that the probability of no injury might be some function of the square root of the radius. It is not meaningful to predict that portion of the curve based on only one data point*, but the fact that shear strength and pole radius have a quadratic relationship lends support to this notion. Also of note in Figure 4-11, is the apparent asymptote in probability of no injury that begins for poles with circumferences between 33 and 38 inches (84 and 97 cm) in circumference. However, it can be seen in Table 4-39 that this constant rate of no injury accidents for circumferences greater than 36 inches (91 cm) was accompanied by an increase in the proportion of fatal accidents. Although the results were based on a small sample size (21 fatal accidents), the extremely high fatality rate for poles with small circumferences suggests an interaction with some other injury producing factors.

Accordingly, the data leading to this result were examined in more detail; specifically, the frequency of rollover after the pole contact in these fatal accidents was tabulated and is given in Table 4-40. It can be seen that rollovers were apparently more frequent for the lower circumference poles although sample sizes were small. This could indicate that there is a trade-off between reducing injuries resulting from pole contact and, at the same time, increasing severity from rollover. Table 4-41 looks at the entire sample of pole accidents without knockdown with respect to rollover. The number of rollovers after contacting a utility pole seemed to vary with pole size and was highest for poles of less than 30 inches (76 cm) circumference. Obviously, without including poles that were knocked down, this conclusion must still be considered as tentative.

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*The abscissa of this data point has also been estimated at 25 inches (64 cm). At the time the data were prepared for analysis, it was felt that 30 inches (79 cm) was a reasonable lower bound for pole circumference; obviously, in the light of this result, a lower value should have been adopted.

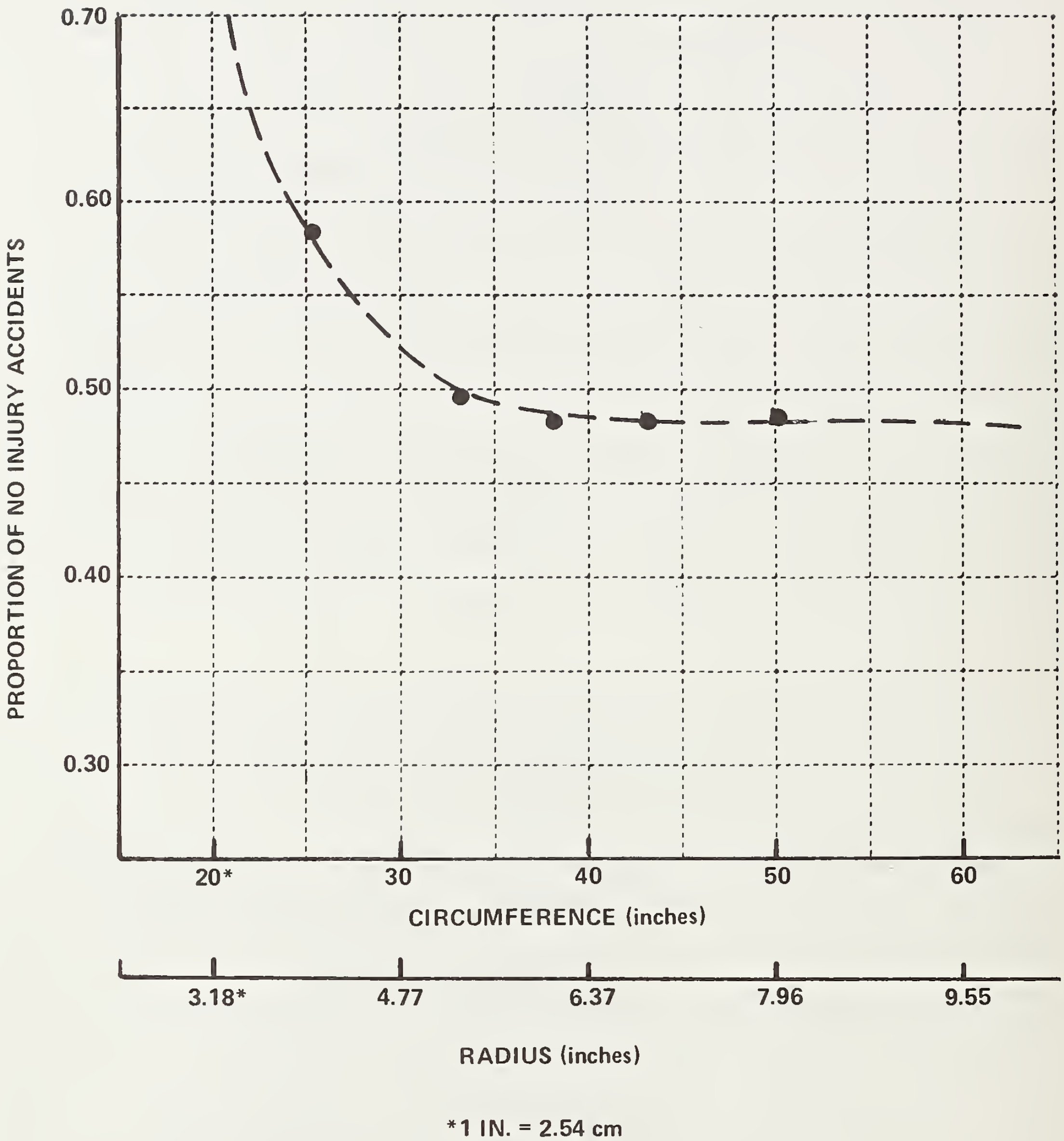

Figure 4-11 PERCENT OF NO INJURY BY POLE CIRCUMFERENCE

TABLE 4-40 - ROLLOVER IN FATAL POLE ACCIDENTS (EXCLUDES KNOCKDOWNS)

Pole Circumference (in.)	No Rollover	Rollover After Pole Contact	Total
≤ 30*	3	3	6
31 - 35	1	2	3
36 - 40	4	0	4
41 - 45	5	1	6
≥ 46	2	0	2
TOTAL	15	6	21

*1 inch = 2.54 cm.

