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Breakaway Utility Poles

Feasibility of Energy Absorbing Utility Pole Installations in New Jersey

Final Report
December 2007

Submitted by

H. Clay Gabler
Douglas J. Gabauer
Virginia Tech
Department of Mechanical Engineering

William T. Riddell
Rowan University
Department of Civil and Environmental Engineering

NJDOT Research Project Manager
Edward Kondrath

In cooperation with

New Jersey
Department of Transportation
Bureau of Research
Trenton, NJ 08625

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16. Abstract

Vehicle impacts with utility poles are one of the most unforgiving types of crashes to which motorists are exposed. In New Jersey, nearly 200 vehicle occupants died on state highways after crashes into utility poles between the years 2000 to 2003. This report describes the findings of a research program to reduce the fatalities and injuries that result from traffic crashes with utility poles in New Jersey. The specific objective is to develop recommended procedures which will enable a designer to select the countermeasures which are most appropriate for reducing the frequency or severity of vehicle impacts with utility poles at a specific site.

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1. Summary

Problem

Each year in New Jersey, approximately 10,000 vehicle occupants are involved in a utility pole crash. Annually, these collisions result in 50-60 deaths and 200 persons who are incapacitated. The State of New Jersey has a particularly urgent utility pole problem. New Jersey is only 22nd among the states in number of traffic fatalities, but ranks 8th in number of fatalities resulting from utility pole impacts. In terms of utility pole crash fatalities as a percentage of all fatalities, NJ ranks 4th among all states.

Objective

The goal of this research program was to investigate and recommend methods to mitigate the fatalities and injuries that result from traffic crashes with utility poles in New Jersey.

Current National Practices

Both AASHTO and TRB have established recommended guidelines and practices for reducing utility pole crash frequency and severity: Utility pole crash mitigation strategies include moving the utilities underground, increasing the lateral offset of the poles, shielding with roadside safety hardware, breakaway poles, and delineation. Selection of a particular strategy should be site-dependent based upon an assessment of both the historical and predicted future crash risk.

Performance of Breakaway or Energy Absorbing Utility Poles

Breakaway or energy absorbing utility poles are recommended for high risk crash locations where pole relocation or underground line placement is not feasible. In field trials, steel-reinforced breakaway timber poles were found to be resistant to high winds, less expensive to repair than traditional poles, and not highly susceptible to environmental degradation. New fiberglass-reinforced composite utility poles appear to offer significant benefits over the traditional wooden utility poles, especially with respect to life-cycle issues and crashworthiness.

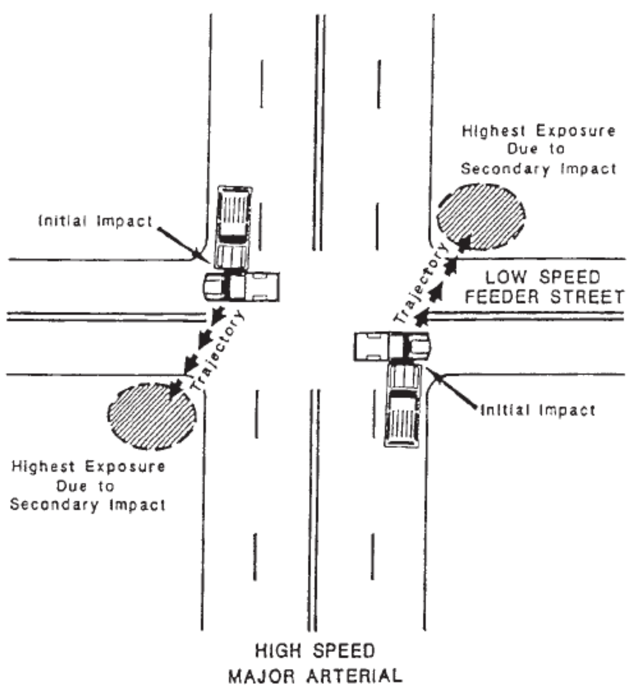
Breakaway or energy-absorbing poles are less dangerous to drivers than traditional timber poles, but are also more expensive. This research program has developed a methodology for evaluating the cost vs. benefit of installing these more benign utility pole designs, and presents recommendations for their use based upon site characteristics.

Review of New Jersey Utility Accommodation Policy

The New Jersey Utilities Accommodation policy focuses solely on pole placement for new construction or reconstruction. In general, the NJ Accommodation policy follows national guidelines closely, if not verbatim. There are however two important exceptions which should be considered for modification:

1) Lack of policy for pole placement at or near intersections. TRB State of the Art Report Number 9 describes special considerations for utility pole placement under various site-specific conditions. This section of the TRB State of the Art Report is reproduced in appendix B. Most of the conditions described in the State of the Art report are addressed in the New Jersey Accommodation Policy. However, there is a specific recommendation to reduce secondary collisions with utility poles near intersection zones that is not addressed in the New Jersey Accommodation Policy. Specifically, include the following paragraph and figure:

> Where critical traffic conflicts can be foreseen, especially at intersections of high-speed roadways, pole placement may be designed to avoid the most critical secondary collisions. For example, if the major roadway is in a north–south direction and the minor roadway is east–west, the most critical quadrants for a secondary collision (collision of a vehicle with a pole after an initial two-vehicle collision) are the northeast and southwest quadrants. Thus, the preferred placement for poles at this intersection would be in the northwest and/or southeast quadrants, as indicated in the figure below.



Intersection zones having highest exposure to secondary collisions [Ref: TRB SAR 9].

2) No Formal Mechanism to Remediate Existing High Risk Sites. One important strategy for reducing utility pole fatalities is to consider the mitigation of existing high risk poles or sites. There is currently no mechanism in New Jersey to remediate high risk utility pole sites which are not undergoing reconstruction. The Fixed Object Program identifies utility pole (or adjacent poles) that have been struck three times in three years. We are not aware of any formal program to act on knowledge of these high risk sites unless the site is scheduled for reconstruction. An additional check for utility pole hazards is explicitly called for in the New Jersey Highway Design Manual for new construction or reconstruction. Again, these checks are not applied to existing high risk sites not planned for reconstruction.

Recommendations for Implementation

Based upon our investigation of New Jersey crash experience in utility pole collisions, we make the following recommendations to reduce both the number of crashes and severity of crashes into utility poles.

1. Initiate a Formal Program to Mitigate Existing High Risk Utility Pole Crash Sites. AASHTO and TRB recommend an ongoing comprehensive crash reduction program periodically analyzes crash data to identify, prioritize, and mitigate locations where pole crash risk is high. New Jersey should adopt this national guideline, and initiate a formalized program to regularly identify and remediate high risk utility pole crash sites. Remediation should not be limited to sites planned for or undergoing reconstruction.

2. Update the NJ Utility Pole Guidelines to reflect current national best practices. The New Jersey Utility Accommodation Policy and Roadway Design Guidelines should be updated to reflect current national best practices as recommended by AASHTO and TRB. Specifically,

    - Adopt a policy that is specific to Utility Poles for identifying high-risk sites and mitigating these. The policy should consider social cost and accident frequency. The Bureau of Safety Programs should monitor accident data and develop a list of high-risk sites each year.

    - Require designers to consider cost-benefit analysis based on historical accident experience using both a societal cost metric and crash frequency when considering how much right of way to purchase for highway construction or reconstruction.

    - Adopt National Guidelines for placement of poles near intersections.

3. Investigate US Highway 22 as a candidate for utility pole crash mitigation. Using four different ranking schemes to identify high risk utility pole impact areas, several locations along U.S. Highway 22 consistently ranked in the top 20 high risk locations in New Jersey. Based on this analysis and site visits, we recommend that this highway, especially the stretch between MP 46 and MP 56, be considered for remediation of the pole impact problem.

4. Install Shakespeare composite energy absorbing poles as a new technology demonstration project in New Jersey. We recommend that Shakespeare composite energy absorbing poles be installed as a new technology demonstration project for a limited number of sites with a utility pole crash problem. Appropriate sites should be selected using the cost-benefit methodology developed as part of this research effort.

5. Develop NJDOT design standard to allow breakaway utility poles to be installed at high risk locations. Upon the completion of a successful demonstration project, consider revising NJDOT Design Manual to Install Breakaway or Energy-Absorbing Pole Installations at high risk locations, which could include horizontal curves with a safe speed less than the posted speed; or where design exceptions have been approved for substandard radius, cross slope, and shoulder width; or high posted speed limits with small pole offsets where utility companies are replacing poles that have been previously hit.