TABLE 4-41 - ROLLOVER BY POLE CIRCUMFERENCE (EXCLUDES KNOCKDOWNS)

Pole Circumference (in.)	None	Rollover Before Contact	Rollover After Contact	Rollover Unknown When	Unknown	Total
≤ 30**	377 (95.4)*	0 (0.0)	18 (4.6)	0 (0.0)	3	398
31 - 35	662 (97.8)	2 (0.3)	13 (1.9)	0 (0.0)	1	678
36 - 40	790 (97.8)	4 (0.5)	13 (1.6)	1 (0.1)	2	810
41 - 45	360 (98.9)	0 (0.0)	3 (0.8)	1 (0.3)	1	365
≥ 46	204 (97.6)	1 (0.5)	4 (1.9)	0 (0.0)	2	211
NA	6	0	1	0	0	7
Unknown	402	1	15	1	4	423

*Percentage of Total less Unknown in parentheses.

**1 inch = 2.54 cm.

Initially, it was thought that the effect of pole circumference would be evident within speed limit, on the assumption that the severity was a function of both impact speed and pole strength. (In knockdowns, severity would only be related to pole circumference.) However, because of the variation of impact speed, within speed limit categories and the influence of other variables on accident severity, e.g., vehicle weight and stiffness, condition of the pole, etc., no significant effect was found during the analysis.

As a side issue, but perhaps the most significant part of this analysis, the injury severities of restrained and unrestrained occupants were compared for the various categories of pole circumference in Table 4-42. Note the huge advantage that restrained occupants enjoyed in non-knockdown pole accidents!

TABLE 4-42 - PROPORTION OF NO INJURY FOR RESTRAINED AND UNRESTRAINED OCCUPANTS, BY POLE CIRCUMFERENCE (EXCLUDES KNOCKDOWNS)

	Pole Circumference									
	≤30*	N	31-35	N	36-40	N	≥41	N	Overall	
Unrestrained	49.7	185	47.1	346	46.4	392	38.8	258	45.5	1181
Restrained	74.3	35	68.3	60	65.7	35	72.4	29	69.8	159

*1 in. = 2.54 cm

Further evidence of the efficacy of restraint use is given in Table 4-43, which presents the proportions of uninjured, injured and fatally injured occupants as a function of seat belt use in all utility pole accidents. It can be seen that restrained occupants had 46% less chance of injury than unrestrained occupants.

TABLE 4-43 - EFFECT OF RESTRAINT USAGE ON ACCIDENT SEVERITY

Restraint Use	% No Injury	% Injury	% Fatal	N
Used	70.6	29.4	0.0	218
Not Used	46.2	53.1	0.7	1595
Unknown if Used	53.2	46.2	0.6	2123

4.4.3 Summary of Severity Results

The fact that utility pole accidents are a significant highway safety problem in urban areas is amply demonstrated in that utility pole contacts resulted in more injuries (inclusive of fatalities) than any other roadside object or rollover. Relative to these other single vehicle accidents, utility poles were one of the most severe accident types; only rollovers had a greater proportion of injury accidents, although bridges, trees, and rollovers had higher fatality rates.

Within the utility pole accident sample, factors which affected the probability of occupant injury were identified. Not unexpectedly, the major parameters were directly related to the level of occupant deceleration; the proportion of injury increased with both higher impact speeds (as estimated by the prevailing speed limit) and increased pole stiffness. Whereas the probability of injury appeared to increase over the entire range of "impact speeds", the effect of pole stiffness leveled off for poles with circumferences of approximately 36 inches (91 cm) or greater. Factors related to the distance traveled to impact e.g., pole offset, demonstrated little correlation with accident severity; these parameters had a more noticeable effect on the likelihood of pole contact.

During the course of the severity analysis, it was found that less substantial (thinner) poles tended to increase the probability of subsequent rollover; obviously, this could have a detrimental effect on the benefits of countermeasures which weaken existing poles or involve installation of breakaway poles. However, generally less severe injuries may adequately compensate for the increased frequency of rollover under these conditions. It should be stressed that this result was only established for accidents where the pole was not knocked down and should be replicated with a sample of utility pole accidents which includes knockdowns.

Finally, and perhaps most significantly, occupants who were using their available restraint systems were found to have a markedly reduced chance of injury (and death) in utility pole accidents.

5. COUNTERMEASURE EVALUATION

Possible countermeasures to the utility pole accident problem were discussed in Section 2.2 and the techniques used to evaluate them on a cost-benefit basis were presented in Section 3.6. This section discusses the implications of applying cost-benefit analysis to these countermeasures in light of the results of the accident analysis in Section 4.

5.1 Cost-Benefit Analysis of Undergrounding Cables

As an example of cost-benefit analysis, the removal of all utility poles from the roadside environment by undergrounding power lines and telephone cables will be evaluated. This should serve to illustrate the problems that arise even for such a conceptually straight-forward countermeasure.

From Section 3.6 it was seen that one must estimate the savings (or loss) in societal injury costs that result from implementation of the countermeasures. Only the 1,490 pole accidents which occurred in the run-off-road areas will be considered in this example. As a result of countermeasure introduction, the poles will have been removed from the roadside; thus, the assumption will be made that the run-off-road accident sample is representative of accidents occurring under these conditions. (This is not entirely accurate, since in Section 4, it was reported that pole accidents typically involve shallower departure angles at slightly higher pre-impact velocities.) The probability of the various injury severity levels, in the 1490 now run-off-road accidents, can then be best estimated by the corresponding proportions in the run-off-road occupant injury distribution. This predicted post-undergrounding injury distribution is presented in Table 5-1, along with the original occupant injury distribution from the utility pole accident sample. (Note that the percentages of the predicted distributions in Table 5-1 are the same as those in the run-off-road univariate distribution of occupant injury severity given in Appendix 4.)

In calculating the societal costs, it was important to avoid including vehicle repair costs, accident investigation costs, traffic delay costs, losses to others, etc. more than once per accident. Accordingly, vehicle repair costs were subtracted from the societal injury costs found in Table 3-9; the results of this adjustment are shown below in Table 5-2.

TABLE 5-1 - ACTUAL AND PREDICTED INJURY DISTRIBUTIONS

Injury Severity	With Utility Poles Present	%	Predicted After Undergrounding	%
K	12	0.6	7	0.4
A	260	13.3	143	7.3
B	424	21.6	223	11.4
C	174	8.9	141	7.2
O/D	908	46.3	1258	64.2
Injured, Severity Unknown	75	3.8	74	3.8
Unknown If Injured	107	5.5	114	5.5
TOTAL	1960	100.0	1960	100.0

TABLE 5-2 - SEPARATION OF OTHER RELATED FACTS FROM INJURY COST

Injury Severity	Societal Cost Per Injury*	Injury Cost	Other Related Cost
K	$287,175	$279,045	$ 8,130
A	30,335	26,023	4,312
B	4,350	1,940	2,410
C	2,190	323	1,867
D or O	520	7	513

*Reference 20

The contribution to the overall cost by the other related costs cannot, however, be ignored. It will be calculated based on the appropriate distribution of severest occupant injury. The severest occupant injury distribution obtained in the utility pole accident sample and the expected distribution after undergrounding can be found in Table 5-3.

TABLE 5-3 - ACTUAL AND PREDICTED
DISTRIBUTIONS OF SEVEREST OCCUPANT INJURY

Severest Occupant Injury	With Utility Poles Present	%	Predicted After Undergrounding	%
K	12	0.8	6	0.4
A	220	14.8	117	7.8
B	330	22.1	179	12.0
C	117	7.9	92	6.2
O/D	664	44.6	927	62.2
Severity Unknown	51	3.4	58	3.9
Unknown If Injured	96	6.4	111	7.5
TOTAL	1490	100.0	1490	100.0

The injury related costs can be found using Equation 5-(1). The savings realized by society as a result of undergrounding overhead cables is then the difference between the injury cost estimates for both conditions.

$$\text{INJURY COST} = \sum_{\substack{\text{injury}\\ \text{severity}}} (\text{frequency of occupant injury})\ (\text{associated injury cost}) + \sum_{\substack{\text{injury}\\ \text{severity}}} (\text{frequency of severest occupant injury})\ (\text{associated other related costs}) \qquad 5\text{-}(1)$$

The results of the calculations show, that in the six run-off-road areas, utility pole accidents cost society $13,400,029 from injuries and other related costs. The estimate of societal injury costs if the poles were removed is $7,793,562 - a potential savings of approximately $5.6 million.*

Other financial benefits would be realized by the removal of utility poles from the roadside; specifically, with no poles available to be knocked down or damaged, no repair costs would have to be incurred. Whether this benefit should be assigned to the utility company or society in general is in doubt. Several interrelated factors are relevant in deciding the above issue. In most cases, the operator/owner of the involved vehicle was liable for the damage to the utility pole**, although the utility companies has costs associated with their legal staffs and absorbed the cost-to-repair in hit-and-run accidents. Furthermore, in the various localities, the amount the driver was billed by the utility company was determined differently: in some areas, the entire cost-to-repair was recovered, whereas in others, the amount was depreciated by the age of the pole in question. Table 5-4 summarizes, by area, the basis for calculating the repair costs for which a utility company could be reimbursed.

For the purposes of this discussion, the cost-to-repair that was associated with any utility pole accident was the amount that the utility company could recover from the liable party. In the six run-off-road areas, pole accidents cost the utility companies a total of $233,841, or an average of $161 for each of the 1,452 accidents for which the repair costs were known.

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*The "Unknown if Injured" and "Injured, Severity Unknown" categories were not included in the cost calculations. Since their frequencies in the actual and hypothetical distributions were not equal, then, strickly speaking, the two costs are not directly comparable. However, if the benefits were calculated on a per accident basis, there is a $4,078 difference, which for 1,400 accidents, amounts to $5.7 million.