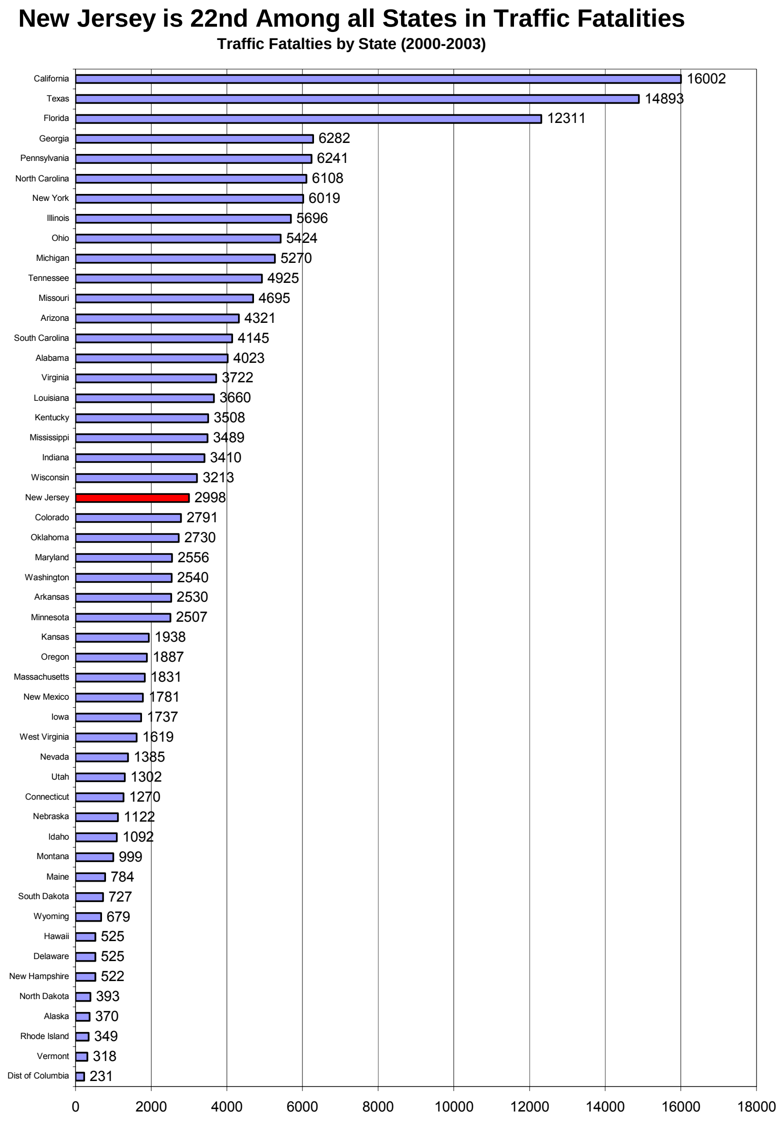
2. Introduction and Background

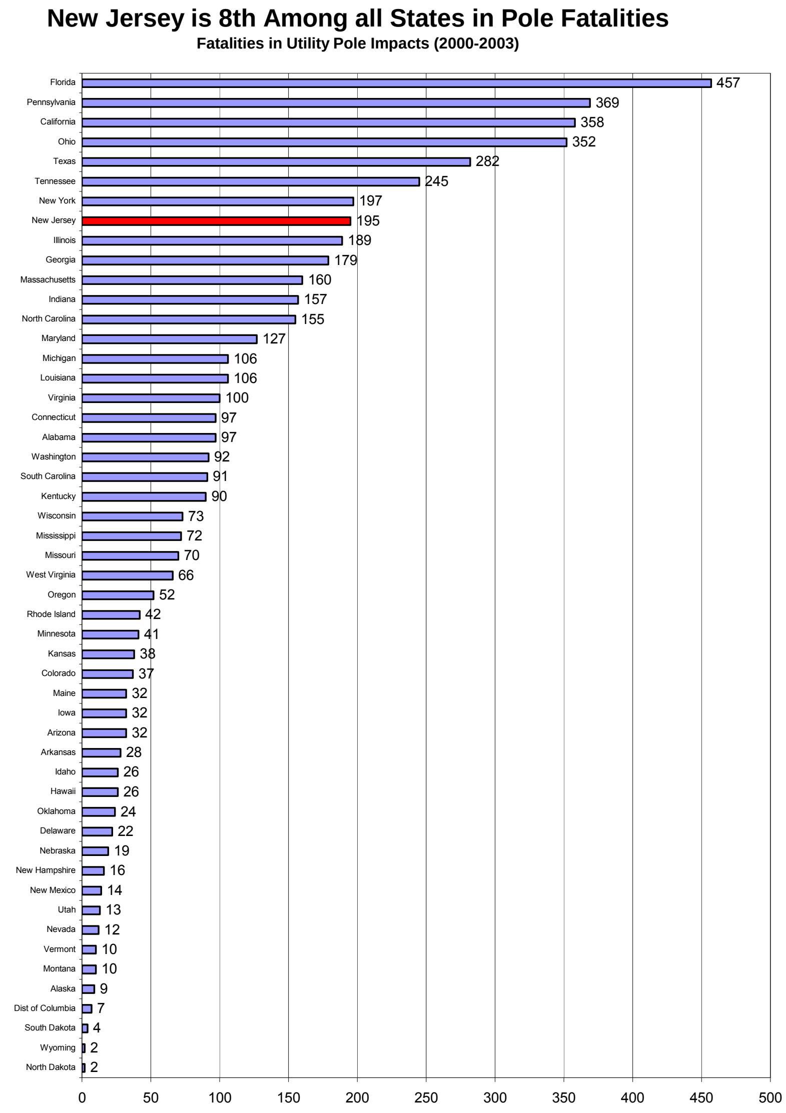
Vehicle impacts with utility poles are one of the most unforgiving types of crashes to which motorists are exposed. In 2003, the most recent year of statistics available, there were over 1,200 fatalities in the U.S. from impacts with utility poles [1]. In New Jersey, nearly 200 vehicle occupants died after crashes into utility poles from the years 2000 to 2003. The rigid design of a utility pole, which allows the pole to survive the high winds of a storm, unfortunately makes the pole particularly unyielding in a traffic accident. Vehicles which undergo pole impacts suffer large, frequently devastating, deformation of the occupant compartment which too frequently leads to serious or fatal injuries.

Figure 1. Impacts with Utility Poles have resulted in the death of over 200 vehicle occupants in New Jersey since 2000

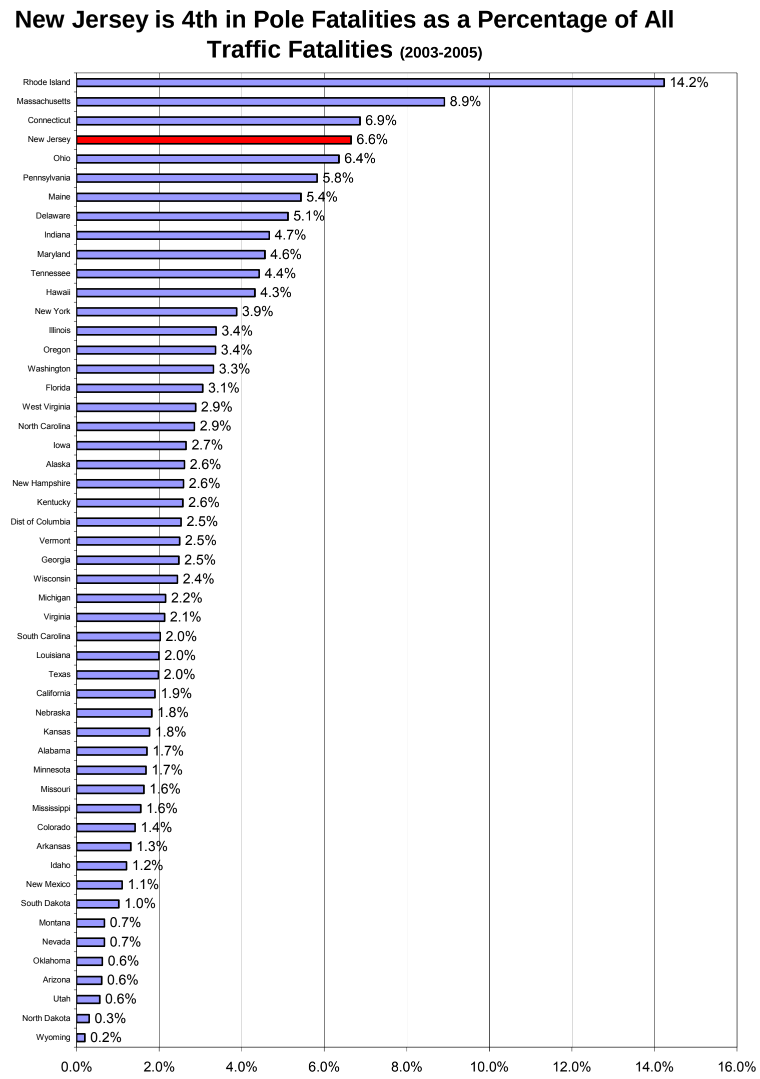
The State of New Jersey has a particularly urgent utility pole problem. As shown in the figures which follow, New Jersey is only 22nd among the states in number of traffic fatalities, but surprisingly ranks 8th in number of fatals resulting from utility pole impacts. Our analysis was based upon examination of U.S. fatality counts extracted from the Fatality Analysis Reporting System (FARS) 2000-2003. When compared with other states, utility pole impacts represent an unusually high percentage of traffic fatalities in New Jersey.

The Problem - Utility Pole Crashes in New Jersey





The Problem – Utility Pole Crashes in New Jersey



3. Objective

The goal of this research program is to investigate and recommend methods to mitigate the fatalities and injuries that result from traffic crashes with utility poles in New Jersey. The specific objective is to develop recommended procedures which will enable a designer to select the countermeasures which are most appropriate for reducing the frequency or severity of vehicle impacts with utility poles at a specific site.

4. Utility Pole Collisions and Countermeasures: Literature Review

Summary

This review examines documented national and state experience regarding utility pole collisions, factors contributing to those collisions, and potential countermeasures.

Several researchers have attempted to quantify and develop models to describe utility pole collisions. Like tree collisions, utility pole impacts are found to be more hazardous than impacts with other objects. Based on published crash statistics, approximately 2 percent of utility pole crashes result in fatality whereas roughly 50 percent result in some degree of occupant injury. Traffic volume, pole offset and pole density are factors significantly linked to utility pole collision frequency. Other contributing factors identified in the literature include roadway class, shoulder width, lighting, speed limit, and horizontal curvature. A statistical model has been identified that predicts utility pole collision frequency based on traffic volume, pole offset, and pole density.

Numerous utility pole collision countermeasures are available and include placing utility lines underground, increasing pole offset, increasing pole spacing, shielding poles with roadside safety devices, and delineating the pole. Similar to sign supports, breakaway devices can also be employed to lessen the severity of a utility pole impact. In field trials, steel-reinforced breakaway timber poles have been found to be resistant to high winds, less expensive to repair than traditional poles, and did not exhibit problems with environmental degradation. New fiberglass-reinforced composite utility poles appear to offer significant benefits over the traditional wooden utility poles and even steel-reinforced safety poles.