**As suggested in Section 3.6, the repair costs are paid by the drivers' insurance companies.

TABLE 5-4 - SUMMARY OF RECOVERABLE COST-TO-REPAIR, BY UTILITY COMPANY

Depreciated	Non-Depreciated
New York Telephone	New York State Gas and Electric
Niagara Mohawk	Georgia Power
Central Maine Power	Southern Bell
Bangor Hydroelectrics	Knoxville Utilities Board
New England Bell	Memphis Light, Gas, and Water
Pacific Gas and Electric	Nashville Electric Service
San Diego Gas and Electric	South Central Bell
Pacific Telephone	Mountain Bell
	Pacific Power and Light
	Cheyenne Light, Fuel, and Gas
	Northwestern Bell
	Northern States Power
	Black Hills Power and Light
	Northwestern Public Service

This result combined with the savings in injury related costs of $5,606,467 indicates that in the six run-off-road areas, society would realize a benefit of $5,840,308 per year (in 1975 dollars). However, prior to any implementation decision, several additional factors remain to be evaluated.

Table 5-5 provides a breakdown of the benefits of undergrounding services for the different run-off-road data collection areas; these figures were calculated in the same manner as the aggregrate benefits just illustrated. It is obvious from the table that there are large inter-area variations in a countermeasure's financial benefits. This does not appear to be a function of any one factor. For instance, as shown in Table 5-6, the average cost-to-repair varied across areas; factors contributing to this phenomena include: differences in labor costs, expected pole life (affecting the rate of depreciation), and the percentage of pole accidents requiring repairs (also presented in Table 5-6).

TABLE 5-5 - EXPECTED BENEFITS FROM UNDERGROUNDING CABLES BY AREA

Area	Costs with Utility Poles Present				Costs After Ungrounding				
	Injury Costs	Other Accident Related Costs	Repair Cost	Total	Injury Costs	Other Accident Related Costs	Total	Total Savings	Savings Per Accident
Erie and Niagara Counties	$ 3,726,686	$ 958,131	$126,810	$ 4,811,627	$1,819,141	$ 658,300	$2,477,441	$2,334,186	$ 4,131
Nashville	3,892,709	635,586	47,170	4,575,465	2,924,622	480,860	3,405,482	1,169,983	3,811
Knoxville	1,412,352	301,074	12,274	1,725,700	896,090	215,016	1,111,106	614,594	4,097
Macon	765,418	114,692	5,222	885,332	634,046	90,024	724,070	161,262	1,715
Columbus	247,773	150,642	8,582	406,997	299,618	114,967	414,585	- 7,588	- 70
San Diego	954,700	240,390	33,783	1,228,873	146,237	104,591	250,828	978,045	8,655
TOTAL*	$10,999,638	$2,400,515	$233,841	$13,633,994	$6,719,754	$1,663,758	$8,383,512	$5,250,482	$ 4,078

*Total figures will vary slightly from the overall costs, due to rounding errors in adjusting data for the sampling fraction and in estimating the hypothetical injury distributions.

TABLE 5-6 - VARIATIONS IN COST-TO-REPAIR RELATED DATA BY AREA

Area	Average Cost to Repair/Repair	Average Cost to Repair/ Utility Pole Accident	% Utility Pole Accidents Requiring Repair
Erie and Niagara Counties	$590	$204	34.0%
Nashville	582	151	25.2
Knoxville	299	71	22.9
Macon	326	51	15.5
Columbus	318	79	24.8
San Diego	786	250	29.7
OVERALL	$553	$161	71.6%

Also affecting a countermeasure's potential benefit is the severity of run-off-road accidents relative to utility pole accidents in each of the areas. In, for instance, areas which are classified as light or medium loading districts, the utility poles may be thinner (thus, less rigid), and it is likely that the severity differential for that area would be greater than that of a heavy loading district. By the same token, poles may "protect" errant vehicles from even more dangerous off-road events, e.g., extremely steep embankments which may encourage rollover.

Surprisingly, it was found that in Columbus, Georgia, the elimination of utility poles from the roadside would increase injury-related costs; in fact, injury costs were increased to such a point that negative benefits were realized! Table 5-7 presents the actual and predicted distributions for injury severity and severest occupant injury for the relevant accidents in the Columbus data collection area.

TABLE 5-7 - INJURY DISTRIBUTIONS BEFORE AND AFTER UNDERGROUNDING - COLUMBUS, GEORGIA*

	Occupant Injury			Severest Occupant Injury	
	With Utility Poles Present	Predicted Undergrounding		With Utility Poles Present	Predicted Undergrounding
O/D	65	84	O/D	60	76
C	0	--	C	--	--
B	47	20	B	39	16
A	6	10	A	6	8
K	--	--	K	--	--
TOTAL	118	114	TOTAL	105	100

*"Injured, Degree Unknown" and "Unknown if Injured" are omitted

There are three possible explanations for this result: 1) it is a true result, 2) there was an anomaly in the data during 1975, 3) it is an artifact of the injury severity code and the injury cost structure. This latter possibility requires a further explanation. Assume for the moment that all the Type "A" injuries in the pole accident sample were critical or AIS-5 injuries, while the Type "A" injuries sustained in run-off-road accidents were moderate (AIS-3) injuries. The AIS injury distributions before and after the hypothetical removal of utility poles would then be as shown in Table 5-8.

TABLE 5-8 - AIS INJURY DISTRIBUTIONS - COLUMBUS, GEORGIA

AIS	With Utility Poles Present	After Undergrounding
0	65	84
1	--	--
2	47	20
3	--	10
4	--	--
5	6	--
6	--	--
TOTAL	118	114

Using the cost associated with AIS injury severity presented in Table 3-9, pre-countermeasure injury costs would be $1,391,690; the injury related costs after countermeasure introduction would be $211,580. Thus, in this (admittedly extreme) example, society would obtain a $1.2 million benefit, instead of the previously estimated cost of over $7,000. This points out the disadvantage of using the K-A-B-C injury code: functionally a distinction can only be made between not injured/injured/killed, rather than the different levels of injury severity.

In any event, the magnitude of the inter-area variation in a countermeasure's potential benefits raises a question concerning the selection of the geographic regions upon which an implementation decision should be based. Assuming that in the aggregrate, countermeasure introduction is warranted, should it be inclusive of Columbus, Georgia, in light of the fact that the data projected an increase in accident injury severity within the area?

There are variations among areas in implementation costs as well. These are caused by such factors as an area's size, topography, geology, pole density, and even its political structure. Table 5-9 gives rough estimates of average implementation costs for three selected countermeasures (Reference 24). Thus, any implementation cost determined for a data collection area in this study would not be generalizable to other areas of the nation; furthermore, considering the complex nature of society and its present economic system, the costs would, at best, be accurate for a short period of time.

TABLE 5-9 - ESTIMATED COUNTERMEASURE IMPLEMENTATION COSTS

Countermeasure	Estimated Cost
Weakening Utility Poles (by drilling)	$40 - 80 per pole
Relocation of Poles*	$150,000 - 250,000 per mile
Undergrounding Cables*	$300,000 - 500,000 per mile

*Costs will obviously vary as a function of the degree of urbanization, number of poles per mile, and the number of salvagable poles.

Another aspect in the cost benefit analysis which must be addressed is that of time. The utility companies will amortize the cost of undergrounding services over a relatively long period of time; similarly, society will enjoy the beneficial effect of the countermeasure for a long - but not necessarily the same - time as well. In addition to defining the relevant time period(s), other factors such as interest rates, general inflation rates, rate of increase in medical costs, etc. must also be estimated. Unfortunately, this type of information is beyond the scope of this study.

In Section 4.2.10, it was brought out that 33.6% of struck utility poles had streetlamps attached. With this in mind, the cost of removing utility poles from the roadside would have to include the expense of installing new street lighting or the cost of having no street lighting. The estimates of these costs are beyond the scope of this study as well.

5.2 Problems Associated with Other Countermeasures

Many potential countermeasures presented in Section 2.2 pose unique problems when applying cost-benefit techniques. To illustrate these problems, the difficulties of cost-effective methods will be discussed for two possible countermeasures to the utility pole accident problem: requiring a minimum pole offset of ten feet (3 m) and decreasing the shear force necessary to break a pole (such as drilling holes through the pole).

Adopting a minimum pole offset of ten feet (3 m) requires assumptions regarding the vehicles' trajectories. Consider, for example, the case in which an automobile struck a utility pole placed one foot (.3 m) from the road edge. There are three possibilities if all the poles were ten feet (3 m) from the road edge:

- the car could miss the pole entirely and strike another roadside object, in which case, the accident would be classified as a run-off-road type

- the car could strike a pole despite the change in the roadside environment, but the severity may be different, i.e. the vehicle may have a lower impact speed. Thus, the severity distribution should be approximated by those pole accidents with a ten foot (3 m) offset.

- the countermeasure would allow the driver sufficient room/ time to regain control of the vehicle; thus, there would be no accident.

The injury and other accident related costs can be computed for each of the above conditions using Equation 5-(1). The total savings realized by the countermeasure is obtained by combining the costs for the three alternatives into one figure, which is then subtracted from the cost of pole accidents in the six areas ($13 million). Equation 5-(2) is used to combine the three alternatives.

$$\text{Combined Cost} = \sum^{3} p_i C_i \qquad 5\text{-}(2)$$

Where p_i = the probability of the i^{th} alternative, and C_i = the cost associated with the i^{th} alternative.

Estimation of the respective probabilities is, unfortunately, not yet possible, although there is a potentially viable method to accomplish it. It involves the use of trajectory simulation techniques on a sample of utility pole and run-off-road accidents; necessary inputs would include locations of all roadside objects, the immediate terrain, and sufficient other scene, vehicle, and accident information to obtain actual impact speed from accident reconstruction. The data collected in the present study, obviously, did not approach this level of detail (nor will any other study which makes extensive use of police reported data).

Another factor which must be considered in assessing the cost-benefit of moving all utility poles away from the road edge is the cost associated with run-off-road accidents which become utility pole accidents as a result of the countermeasure implementation. An example of this situation is given below in Figure 5-1.