Various states, cities, and even some electric companies have undertaken initiatives to reduce utility pole collisions. The general approach is to first eliminate historically hazardous locations, implement placement guidelines, and then continue to monitor crash statistics. The most effective programs are those that elicit utility industry cooperation. Successful cooperative initiatives include PennDOT's cost sharing with utility owners, the partnership of Jacksonville Electric Authority and TTI, and the Clear Roadside Committee in Georgia.

In terms of cost effectiveness, previous studies detail procedures to evaluate different utility pole collision countermeasures and present results based on hypothetical roadways/scenarios. In general, a given countermeasure must be evaluated on a site-by-site basis. Tort liability appears to be an increasing trend in the United States. To reduce liability in utility pole tort suits, state DOTs should utilize a "hold-harmless" clause when granting utility permits, purchase insurance, and develop methods to classify and mitigate utility hazards.

Objective

The purpose of this chapter is to examine documented national and state experience regarding utility pole collisions, factors contributing to those collisions, and potential countermeasures.

Figure 2 Vehicle Damage Caused by Utility Pole Collision

Utility Pole Collision Scope and Characteristics

Crash Statistics

Dating back as far as the mid-1970's, researchers have quantified the utility pole collision problem. An early study by Graf et al. [2], suggests that fatal utility pole collisions result in 1 to 8 percent of the total vehicular fatalities but account for roughly 15 percent of the total number of fixed object fatalities. The investigation used 2 years of police-reported crash data (1971-1972) from a total of 5 different states (Kansas, Massachusetts, Oklahoma, Michigan, and Pennsylvania). No mention is made of whether the analyzed data is nationally representative. The authors do stress the importance of more comprehensive crash data to further quantify the utility pole collision problem.

Jones and Baum [3] present what appears to be the first attempt to quantify the effect of roadway and pole characteristics on utility pole collisions. The researchers used 1975 police-reported run-off-road crash data from 20 urban-suburban areas; site visits were conducted for each utility pole accident site. Based on the available data, utility poles were the most frequently struck object and were second to rollovers in terms of percentage of injury crashes. An overrepresentation of utility pole accidents was found on roadways where the speed limit was 30 to 40 mph and the roadway width was 30 to 50 feet. Note, however, that these road characteristics also corresponded with the highest utility pole densities. Jones and Baum also found increases in vehicle travel speed, decreases in pole spacing, and decreases in pole offset to correlate with an increased probability of a utility pole collision. Based on a stepwise multiple regression analysis, the pole density was found to explain roughly 25 percent of the variance, followed by lateral offset (explains 0.6 percent of the variance), road grade (explains 0.5 percent of the variance), and speed limit (explains 0.3 percent of the variation). The authors suggest that better characterization of roadway departure (vehicle angle and speed) may allow for a higher proportion of the variance to be explained by these variables.

Jones [4] presents utility pole crash statistics over a six-month period in 1970 at four locations within the Knoxville, Tennessee area. The researchers found approximately 5 percent of the 37 collisions studied were fatal and approximately half resulted in occupant injury. These statistics are not probed further, as the main objective of the study was to discuss problems between highway and utility authorities (and potential solutions) in light of a before-and-after study.

Perhaps the most comprehensive pole study was performed by Mak and Mason [5] in 1980. A large number of pole types were examined in the study including sign posts, luminaires, utility poles, and breakaway devices. The objectives of this study were to quantify the extent of the pole collision problem, determine collision and severity rates for pole crashes, determine vehicle and highway-related characteristics of pole collisions, and evaluate the cost effectiveness of breakaway devices. Data was collected primarily from Texas and Kentucky from January 1976 to October 1979. A large portion of the analysis was based on 1,014 in-depth studies of specific pole collisions that include detailed data on roadway, vehicle and occupants. Major findings of the study are as follows:

- Utility poles are found to be the most frequently struck type of pole, comprising roughly two-thirds of pole crashes.
- The authors found nearly identical crash rates on urban and rural roadways (3.4 pole collisions per billion vehicle-pole interactions) but note that pole collisions are primarily an urban problem (due to the high exposure).
- Pole collision sites were found to have higher pole densities and lesser median lateral offsets than the population average.
- Collisions with utility poles were found to have the highest frequency of K+A (fatal and incapacitating) injuries (7.4%).
- Probability of severe to fatal injury (AIS≥3) for a utility pole collision is less than 10 percent for impact speeds below 32 mph. However, at impact speeds of 50 mph, the probability jumps to 50 percent.
- Occupants in smaller vehicles subjected to a utility pole collision were found to be at higher risk for injury than those occupants in a larger vehicle.

Good et al. [6] retrospectively examined 879 utility pole collisions (31 fatalities and 374 injured persons) in the area of Melbourne, Australia. The researchers conducted site and vehicle inspections for each case during the 8 month study period from July 1976 to March 1977. Utility pole collisions were estimated to account for 45 percent of fatal fixed-object crashes and 52 percent of injury fixed-object crashes. Despite 70 percent of the crashes resulting only in property damage, utility pole crash severity (number of fatal crashes per 100 injury crashes) is found to be 1.5 times greater than the average severity of all collisions. More than two-thirds of the crashes occurred at non-intersection sites and half involved some form of horizontal curvature. The researchers also found that pole crashes are 4 times more likely on wet roadways. In terms of vehicle orientation, approximately 79 percent were frontal impacts. However, side impacts tended to result in more severe injuries. Life threatening injuries in the frontal impact mode were evenly distributed between head, neck, chest and abdomen injuries, while the side impact mode had higher concentrations of head, neck, and chest injuries.

Zegeer et al. [7] studied roadside crashes on approximately 5,000 miles of two-lane rural roads in seven different states (Alabama, Michigan, Montana, North Carolina, Utah, Washington, and West Virginia). In most cases, data was collected between 1980 and 1985. Although the purpose of the study was to characterize the influence of roadway factors that affect roadway safety and estimate the benefits of roadside safety improvements, the authors present general crash statistics and findings as well. Trees and utility poles were found to be the most often struck roadside objects. On roadways with less than 4,000 vehicles per day, trees are the most common object struck while utility poles are most frequently struck for average daily traffic in excess of 4,000. Also, similar to the finding of Mak and Mason [5], utility poles were found to be associated with highest percentage of severe (injury + fatal) roadside accidents.

Turner and Barnett [8] present pole collision statistics in an effort to establish utility pole placement guidelines for the city of Huntsville, Alabama. From January 1985 through June 1987, the researchers investigated 458 police-reported utility pole collisions. The distribution of injury outcomes for utility pole collisions were 1.6 percent fatal, 39.7 percent injury and the remaining 58.7 percent property damage only. In contrast to the Australian study [6], the researchers did not find wet roadway to be a significant factor. More than half of the collisions occurred on straight and level roadways. However, curves are found to be overrepresented by a ratio of 6 to 1 (5% of roadways are curved but account for 30% of utility crashes). The majority of collisions (roughly 90%) were found to occur within 10 feet of the edge of the traveled way

Troxel et al. [9] examine side impacts with roadside objects using national level crash data, including FARS (1980-1985) and NASS (1982-1985). One major finding is that most serious injuries are caused by tall, narrow, rigid objects like trees and utility poles. In the side impact mode, the authors find that trees are the most frequently struck object with utility poles ranking second. Risk of injury is not found to vary greatly as a function of vehicle mass and the most harmful impacts are found to be those where the occupant compartment is directly impacted.

Allen and Weiss [10] investigated relative risk of fixed object collisions in Pennsylvania using police reported data that is linked to emergency medical services data. Of the total number of utility pole collisions, 0.8 percent were found to be fatal, 5.1 percent were found to result in “major injury”, while exactly half resulted in some injury. In addition, victims of utility pole collisions were found to be about 10 percent more likely to be fatally injured (compared to all other fixed objects) and 50 percent more likely to suffer a major injury. Trees were the only other fixed object consistently found to pose a greater risk to vehicle occupants than utility poles. For single vehicle tree collisions, 1.8 percent were found to be fatal, 7.1 percent were found to result in “major injury”, while roughly 45 percent resulted in some form of occupant injury.

Marquis [11] analyzed Maine crash data between 1994 and 1998 to characterize utility pole impacts. A total of 7,544 utility pole crashes resulted in 54 fatalities and 4,077 injuries. Fatal utility pole collisions are found to be over-represented in rural areas (74 percent of crashes occur but 87 percent of fatalities) and curved roadways (39 percent of crashes but 59 percent of fatalities). Young male drivers (age 16 to 25) are found to account for 41 percent of utility pole collisions. In approximately half of the utility pole collisions, either excessive speed or driver inattention is reported as primary contributing causes. A unique attribute to this study is the use of the Automated Road Analyzer (ARAN), which is essentially a vehicle-mounted wide angle camera used to capture right-of-way video data. This video data was analyzed for roughly 2,000 of the utility pole impacts in the study period. Major findings from this analysis included identification of hazardous pole locations (e.g. poles in medians, islands, across from T intersections, and on the roadway side of the curb) and that the number of utility pole collisions was significantly less where pole offsets were greater than 14 feet and 8 feet in rural and urban areas, respectively.

As part of an effort to reduce vehicular fatal and injury-producing collisions in the state of Alabama, Lindly [12] presented statistics on utility pole crashes. An examination of crash data from 1996 to 2000 suggested an overrepresentation of utility pole fatalities on state roadways (1 percent of crashes accounting for 2.4 percent of fatalities). Consistent with Mak and Mason [5], a higher proportion of utility pole collisions were found to occur on mainline sections rather than at intersections. One interesting finding was that police-reported crash data was not usually sufficient to pinpoint the exact pole where the collision occurred. According to the researchers, the police reports typically provided only a coarse milepost number and not enough nearby landmarks on the crash scene diagram to locate the pole precisely.

Holdridge et al. [13] investigated the performance of roadside hardware on the entire urban State Route system in Washington State using various statistical analyses. Although the main objective was to determine the factors that significantly affected the crash severity of crashes into roadside hardware, limited statistics were presented with respect to utility poles and poles in general.

Collisions into poles of all types were found to represent roughly 9 percent of the total crashes while 0.71 percent and 39 percent of the collisions resulted in fatality and injury, respectively (presumably lower due to the inclusion of all pole types).

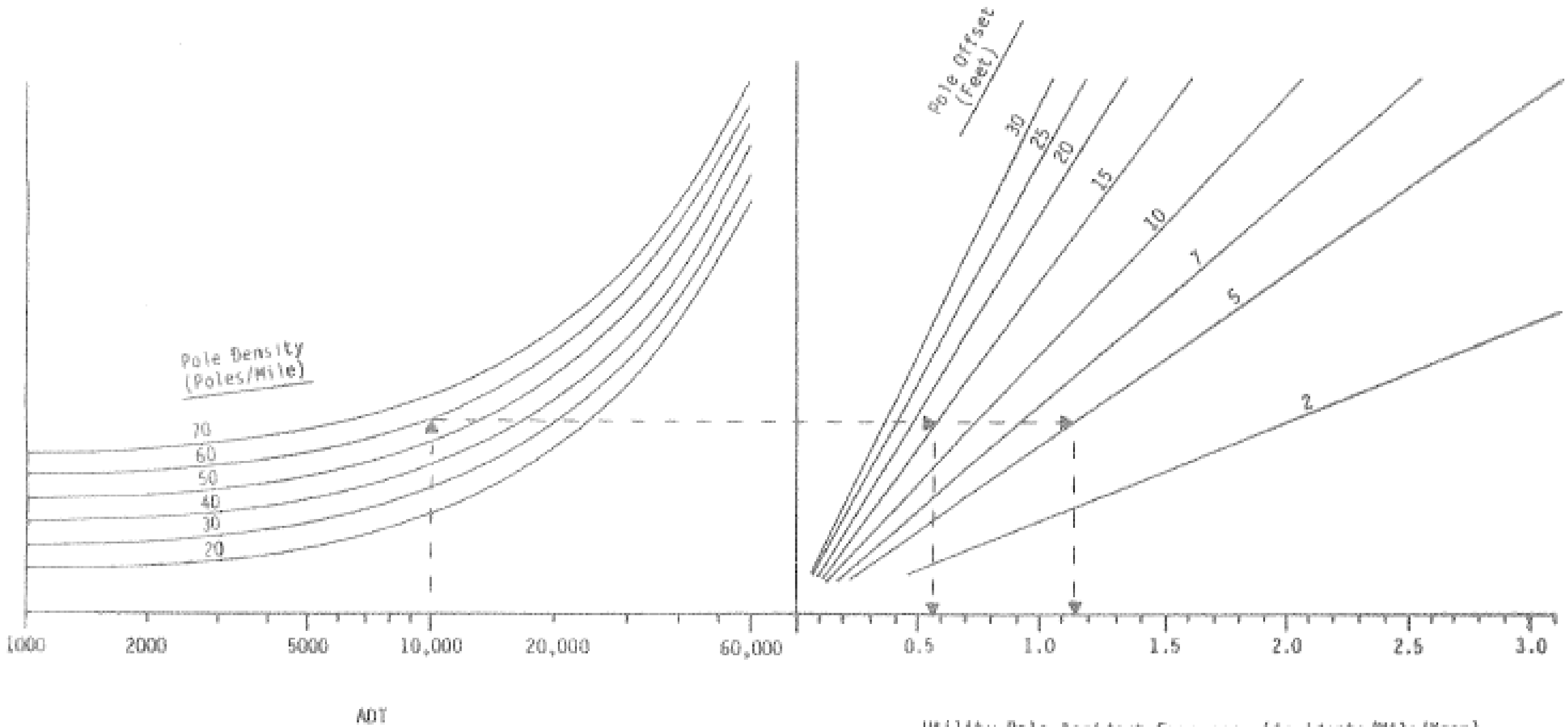
A table summarizing crash statistics related to utility pole collisions can be found in the Appendix.

Contributing Characteristics and Statistical Modeling

Zegeer and Parker [14] presented one of the first efforts to correlate roadway and traffic characteristics with the frequency and severity of utility pole collisions. Data were collected on 1,534 sections of roadway encompassing roughly 2500 miles of roadway in four states (North Carolina, Michigan, Colorado, and Washington). The researchers collected police accident records (between 5 and 10 years of data depending on state), photologs and conducted site visits (in some cases) to determine the roadway characteristics as well as utility pole accident experience for the sampled road sections. The overall accident rate for the collected data was 16.61 utility pole accidents per hundred million vehicle miles (acc/HMVM), which is close to the value of 16 acc/HMVM presented by Mak and Mason [5]. The distribution of injury outcomes for utility pole collisions were 1.0 percent fatal, 46.3 percent injury and 52.7 percent property damage only. These values match closely with the values of 1.6, 39.7, and 58.7 (fatal, injury and property damage only, respectively) reported by Turner and Barnett [8]. Statistical methods, including analysis of variance, analysis of covariance, correlation analysis, and contingency table analysis were used to analyze the available data. Based on the analysis, traffic volume, pole offset and pole density was found to significantly impact utility pole collision frequency. Controlling for these three primary variables, other significant factors (to a lesser extent) are roadway class, shoulder width, horizontal curvature, roadway lighting and speed limit. A contingency table analysis revealed that higher severity collisions were associated with wooden poles than metal poles (presumably because most of the metal poles were frangible base luminaires) and that speed limit has no significant effect on severity. Note, however, that the degree of injury was coarser than the KABCO scale, perhaps partially explaining the unexpected result.

Another result was the development of a multiplicative model to predict utility pole accident frequency (acc/mi/yr) as a function of traffic volume, pole density and pole offset. The model and associated nomograph are shown below in Figure 3. Based on tests using the available data, the model is found to be a reasonably good predictor within the specified range of input values: ADT from 1,000 to 60,000, pole offsets from 2 to 30 feet, and pole densities of 10 to 90 poles per mile. Note that the developed model was validated against independent roadway sections from four different states and that the reported r^2 value is 0.63.

Acc/Mi/Yr = [9.84 x 10^{-5} (ADT) + 0.0354 (Density) / (Offset)$^{0.6}$] - 0.04



Note:

1 foot = 0.3 meter
1 pole/mile = 0.6 poles/km
1 accident/mile/year = 0.6 accidents/km/year

Figure 3. Utility Pole Predictive Model and Associated Nomograph [14]

Good et al. [6] also developed a collision predictor model based on the 8-month investigation of utility pole crashes in the metropolitan Melbourne, Australia area. Comparison of the in-depth data to that collected by the Victorian Road Safety and Traffic Authority indicates complete coverage of fatal pole crashes and roughly two-thirds of the injury pole crashes during the study time period. The statistical analysis focused on the concept of relative risk computed using the method of maximum likelihood. Contingency tables were used to test possible correlations and interactions which were found to be weak and small in number. A model was developed to predict the utility pole collision rate for major roadway intersection and non-intersection locations; the parameters required for each model are summarized in Table 1. The basic procedure involves determining a relative risk for a single pole (using the tables presented in a user's manual) and then determining the accident frequency for the given pole by multiplying by the average accident frequency for all poles. Note that the data presented is specific to the Melbourne area and may not be applicable to other areas, especially those in the United States. However, the general methodology could be used to develop a similar model using state-specific data.

Table 1. Summary of Model Parameters for Good et al. Model [6]

Model	Parameter	Description
Non-Intersection	$\|K_{max}\|$	Maximum horizontal curvature upstream of pole
	AADT	Annual Average Daily Traffic
	ST	Pavement skid resistance
	LO	Lateral pole offset
	W	Road width (undivided roadways only)
	DC	Distance from pole to start of horizontal curve
	PD	Presence of pavement deficiencies indicator (e.g. ruts)
	e	Superelevation at horizontal curve
	OIB	Pole relative to bend (inside/outside)
Intersection	AADT	Annual Average Daily Traffic
	ST	Pavement skid resistance
	G	Grade into the intersection
	DV	Road divided or undivided indicator
	LO	Lateral pole offset
	IT	Intersection type

Relating to the influence of roadway characteristics, Good et al. [6] found the relative risk of a utility pole collision rises sharply as the lateral pole offsets decreases below 3 meters, and that site characteristics associated with 10 percent of the sites were found at half of the crash sites. Also, collisions at non-intersection sites were considerably more severe than those at intersections. Relative to the vehicle, crash involvement increased markedly for tire tread depths less than 3 mm and reductions in vehicle mass were found to associate with higher occupant injury levels. In terms of impact modality, side and oblique impacts are found to have a higher mean cost per collision than frontal collisions.

Zegeer et al. [7] present a more generalized model intended to predict collisions with roadside objects on two-lane rural roads. Although not directly examining utility pole collisions, utility poles were found to be the most frequent object struck on two-lane highways with ADT in excess of 4,000 vehicles per day. The log-linear model is based on a seven point roadside hazard scale as well as other roadway characteristics (including average daily traffic, lane width, and shoulder width). One pertinent finding was that an increase in roadside recovery distance (lateral clear area) by 20 feet corresponded to a 44 percent reduction in related collisions. Also, a steady reduction in roadside object collisions is found when side slopes are reduced from 3:1 to 7:1 or flatter.