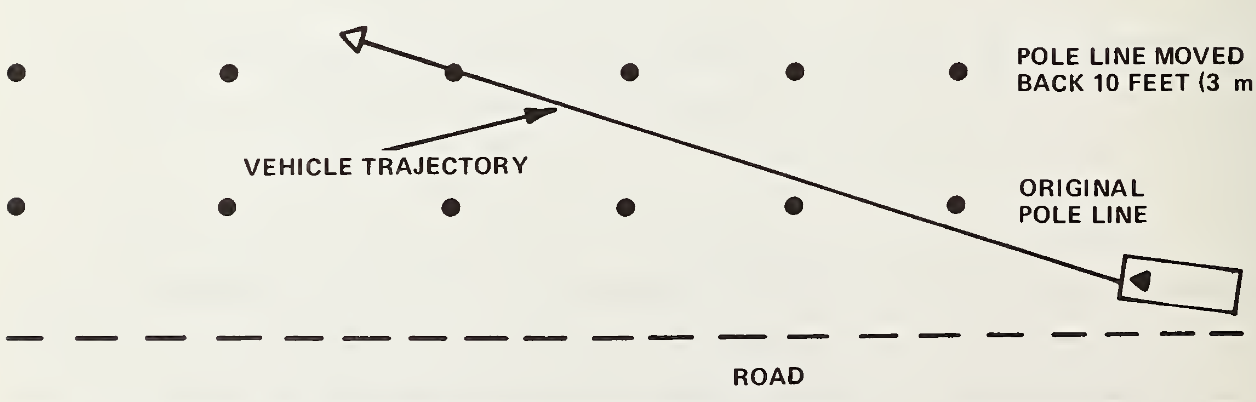

Figure 5-1 SCHEMATIC OF RUN-OFF-ROAD ACCIDENT BECOMING A UTILITY POLE ACCIDENT

Obviously, this will detract from the countermeasure's benefit and the magnitude of the effect will depend on the likelihood of the event occurring, which unfortunately, can only be estimated.

Countermeasures which reduce the impact severity of utility pole contact pose the opposite set of problems. Instead of not knowing the probabilities of pole contact, the injury distributions associated with the modified impact conditions are not known. In the case of contact with weakened or breakaway utility poles, the following events can occur:

- the vehicle's impact speed is insufficient to produce enough momentum to cause the pole to break away; the resultant injury distribution would then be similar to one for low speed utility pole accidents (the upper limit of impact speed would obviously be a function of the pole design,

- the pole would break away, and the vehicle would subsequently come to rest, resulting (presumably) in less severe occupant injury; the injury distribution would be dependent upon the design specification of the pole,

- the pole would break away, but additional contacts (or rollovers - see Section 4.4.2) could occur; thus additional, non-pole related injuries could be sustained.

One possible solution to the problem would be to predict occupant injury from accident parameters, i.e., impact speed and orientation, restraint use, etc. Unfortunately, such a process is not yet possible, since very little work has been done to associate measures of accident severity* with injury severity. If there were such techniques, the knowledge of the shear

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*The National Crash Severity Study (NCSS) presently being conducted by the NHTSA is attempting to relate occupant injury severity with the change in velocity (ΔV) experienced in the passenger compartment.

properties of the redesigned utility poles and the impact velocity could be utilized to predict the ΔV sustained under the improved conditions. As discussed previously, however, the data collected in this study was not sufficiently detailed for accident reconstruction. Also, as discussed in Section 5.1, the injury severity code used in the present study does not sufficiently discriminate among the various levels of injury severity to allow the application of such an approach.

5.3 Summary

It should be obvious that this study will not use cost-benefit analysis to recommend for or against implementation of any particular countermeasure; rather, it is hoped that the discussion will be useful at the time an implementation decision is to be made for a given area. Moreover, the study can provide pre-countermeasure injury distributions and the repair costs associated with the utility pole problem. It would seem that the cost-to-repair figures can be readily adjusted for inflation, thereby providing a relatively accurate estimate for the future; however, it is also suggested, that up-to-date societal injury costs be applied to the pole-accident injury distributions, instead of adjusting the figures cited in this report.

The following statements related to the cost-benefits of utility pole countermeasures can be made:

- the mean cost of a utility pole accident in the run-off-road sample areas was $9,978

- the above figure included, on the average, $161 per accident necessary to repair damage sustained by the utility company

- the mean cost of a run-off-road accident was $5,900; this presumably is the lower bound for the costs associated with single vehicle accidents; thus, to be cost-effective, a countermeasure cannot cost more than $4,078 per expected utility pole.

- utility pole accidents cost society $34,055,107 (an average of $10,414 per accident) in the twenty data collection areas alone; this included $28,152,766 in injury related expenses, $5,529,579 in other accident related costs, and $372,762 in cost-to-repair damaged utility poles (approximately $177 per utility pole accident).

6. CONCLUSIONS

6.1 Utility Pole Accident Frequency

1. Utility poles were the most frequent object struck in urban areas accounting for 21.1 percent of objects struck compared to 11.1 percent for trees, the next most substantial object struck.

2. National figures show that single vehicle accidents represented 10.4 percent of all urban accidents, which means that 2.2 percent of all urban accidents involve impacts with utility poles.

3. For the six urban-suburban areas where run-off-road accidents were collected, the relative proportion of utility pole accidents ranged from a high of 40.7 percent in Macon, Georgia to a low of 15.2 percent in San Diego, California. The majority of this range can be explained by the relative pole density of each area - the proportion of utility pole accidents decreased as a logarithmic function of the proportion of run-off-road accidents that occurred where there were no poles.