Council and Stewart [15] developed severity indexes (SI's) for various fixed roadside objects using data from the Highway Safety Information System (HSIS). Essentially, the SI is a single value used to describe the typical severity for a vehicle impacting a given object (expressed as proportion of severe injuries experienced with crashes of a given fixed object). Note that these values can be adjusted based on roadway and traffic factors as well. For utility poles, the SI values ranged between 0.08 and 0.19; the only objects with larger SI values were bridge rail ends, underpass abutments, trees and culverts. In general, the authors found that increasing speeds, rural location, and non-intersection locations were associated with a higher utility pole SI value. As this indicates higher severity collisions, it is inferred that higher speeds, rural and non-intersection location result in larger numbers of higher severity collisions, which is consistent with the findings of the other studies.

Holdridge et al. [13] present a novel system-wide modeling approach rooted in a crash severity context rather than collision frequency prediction. Unlike the other statistical studies that focus on a small area and rely on extrapolation, the authors use multivariate nested logit models to analyze the in-service performance of roadside hardware on the entire State Route system in Washington State. The advantage of this method is improved statistical efficiency and the ability to control for a wide range of factors simultaneously. As all roadside objects are considered, though, there is limited data presented with respect to utility poles only. The researchers do find that utility poles increase the propensity toward fatal collisions.

Countermeasures

General guidance on utility pole mitigation is provided in AASHTO's *Roadside Design Guide* (RDG) [16] and is as follows:

- Place utility lines underground
- Increase lateral pole offset
- Increase pole spacing
- Joint usage of poles
- Implement a breakaway design

- Shield pole with roadside safety hardware
- Delineate the object

State transportation agencies are encouraged to conduct detailed crash record studies to identify high frequency crash locations as a basis for determining appropriate improvements to reduce the frequency and severity of future crashes. Two AASHTO publications [17][18] are referenced as providing additional information on the placement of utility poles in the right-of-way (ROW).

For existing utilities within the ROW, detailed guidance is provided by Horne [19] and is summarized in Table 2. These guidelines are also reiterated in Transportation Research Board *State of the Art Report 9: Utilities and Roadside Safety* (TRB SAR 9) [20]. Note that the recommendations are split between those applicable to highway agencies and those applicable to utility companies and encompass all those mentioned in the RDG.

Table 2. Summary of Suggested Utility Pole Countermeasures [19]

Highway Agencies	Utility Companies
Keep vehicles on the roadway - Pavement markings - Delineators - Skid resistance - Widen lanes - Widen, pave shoulders - Straighten curves	Locate underground Increase lateral offset Locate where less likely to be struck - Behind ditches, guardrail - Inside of curves - Avoid end of lane drop
Safety Devices - Steel-reinforced safety poles - Guardrails - Crash cushions - Concrete barriers	Reduce number - Joint use of poles - Single side of roadway - Increased spacing
Warn motorists of obstacles - Reflective paint, sheeting, markers on poles - Roadway lighting - Warning signs - Rumble strips	Breakaway poles, guylines

As part of the AASHTO Strategic Highway Safety Plan, Lacy et al. [22] outlines a plan to minimize injuries and fatalities resulting from utility pole collisions (NCHRP Report 500). The countermeasures listed are similar to those presented by Horne [19] but are presented with more of an implementation slant. For instance, the first objective to treat historically high-risk locations is essentially a first step to mitigating a utility pole collision problem while the treatment of a corridor is perhaps more of a long-term goal. Also, the strategies are not split between utility company and highway agency as a concerted effort is stressed by the researchers.

Table 3. Summary of Pole Collision Reduction Strategies [22]

Objective	Strategy
Treat specific utility poles in high-risk, high-crash locations	Remove poles in hazardous locations
	Relocate poles further from the roadway or to less vulnerable location
	Employ breakaway device
	Shield drivers from hazardous poles
	Improve the ability of the driver to see the pole
	Employ traffic calming measures to reduce speed
Prevent placing utility poles in high-risk locations	Develop, revise, and implement policies to prevent poles from being placed in the recovery area
Treat several utility poles along a corridor to minimize utility pole collisions if a vehicle departs the roadway	Place utilities underground
	Relocate poles in corridor farther from the roadway or to less vulnerable location
	Decrease the number of poles along the corridor

Below provides a discussion of specific countermeasures that can be used to mitigate utility pole collisions.

Placing Utilities Underground

This countermeasure appears ideal since the utility poles are no longer present. Bauer [24] and a rebuttal published along with Wolf et al. [23] indicate the efforts of the telephone companies to utilize underground utilities wherever possible, especially in new construction. While a viable solution, TRB SAR 9 [20] cautions that other existing above ground obstructions, including transformers and switching cabinets required for the under-grounding, may still pose a hazard to motorists. Other issues raised by TRB SAR 9 [20] include the increased installation and maintenance costs, potential need for private easements to accommodate the above-ground devices, limitation on current carrying capacity on lines placed below ground, potential presence of other underground utilities (same ROW), and space requirements (underground utilities require more than double the space as overhead utilities).

Alter Pole Position

Another method of reducing the frequency and severity of pole collisions is to alter the pole position with respect to the traveled way. This includes increasing pole spacing, joint use between multiple utilities (telephone, power, cable, etc.), as well as larger lateral offsets from the roadway edge.

Perhaps the most attractive of those options would be to increase the lateral pole offset since an overwhelming portion of utility pole collisions occur within the first 10 feet of the roadway edge 108[6][8]. Unfortunately, ROW is typically expensive to acquire and not always available (especially in urban areas), making this countermeasure heavily site dependent. For roads with open drainage, Turner and Barnett [8] suggest placement of poles outside the ditch line in flat or cut sections. For poles along curved sections, the authors recommended that consideration be given to locating the poles on the inside of the curve.

With respect to increasing pole spacing or joint use, TRB SAR 9 [20] cautions that an engineering analysis should be performed to ensure cost effectiveness. For instance, increased pole spacing can lead to larger, more expensive poles. Also, if joint use is planned, the maximum spacing may be different for different utility types resulting in an additional restriction (e.g. power line spans are typically greater than communication spans).

Breakaway and Energy Absorbing Poles

Breakaway designs were first incorporated into roadside signs and lighting supports in the mid-1960's to reduce the severity of collisions with these roadside structures. In 1974, Wolfe et al. [23] made the first attempt at adapting this concept to utility poles. The purpose was to determine the feasibility of field modifying existing utility poles such that they break away in the event of an errant vehicle strike. A total of 13 pendulum tests (4000 lb mass impacting at 20 mph) were performed in two phases to determine the final design. Converting an existing pole to a breakaway design consisted of drilling two perpendicular 3" holes and a 0.5 inch full-circumference groove at the bottom section (6 inches from the ground line) and two perpendicular 2" holes situated 6 feet from the top of the pole. Rebuttals to this proposed design were provided by the American Telephone and Telegraph Company as well as the Commonwealth Edison Company (a power company). Issues that were raised include the following:

- Careful consideration of the reduction of pole load-carrying capacity is required
- The "domino effect" of a single weak pole causing many to fall
- Supplementary preservative treatment would be required to prevent decay of the newly exposed wood fibers.

Bauer [24], on behalf of AT&T, reiterated many of these concerns with the proposed "retrofix" design. A recurring theme expressed is the fact that a utility pole is not an isolated element, unlike luminaries and signs (where the author notes benefits of breakaway supports are better suited). Specific concerns with the breakaway pole concept are stated as follows: (1) an unknown factor of safety will make it extremely difficult to maintain employee safety, (2) a larger percentage of the poles will fail resulting in additional hazards to motorists and increases in service outages, and (4) increase the cost of pole maintenance by reducing the life of the pole and requiring additional poles to be replaced.

In 1983, Labra et al. [25] presented further development of the breakaway utility pole concept. The goal of this research was to generate a breakaway pole design that will consistently meet TRC 191 criterion [26], a 2250-lb subcompact car impacting at both 20 and 60 mph. More than 20 designs were tested with pendulum tests, static bending tests, and computer simulations prior to the selection of a three-bolt slip-base design coupled with an upper cross-arm release mechanism. Static bending tests with the final design find no discernible difference in bending strength (compared to traditional wooden). Six full-scale crash tests demonstrated the ability of the breakaway mechanism to properly activate and subsequently reduce the total vehicle change in momentum. Note that the average change in momentum for the breakaway device was on the order of 1,000 lb-s while the change in momentum for a fixed pole is reported as 3,200 lb-s.

In 1986, Ivey and Morgan [27] proposed a modified slip-base design referred to as the Hawkins Breakaway System (HBS). Similar to the device tested by Labra et al., the HBS consists of a slip base mechanism 3 inches above grade and an upper hinge consisting of a band and strap mechanism that allows the bottom pole segment to rotate clear of the impacting vehicle. The main difference between the HBS and the previous design is the 6-bolt slip base (as opposed to the 3-bolt system) and the upper hinge mechanism. Five full-scale crash tests were performed (impact speeds 20 to 60 mph and vehicle weight 1,700 to 4,300 lbs) to test the design against NCHRP 230 [28] standards. All tests produced acceptable occupant risk values, with the exception of the high speed test (occupant impact velocity of 15.6 fps compared to the 15 fps threshold). Using injury probability distributions developed by others, the authors calculate that the HBS system results in an average reduction of 91 percent for severe injuries (AIS≥3) when compared to a non-breakaway design.

Roughly 10 years later, Alberson and Ivey [29] introduced an improved version of the HBS referred to as the AD-IV. Improvements to the previous system include switching from a six-bolt circular lower slip base connection to a four-bolt square slip base connection and converting the upper connection from a 4-strap mechanism to a 4-strap/4-bolt mechanism. These changes have reduced the amount of material used in the base connection, reduced the cost of the upper hinge, and reduced the maintenance costs. The revised design was subjected to three pendulum tests and a single full-scale crash test with a 1,800 lb vehicle impacting at 60 mph and 15 degrees. The AD-IV was found to satisfy the requirements set forth by NCHRP 230 and was approved for use by the Federal Highway Administration (FHWA) on June 17, 1993.

In 2003, Foedinger et al. [30] developed a fiberglass-reinforced composite utility pole designed to absorb vehicle crash energy in the event of a collision. The Shakespeare composite pole (Figure 4) consists of filament-wound fiberglass-reinforced polyester that is tapered (from bottom to top) along its 45 foot length. The cross-section is octagonal and hollow at the base and transitions to a hollow circular cross-section near the top of the pole. The pole offers a significant advantages over traditional wooden poles including weight savings (475 lbs compared to 1000 lbs), increased service life (80 years uniform performance compared to 20-50 years of declining performance), reduced maintenance (none compared to every 5-7 years), as well as faster installation. Based on two bending tests, the composite pole is found to be satisfactory with respect to 2,400-lb load requirement. Two test level 2 NCHRP 350 [31] full scale crash tests were performed with an 1800 lb vehicle impacting at 15 degrees and 50 kph (31 mph) and 70 kph (43 mph). Both tests were satisfactory and the occupant risk values were within prescribed maximums

Figure 4. Shakespeare Energy Absorbing Utility Pole

Table 4 presents a summary of the published costs of breakaway utility poles. Note that all costs are in 1996 dollar amounts with the exception of the AD-IV (2002 dollars). Even with the dollar-year discrepancy for the AD-IV pole, the Shakespeare composite appears to offer a significant advantage over the wooden retrofit-type solutions in terms of cost.

Table 4. Summary of Reported Breakaway Pole Installation Costs

Breakaway Pole	Installation Cost	Maintenance Cost	Source
HBS	2,710	-	[30]
FHWA Retrofit	6,000	-	[30]
AD-IV	3,000*	1,000/hit*	[20]
Shakespeare Composite	2,200	-	[30]

* Indicates 2002 dollars. All others are in 1996 dollars.

Shield Hazardous Poles

For poles that cannot be relocated due to prohibitive cost or other reasons, one potential solution is to shield the hazard using one of the safety devices listed in Table 5. Longitudinal barriers provide attenuation of crash forces and redirect errant vehicles away from the pole while the extruder terminals and crash cushions absorb crash energy to bring the errant vehicle to a controlled stop prior to impacting the pole. Note that in the hierarchy of the RDG [16], shielding a device is typically considered after removal or relocation has been ruled out. Also, TRB SAR 9 [20] suggests that these solutions should be evaluated on a case by case basis as not all are appropriate for a given site.

Table 5. Summary of Potential Shielding Devices [20]

Device Type	Safety Device	NCHRP 350 Test Level
Longitudinal Barrier	Low Profile Barrier	Level 2
	W-Beam Guardrails	Level 3
Extruder Terminals	ET-2000	Level 3
	SKT-350	
Crash Cushions	Sand Filled Containers	Level 3
	EASI-Cell Cluster	
	TRACC	
	REACT	
	QuadGuard	

Delineation and Avoidance

Delineation and avoidance tactics refer to those countermeasures that prevent vehicles from leaving the roadway or warn the motorist of impending hazardous conditions. Utility pole avoidance tactics typically refer to those at the design level. For instance, improving roadway skid resistance, employing traffic calming measures, installing rumble strips, providing wider lanes and shoulders, and straightening horizontal curves are all considered avoidance measures [20][22]. Delineation tactics are usually employed when all other options have been exhausted [16]. For instance, a pole that cannot be relocated or shield is often delineated using reflective markings to warn approaching motorists.

Initiatives and Experience

Initiatives by cities, state departments of transportations, and utility companies are described below. Both TRB *State of the Art Report 9* [20] and *Utility Safety: Mobilized for Action and State, City and Utility Initiatives in Roadside Safety* [19] present summaries of these initiatives (as many are unpublished).

Alabama

Early efforts in pole mitigation in Alabama were focused in the Huntsville area. Turner and Barnett [8] investigated 458 pole collisions to develop guidelines for the placement of utilities in the urban Huntsville area. Based on these investigations, the authors make several recommendations with respect to utility pole placement. The minimum required lateral clearance suggested is 6 feet behind curb (reduced to 2 feet in the case of a parking lane), 20 feet from the edge of traveled way (speed limits below 50 mph) or 30 feet from the edge of the traveled way if the speed limit is in excess of 50 mph. Ideally, however, the authors recommend that the utilities should be placed at the outer limit of the right of way. On roadways with open drainage, the authors suggest placing the utilities outside of the ditch line and placing utilities on the inside of curves, if possible. For existing poles, the researchers suggest rank-ordering the highest risk sites based on historical accident data coupled with average daily traffic information. Site visits should then be conducted to determine if the site meets current horizontal clearances. A benefit/cost procedure should be used to determine the most appropriate treatment for each specific site.

More recently, Lindly [12] investigates the feasibility of mitigating utility pole collisions in Alabama to aid the state in its effort to reduce vehicular fatalities by 20 percent over the next 10 years. Specific objectives included an in-depth analysis of the utility pole crash problem in Alabama, field investigations of utility pole crash sites in Alabama, an investigation of utility pole crash reduction programs in other states, and the development of a sample utility pole safety policy for use by the Alabama Department of Transportation. The crash data investigation involved searching for areas of high risk, defined as more than 2 crashes in a 3 year period (5 mile increments). Interestingly, only one five mile section of state-controlled roadway was identified as having more than one utility pole fatality (the two fatal crash locations were 3.6 miles apart). A further investigation considering total crashes (all severity crashes were converted to equivalent PDO crashes) identified 28 potential sites for remediation. The overall conclusion is that a reduction in the utility pole collisions will only have a small effect on reducing the overall number of crashes and that most hazardous pole sites in Alabama are not suitable to receive federal funding and must be mitigated with reconstruction projects. Regardless, this study provides a general methodology for the future evaluation of hazardous pole sites in Alabama. It should be noted that the research team conducted site visits with members of a utility company, the Alabama Power Company.

Florida

Similar to the effort in Georgia, the initiative in Florida is a collaborative effort between the Florida Department of Transportation (FDOT) and the Florida Utilities Coordinating Committee (FUCC) [20]. The approach consists of identifying crash hotspots (referred to as “conflict points”) based on 10 year of crash data and relating the conflict points to roadway conditions (utility pole or other roadside object placement). For these locations, utility pole replacement is required only when all other potential causes can be ruled out (e.g. pavement rutting, improper superelevation, etc.) [20]. Guidelines relating to cost-effectiveness from the RDG are used to determine which locations require relocation. A 2:1 benefit to cost ratio is required to relocate poles in a reconstruction project while a 1:1 ratio is sufficient for relocation on new construction [20].

Georgia

The foundation of the utility pole mitigation plan in Georgia is the Clear Roadside Committee, which is composed of members of the Georgia Department of Transportation and utility industries, and the Georgia Utilities Coordinating Council, which exchanges information and resolves conflicts between utilities and the public sector [20]. A plan was developed to relocate hazardous utility facilities within the clear zone of US and State roadways over a 30 year period.

Crash records were examined for 3-mile stretches of roadway during a 3 year time frame [19]. The sites were prioritized based on total number of crashes as well as fatalities. Sites are then mitigated based on crash susceptibility and in light of the number of poles that need to be mitigated over the 30 year period. The method of mitigation, however, is identified as "give and take"; utility companies willingly move a certain number of poles while the Georgia Department of Transportation allows variances in the meantime [20].

Jacksonville Electric Authority

Serving a 2,000 square mile area in northeastern Florida, the Jacksonville Electric Authority (JEA) announced an intra-utility roadside safety program in conjunction with the Texas Transportation Institute (TTI) in 1989 [20]. TTI instituted a program to periodically analyze all police reported crashes in the area with particular attention given to those sites with a high frequency of utility pole collisions. The sites are then prioritized and the top sites are to be treated each year ($100,000 cap on treatment expenditures per year). A policy commitment was also made by JEA to the specific objective of improving roadside and utility pole safety.

Lafayette Utilities System

Similar to the Washington State initiative, the Lafayette Utilities System provides a ranking system based on pole crash history [20]. Category 1 poles are those with repeated collisions, Category 2 are poles subject to random collisions unlikely to be repeated, while Category 3 poles are those that do not fit into either Category 1 or 2. A continuous monitoring of crash statistics as well as predictive analyses for heavy traffic areas helps develops priorities such that roughly 10 high priority sites can be mitigated each year. The benefits of this program are expected to include increased safety for the citizens of Lafayette, Louisiana, savings in pole maintenance costs, as well as savings in legal costs [20].

Maine

As a result of the study and recommendations by Marquis [11], Maine Department of Transportation (MDOT) revised their utility accommodation policy [21]. Previously, MDOT policy was to relocate poles only during reconstruction, rehabilitation, and structural overlay projects. Recognizing the need for faster mitigation in high crash areas, the new accommodation policy allows for relocation of poles during reconstruction projects as well as spot mitigation in high crash locations. Also, the offset guidelines have been updated based on the recommendations provided by the Marquis [11] study.

In addition, MDOT also developed a utility task force to provide an avenue of communication between MDOT and the utility companies throughout the state. Meetings are held semiannually to address current issues which affect utilities occupying state ROW.

New York

After experiencing 8,000 utility pole crashes resulting in over 100 fatalities in 1982, New York State Department of Transportation (NYSDOT) launched a statewide campaign to identify and treat hazardous utility poles [12]. The procedure for identification and treatment is summarized in TRB SAR 9 [20] and is presented below:

1. Quantify the pole collision problem and develop a prioritized listing of sites. This is facilitated by tabulating utility pole related collisions during a 7-year period for each tenth of a mile roadway increment. Sections experiencing more than 5 crashes or one fatal crash plus at least one additional crash in 7 years are put on a “bad actor” list.
2. Identified locations are field investigated by NYSDOT and utilities engineers and are subjected to a comprehensive engineering study.
3. Countermeasures are developed on a site-by-site basis and analyzed for cost-effectiveness. Countermeasures, in descending order of desirability, are
    a. Remove pole, place lines underground
    b. Relocate pole farther from roadway
    c. Increase pole spacing
    d. Encouraging joint/multiple use of poles
    e. Relocate poles from outside to inside curves
    f. Use a breakaway pole
    g. Shield the pole
    h. Delineate the pole
4. The most cost effective and best suited countermeasures are recommended for implementation.
5. Actual performance of the countermeasure is then evaluated based on field performance.