4. Utility pole accidents are a subset of single vehicle accidents, such that parameters describing general accident characteristics showed little difference, i.e., hour/day/week/month, vehicle age and type, light/road/weather conditions, driver age/sex/drinking involvement/condition, occupancy, etc. showed little variation between utility pole and run-off-road accidents. Exceptions included: utility pole accidents were underrepresented on ice/snow covered roads; drivers had fewer moving violations in utility pole accidents; situations where the driver fell asleep were overrepresented.

5. Differences between utility pole and run-off-road accidents in general appeared in parameters which affected or described vehicle departure attitudes and roadside environment.

6. For parameters describing general roadway characteristics, overrepresentation of utility pole accidents tended to be linked to situations with higher than average pole densities. Road type and width, ADT, and speed limit were all highly correlated, such that road width and speed limit were sufficient to characterize the road system. Utility pole accidents were overrepresented on roads with speed limits of 30-40 MPH (48-64 KPH) and widths of 30-50 feet (9-15 m), the result of higher than average pole densities. Roads of widths less than 30 feet (9 m) in general had high pole densities but did not have high pole accident frequencies because of lower travel speeds (as estimated by speed limit).

7. Utility pole accidents were overrepresented on two lane roads; however, 80 percent of all accidents sampled were on these roads.

8. Utility pole accidents were overrepresented on roads with medians (perhaps the result of higher travel speeds) although the number of accidents on roads with medians was small.

9. Utility pole accidents were overrepresented on roads without shoulders and decreased as shoulder width increased. However, this was the result of increased offset rather than the presence of a shoulder

10. While utility poles were overrepresented at intersections (relative to run-off-road accidents), intersections did not play an important role in pole accidents. Only 25 percent of all pole accidents occurred at an intersection; furthermore, of this 25 percent, the intersection was judged to be incidental to the accident in the majority of the cases.

11. Travel speed and speed limit were highly correlated. The proportion of utility pole accidents increased with travel speed, however, travel speed was unknown in 72 percent of the cases, so that the results must be treated cautiously. The proportion of utility pole accidents also increased with speed limit up to 40 MPH (64 KPH) but then decreased thereafter. This appeared to be the result of variations in pole density which overshadowed any speed effect.

12. Utility pole accidents were more severe than run-off-road accidents as evidenced by a higher frequency of frontal impacts and disabled vehicles (towed from the scene).

13. Although departure angle could not be measured, a number of trends suggested that departure angles were shallower for utility pole accidents:

    (i) Utility pole accidents were overrepresented on straight roads although the effect was less pronounced for wet, snow-covered, or icy roads than for dry roads.

    (ii) Utility pole accidents were overrepresented on left curves compared to right curves. Surprisingly, in both situations adverse weather conditions tended to increase utility pole involvement.

    (iii) Irrespective of whether the accident occurred on a straight road or a curve, utility pole accident involvement was higher for right side than for left side departures.

    (iv) A greater proportion of vehicles departed from the lane nearest the struck object in utility pole collisions.

    (v) Departure speeds were marginally higher for utility pole accidents.

14. Utility pole accidents were overrepresented on level roads with a consequent underrepresentation on grades.

15. Utility pole accident frequency was very dependent on pole density, i.e., both the presence of poles and their relative spacing. Forty-three percent of non-pole accidents occurred where there were single or no poles present. The proportion of utility pole accidents decreased as pole spacing increased.

16. Mean departure angle was estimated as a function of pole spacing; departure angle was surprisingly constant, ranging from between 5.1° and 8.7°.

17. The proportion of utility pole accidents decreased with increasing utility pole offset. Fifty percent of all utility pole accidents occurred with an offset of 4 feet (1.2 m) or less, whereas, fifty percent of vehicles in run-off-road accidents came to rest within 10 feet (3 m) of the road edge - 74 percent of all struck poles were within this distance.

18. The relative importance of the different independent variables in predicting the dependent variable - probability of a utility pole accident given a single vehicle accident - was determined using a stepwise multiple regression program. "Number of poles" was the overriding factor in predicting utility pole accidents, explaining 25.7 percent of the variance. "Offset" was entered second, explaining a further 0.6 percent of the variance. The remaining parameters entered described road type or were related to departure attitude, road grade entered as Step 3, road path Step 4, and speed limit Step 5, explaining an additional 0.5, 0.3, and 0.3 percent of the variance respectively. If better measures of departure attitude, i.e. departure angle and speed, had been available, a higher proportion of variance would be explained.

6.2 Utility Pole Accident Severity

1. Utility pole accidents had, with the exception of rollovers, the highest probability of injury of all single vehicle accidents; 49.7 percent of utility pole accidents were injury producing.

2. Next to bridges, utility pole accidents had the highest non-rollover fatality rate of 0.8 percent.

3. The results of the present study in terms of the relative injury severity of utility pole accidents agreed with previous work (References 4-8). For example, Huelke and Gikas reported trees and utility poles were involved in 52.2 percent of their sample of fatal accidents; the corresponding figure from the present study was 53.3 percent.