Note that original effort began with mitigating individual sites and has now progressed to coordinating pole line relocation with reconstruction or rehabilitation projects (DOT related).

Pennsylvania

The Pennsylvania Department of Transportation (PennDOT) has begun an initiative to reduce roadside fatalities by focusing on sections of roadway with the highest frequency of tree, utility pole and guide rail collisions [20]. By 2005, PennDOT hoped to reduce highway fatalities by 10 percent. In addition to an internal engineering effort to combat utility pole crashes, PennDOT has partnered with utility pole owners and set up relocation cost-sharing options. Criteria for selection of high frequency crash sites are those where 3 or more fatalities have occurred in a half mile section in the past 5 years. Specific initiatives of the program are as follows [20]:

1. Proactively address utility pole collisions in conjunction with utility pole owners and assist pole owners with the high cost of relocations. Potential cost sharing scenarios include the purchase of additional ROW in rural areas, placement of utilities underground in suburban and urban areas, and consolidating poles to a single side of the roadway (if they exist on both sides).
2. Active pursuit of measures to keep motorists on the roadway such as the installation of rumble strips.
3. Development of specifications to delineate hazardous poles that cannot be removed or relocated.

Tennessee

Jones [4] describes problems and conflicts encountered between highway authorities and utility companies during a project to relocate a number of hazardous utility poles. The study site consisted of before-and-after data on a 2-mile section of major arterial in Knoxville, Tennessee. The utility poles along this section were at roughly a 6 inch offset from the curb. Improvements to the site included moving the overhead power lines to an offset of 6 feet behind the curb and using large steel poles to increase the post spacing beyond the 150 foot limit for existing poles. A marked improvement in safety was associated with the improvements. Before the improvements, there were a total of 5 fatalities and 68 personal injuries from utility pole crashes between 1963 and 1974 while, for a 4 year period after the improvements, there was not a single utility pole injury or fatality along the 2-mile stretch of roadway. Some problems identified by Jones include utility companies blocking traffic for installation and maintenance, utilities protecting frequently struck poles with concrete encasements at the pole base, lack of meetings between the highway authority and utility industry, and limited funding available for relocation of poles in the right-of-way. Solutions to these issues include providing good documentation of high risk areas to the utility company (as they are typically concerned with customer safety), mutual cooperation between agencies starting as early as the planning and development stage, and cost-sharing for pole locations when possible. Although not a large scale or statewide effort, the study demonstrates the feasibility of finding viable solutions for a utility pole collision problem.

Washington State

The utility safety program in Washington State is based on Control Zone Guidelines that were cooperatively developed by the Aerial Utility Advisory Committee in 1989 [19]. The “Control Zone” refers to the area from the road edge to the ROW where there is “control” on where utilities can be placed. Using the guidelines, utility objects can be classified as Location 1, 2 or 3 based on their position (see Table 6).

Table 6. Classification of Utility Objects [19]

Location	Description
1	Within the radius of public road intersection
	In a position where roadside features may direct an errant vehicle
	Closer than 5 feet beyond the shoulder edge
2	Located within the control zone but does not meet criteria for location 1
3	Located outside the control zone

The specification of four objectives facilitates the implementation of the guidelines. The first objective is to locate all utilities outside of the control zone. The second objective is to provide a corrective measure such as increasing pole spacing, placing the lines underground, or increasing lateral offset distance. In the case that neither of these are feasible, a variance may be granted for a Location 1 object. A reclassification may be obtained if a Location 2 object cannot meet either of the first 2 objectives.

In general, the Washington State Department of Transportation requires the following [20]:

- New utilities are placed outside the control zone
- Existing utilities must be moved or mitigated in conjunction with construction or reconstruction projects
- Other existing utilities must be relocated or mitigated in a systematic manner in conjunction with an annual mitigation target (AMT)

The AMT is a method of determining the number of poles to be relocated each year by a utility company that accounts for the facilities owned and those utilities that require relocation or mitigation. Note that the plan is only applicable to rural roadways as urban roadways are generally controlled by city and county authorities [20].

Breakaway Utility Poles

Preliminary indication of breakaway utility pole performance in-service was reported by TTI [32]. The authors indicate that the HBS system has been implemented in Kentucky and Massachusetts and withstood excessive winds (70-80 mph) in both states. More recent data on the field performance of these devices is provided in TRB SAR 9 [20]. Kentucky is noted to have installed 10 breakaway poles in the Lexington area in 1989. No serious problems were encountered and the only maintenance work required was to straighten the upper pole segments. No collisions were reported and only six remain due to utility changes and relocations.

The breakaway poles installed in Massachusetts have been hit five times during the evaluation period [20]. No serious injuries were reported and there was no break in utility service. It is interesting to note that the average repair time was 1.5 hours and the breakaway poles were found to be faster and easier to repair than traditional poles. Also note that wood deterioration has not been found to be significant problem.

A total of six AD-IV poles were installed and monitored on an urban arterial in the Dallas-Fort Worth area of Texas [20]. Only one collision was observed with an incorrectly installed pole. Despite the incorrect installation (heavy rains increased the effective height of the slip base), the pole performed correctly and no serious occupant injuries were reported. Similar to the poles in Massachusetts and Kentucky, the ability of the breakaway poles to resist high winds is noted.

Five breakaway poles have also been installed on the eastern shore of Virginia in the mid-1990's [20]. Similar to other states' experiences, no maintenance problems were encountered and the ability of the poles to resist high winds without damage is noted. No collisions were reported.

Evaluating Cost Effectiveness

McCoy et al. [33] present the development and application of a method that can be used to evaluate safety improvement alternatives for utility poles. Based on a conventional annual cost model, the total cost is computed by summing the annual accident cost, capital recovery cost, annual normal maintenance cost, and the annual collision maintenance cost. The total annual accident cost is based on the probability of a given encroachment angle, vehicle speed, vehicle size, fixed-object type, and the cost of a collision with a particular object at a given speed and angle. Note that the encroachment rates have been based on data collected by Hutchinson and Kennedy in the mid 1960's, encroachment angle is assumed independent of vehicle size and roadway type, encroachment speed is assumed normally distributed around the 85th percentile speed for the roadway, and adjustments are made to the collision probabilities based on the number and rows of other fixed objects.

To demonstrate the methodology, the authors presented an analysis of sixteen scenarios split between two hypothetical 1000-foot street sections (two traffic volumes and four variations of other fixed objects for each street). Each street section had standard class four (minimum 33.5 inch circumference 6 feet from ground end) 40-ft utility poles offset 2 feet from the edge of the traveled way and evenly spaced at 80-ft intervals. The only difference between the street sections was the placement of the additional fixed objects: street A had objects located at the same offset as the utility poles while street B had other fixed objects only located 10 feet from the edge of the traveled way. Other assumptions included a speed limit of 35 mph, all passenger car (4500 lb) vehicle fleet, and all other fixed objects were assumed to have the same injury-accident probabilities as non-breakaway utility poles.

For each scenario, the authors evaluated three improvement alternatives:

1. Convert all the utility poles to breakaway devices
2. Relocate the poles to an offset of 10 feet
3. Remove all utility poles and place utilities underground

Results show that in all cases, any improvement had a lower annual cost than the existing condition. However, depending on the number of fixed objects, the lowest cost alternative is not always placing the utilities underground. The authors caution that this demonstration cannot be generalized to all situations, however, the methodology can be applied to a particular site (by modifying the input variables) to obtain relevant results.

Using the predictive model developed by Zegeer and Parker [14], Zegeer and Cynecki [34] determine the cost-effectiveness of several alternative treatments for utility poles to reduce the frequency and/or severity of these collisions. Countermeasures investigated included the following:

1. Placing utility lines underground
2. Increasing pole lateral offset
3. Reducing the total number of poles
4. Using combinations of increased pole spacing and lateral offsets
5. Using breakaway poles

The predictive model previously developed [14] is used in conjunction with direct costs (indirect costs are not included) for the countermeasures as input to a benefit/cost model used to evaluate each countermeasure for different roadway characteristics. Based on the analysis, the authors conclude the following: (1) there are no cost-effective countermeasures associated with large electric transmission lines, (2) placing telephone and electric distribution lines underground (less than 69 Kv) is cost effective for many situations assuming direct burial, (3) increasing the lateral pole offset is cost effective for a range of situations, especially for telephone poles, (4) increasing pole spacing by as much as 20 percent is not cost effective in any situation, (5) multiple pole use is cost effective where traffic volumes exceed 5,000 and poles are within 5 feet of the roadway, and (6) breakaway poles are a cost effective alternative for many situations only if there is a 60 percent reduction in injury and fatal accidents.

Legal Issues

Najafi et al. [35] examined the legal implications of utility pole accidents in Florida from the perspective of departments of transportation as well as utility companies. Claims involving utility poles against the Florida Department of Transportation (FDOT) were limited and frequently did not result in payment. The authors also surveyed the 20 most populous cities and 5 cities with a high rate of pole accidents to determine incidence of tort liability cases against them. Based on the responses, tort liability associated with utility poles is not considered a serious problem especially in light of other tort liability risks (most notable was fixing broken sidewalks, clearing obstructed stop signs, and providing additional guardrails). The data for utility company proved to be mixed as most utility companies within Florida did not express utility poles as a liability concern, however, there were several large payouts made previously from independently owned electric companies in out-of-court settlements.