4. Pole offset and spacing did not appear to affect the severity of utility pole accidents.

5. Higher impact speeds - as estimated by the prevailing speed limit - generally increased the overall severity of a utility pole accident.

6. The stiffness of the contacted utility pole - approximated by its circumference - had three interrelated effects on accident severity; these conclusions are based on accidents where the poles were known not to have been knocked down.

   (i) The probability of injury in a utility pole accident was independent of pole circumference for poles greater than 30 inches in circumference; below that, the probability of injury appeared to be a quadratic function of pole circumference.

   (ii) The number of fatal injuries attributable to pole contact increased with the stiffness of the struck pole.

(iii) The occurrence of rollover after utility pole contact was more frequent with thinner poles (rollover accidents were generally more severe than pole accidents).

6.3 Utility Pole Accident Costs

1. The estimated societal cost of a utility pole accident in 1975 was $10,414, which included $177 per accident for the cost-to-repair the struck pole; in contrast, Newcomb and Negri (Reference 6) reported a cost of $2,740 per accident in 1970.

2. The mean cost of a utility pole accident in the run-off-road sample areas was $9,978, including $161 in pole repair costs.

3. Run-off-road accidents were estimated to cost, on the average, $5,900 (Newcomb and Negri estimated $2,354); presumably this is the lower bound for the cost of a "pole accident" after introduction of the "ideal" countermeasure.

6.4 Countermeasures

1. To be warranted, a countermeasure should cost no more than $4,078 for each expected pole accident over the countermeasure's lifetime.

2. Countermeasures which increase the visibility of utility poles are unlikely to be effective. This is based on the finding that there was little difference in utility pole involvement between impaired and unimpaired drivers. This suggests that once the vehicle has left the roadway, the driver has little control over what he strikes, regardless of the object's conspicuity. The only incapacitated drivers who were overrepresented in utility pole accidents were those who had fallen asleep. Obviously, increasing a pole's visibility in these cases would have little beneficial effect.

3. Protecting all utility poles with barriers and attenuators is probably too expensive to warrant its implementation; installation at particularly dangerous sites might be a possibility, but such sites are difficult to identify since utility pole accidents were overrepresented on straight and level roads.

4. During the course of the severity analysis, it was found that less substantial (thinner) poles tended to increase the probability of subsequent rollover; obviously, this could have a detrimental effect of the benefits of countermeasures which weaken existing poles or involve installation of breakaway poles. However, generally less severe injuries may adequately compensate for the increased frequency of rollover under these conditions. It should be stressed that this result was only established for accidents where the pole was not knocked down and should be replicated with a sample of utility pole accidents which includes knockdowns.

5. Using only utility poles with a circumference which simultaneously minimizes the probabilities of injury, fatality and rollover, may be a cost-effective countermeasure, assuming such a pole has sufficient strength to remain functional.

6. Due to the high costs associated with undergrounding and moving the pole line back from the road edge, on a retrofit basis, it is unlikely that these countermeasures could prove to be cost-effective.

7. The notion of weakening poles located in places of high risk is not a particularly appealing countermeasure, due to the apparently random nature of utility pole accidents. Since they most often occurred on straight and level roads (in addition to being over-represented relative to run-off-road accidents under these conditions), potential sites for modification would include a large proportion of the entire road system. Wolfe, et al.'s (Reference 12) suggestion to weaken alternate poles may be a viable solution. However, four

issues need to be addressed in considering such a proposal; specifically: i) a more precise determination of the additional risk of rollover, ii) legal accountability for weakening one pole that was not struck and leaving unmodified another that was, iii) the integrity of the power line after an unweakened pole (between two weakened ones) is knocked down, and iv) the degree of compliance such a system of poles would have with present safety standards.

8. Undergrounding new power lines or routing them between backyards should be strongly encouraged wherever possible; it is interesting to note the utility companies in the areas which had the lowest proportion of utility pole accidents in single vehicle accidents, also followed such a policy. Where the above countermeasures are not possible, good judgement (and careful planning) should be exercised in erecting power lines along roadways. For instance, the utility pole accident problem can be partially alleviated by confining power lines to only one side of the road; necessary support poles on the opposite side should be located as far away as possible from the road edge. Additional benefits can be realized by running power lines along the insides of curves, since it was shown that vehicles exited the roadway more frequently on the outside of curves.

9. The data showed that perhaps the most cost-effective countermeasure to the utility pole accident problem is restraint use. Since seat belts and/or shoulder harnesses are already installed in most passenger vehicles, implementation costs would be negligible. Seat belts would also enhance the effectiveness of any other countermeasure developed to mitigate this problem. Furthermore, the benefits of restraint use are not specific to utility pole accidents, but rather to all aspects of highway safety.

6.5 Future Work

Limitations of the present study, in general, result from lack of detail in the accident reporting. A number of questions could be better resolved if reporting detail were improved. For example: additional countermeasures might be identified if better classification of injuries, in combination with the vehicle dynamics, were identified; the effect of pole circumference on injury severity and probability of subsequent rollover should be established using all pole accidents, i.e. include knockdown. Obviously, this type of detail would require on-scene or follow-up type investigations. However, these issues could be resolved with a fairly small data sample and would not require a sample of the size of the present study.

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The Appendices are available upon request from the Environmental Division, HRS-43, Federal Highway Administration, Washington, D.C., 20590.

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FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

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