Although the authors found utility pole tort liability a small issue in Florida, they caution that this is different from the national trend towards more tort claims. To deal with a potential increase in tort liability risk, the authors suggest the development of a method to collect and store tort information, requiring that utility companies provide detailed information on tort liability for poles (to a state highway agency), formulation of a criteria for sharing of relocation costs, and development of a method to prioritize relocation of existing hazardous poles. Interestingly enough, the authors indicate that the pole location priorities should be based on tort information rather than on accident statistics.

In TRB SAR 9 [20], legal issues involving utility liability are discussed in light of tort liability resulting from both negligence and nuisance. The author notes that the tort suits against state departments of transportations are a relatively recent trend and that there are several ways to minimize its potential impact. The simplest way for a state DOT to provide protection from lawsuits is to use hold harmless clauses (when granting utility permits) and purchase insurance. Developing methods to classify and mitigate utility hazards is mentioned as another means of reducing potential losses due to tort liability suits. The overall strategy suggested is three-fold: (1) best offense is to determine sites with multiple fatal or injurious collisions and treat the sites, (2) best bet is to use statistical models to determine those locations where collisions are most likely and treat the sites, and (3) best defense is to document those utilities not in compliance with the RDG and rank based on percentage of compliance and perform treatments on a reasonable number of the highest priority sites each year. Note that the first approach is the most logical although it requires the occurrence of a number of costly collisions. The statistical models can be useful but, as the predictive power is relatively limited, the authors suggest that they be used in conjunction with other factors to make the final decision.

Conclusions

Utility Pole Collision Scope and Characteristics

- Along with trees, utility poles are one of the most dangerous fixed objects struck. Based on published crash statistics, approximately 2 percent of utility pole collisions result in fatality while roughly 50 percent result in some form of occupant injury.

- Utility pole collision frequencies are strongly a function of traffic volume, pole offset and pole density. Roadway class, shoulder width, horizontal curvature, roadway lighting and speed limit are found to have a significant, but lesser effect.

- Statistical models are available to predict utility pole collision frequency for single poles as well as roadway sections; most notable are the Zegeer and Parker [14] and Good et al. [6] models.

Countermeasures

- Several countermeasures for utility pole collision problems are available including placing utility lines underground, increasing pole offset, and using a breakaway device.

- In field trials, steel-reinforced breakaway timber poles are found to be resistant to high winds, less expensive to repair than traditional poles, and did not exhibit problems with environmental degradation.

- New fiberglass-reinforced composite utility poles appear to offer significant benefits over the traditional wooden utility poles, especially with respect to life-cycle issues and crashworthiness.

Initiatives and Experience

- Numerous states, cities, and even some electric companies have undertaken initiatives to reduce utility pole collisions.

- The general approach appears to be to start by eliminating historically hazardous areas followed by a continued monitoring of crash data.

- The most effective programs include collaboration with the applicable utility industries. Successful cooperative initiatives include PennDOT's cost sharing with utility owners, the partnership of Jacksonville Electric Authority and TTI, and the Clear Roadside Committee in Georgia.

Evaluating Cost Effectiveness

- At least two previous studies are available that detail procedures to evaluate the cost-effectiveness of utility pole collision countermeasures.

- The applicability of a given countermeasure should be evaluated on a site-by-site basis.

Legal Issues

- State DOTs can minimize tort suits involving utility poles by the use of "hold-harmless" clauses (when granting utility permits) and purchasing insurance.

- To further reduce liability, state DOTs should develop methods to classify and mitigate utility hazards. These should include mitigating historically active sites, employ statistical models to determine sites with highest collision probabilities, and documenting deviances from the Roadside Design Guide.

5. Current National Practices in Mitigating Utility Pole Impacts

Summary

Vehicle impacts with utility poles are one of the most unforgiving types of crashes and account for roughly 1,200 fatalities in the U.S. yearly. Although poles are typically owned by a utility company, they are placed within a roadway right-of-way, which often complicates mitigation of high frequency and high severity utility pole impact locations. Several national guidelines, from organizations such as the American Association of State Highway and Transportation Officials (AASHTO) and the Transportation Research Board (TRB), provide direction for utility pole crash mitigation. National recommendations for utility pole crash mitigation stress the importance of proper pole placement coupled with a comprehensive crash reduction program.

AASHTO and TRB recommend an ongoing comprehensive crash reduction program periodically analyzes crash data to identify, prioritize, and mitigate locations where pole crash risk is high. Numerous strategies and crash countermeasures exist for high risk utility pole crash locations. These include locating utilities underground, increasing offset from the roadway, reducing the number of poles through joint usage, and utilizing safety devices. Specific utility pole crash countermeasures include breakaway and energy absorbing poles, longitudinal barriers, and crash cushions. Breakaway poles are recommended in high crash risk areas where it is not feasible to relocate the pole farther from the roadway or place the utilities underground. Shielding utility poles with longitudinal barriers or crash cushions are recommended only at high risk locations where all the above countermeasures are not feasible.

Introduction

Although poles are typically owned by a utility company, they are placed within a roadway right-of-way, which is within the jurisdiction of the respective highway and/or state agency. From a utility delivery perspective, the poles should be robust and fixed such that the interruptions in service to the customer and maintenance to the system are minimized. Installation of these rigidly fixed objects on the roadside, however, opposes the goal of the highway agency to provide a safe roadside environment. These antagonistic philosophies often complicate mitigation of high frequency and high severity utility pole impact locations. Several national guidelines, from organizations such as the American Association of State Highway and Transportation Officials (AASHTO) and the Transportation Research Board (TRB), provide direction for utility pole crash mitigation.

Scope

The purpose of this section is to document the current recommended national procedures for reducing the frequency and severity of utility pole collisions. The approach is threefold: (1) examine national recommendations with respect to utility pole placement and crash mitigation, (2) determine the state of the art in specific utility pole crash countermeasures, and (3) document lifecycle costs for various breakaway pole designs.

National Procedures in Pole Placement and Crash Mitigation

General guidance on utility pole mitigation is provided in AASHTO's *Roadside Design Guide* (RDG) [38] and is as follows:

- Place utility lines underground
- Increase lateral pole offset
- Increase pole spacing
- Reduce the number of poles through joint usage of poles
- Implement a breakaway design
- Shield pole with roadside safety hardware
- Delineate the object

The mitigation measures are listed in order of descending desirability. One should note, however, that each site must be evaluated on an individual basis. For instance, although placing the lines underground is most desirable, a more viable and cost effective solution for high voltage lines adjacent to a roadway may be to increase the lateral offset.

In the case of new construction or major road reconstruction, AASHTO recommends locating (or relocating in the case of reconstruction) utility poles as far from the travel lanes as practical. Two AASHTO publications [17][18] are referenced as providing additional information on the placement of utility poles in the right-of-way (ROW). For existing utility poles, transportation agencies are encouraged to conduct detailed crash record studies to identify high frequency crash locations as a basis for determining appropriate improvements to reduce the frequency and severity of future crashes. General guidelines for conducting a comprehensive crash reduction program are identified as follows:

- Implement a traffic records system
- Identify high frequency crash locations
- Analyze high frequency crash locations
- Correct high frequency crash locations
- Review the program results

AASHTO provides additional guidance on utility pole placement for freeways with full access control [17]. For new construction and major reconstruction, the proper placement of the utility poles becomes the countermeasure. According to the guide, new longitudinal installations (e.g. parallel with the roadway) should not be permitted along freeways unless the utility company can demonstrate the following:

- Utility installation will not adversely affect the safety, design, construction, traffic operations, or maintenance of the freeway.
- All other alternatives are cost prohibitive
- Utility installation will not interfere with future expansion of the freeway
- Locating the utilities outside of the ROW would have an adverse impact on agricultural land.

For overhead utilities crossing a freeway, the poles should not be placed within the clear zone of the freeway (as determined by the current edition of the RDG). Intermediate poles may be placed in the median to meet span requirements as long as the median is of sufficient width such that the pole will be outside of the clear zone (from the edge of both travel lanes). If in a rare instance it is not feasible to span the freeway, the utility line can be converted to an underground facility to cross the freeway. In interchange areas, utility poles must be out of the clear zone for the through traffic lanes, beyond the clear zone with respect to the edge of the ramp, and should not impair driver sight distance. Also, utilities along freeways should be constructed and maintained without direct access from the freeway.

The more general utility placement guidelines set forth by AASHTO apply to all public utilities along any highway [18]. Recommendations with respect to overhead facilities are more detailed than those in the RDG and include the following:

- Utility poles should be outside of the roadway clear zone and as near to the ROW line as practical. If there are curbs, the utilities should be located as far as practical behind the face of the curb and behind sidewalks if possible. Exceptions to these clearances can be made for instances where the pole is in a protected location (e.g. behind a guardrail, and/or beyond drainage ditches, the toe or tops of slopes, etc.).
- On urban streets or roads with narrow ROW, consideration should be given to self-supporting (e.g. no guy wires) armless, single pole designs with vertical alignment of wires or cables. See Figure 5 below.
- Appurtenances that extend more than 4 inches above ground should be located outside the clear zone or as near the ROW line as practical. If this is not practically feasible, the appurtenance should be breakaway or be shielded by a traffic barrier.

Figure 5. Cross-Arm Design (Left) and Armless Utility Pole Configuration (Right)

- Where irregular-shaped portions of ROW exist, variances should be granted such that longitudinal utility installations maintain a relatively uniform alignment with respect to the roadway.
- Utility poles should not be located longitudinally in the highway median. For overhead utilities crossing a highway, poles should not be located in the median. If there is no other viable option, the pole(s) should be breakaway or shielded by a traffic barrier.
- Joint use, single pole construction is encouraged at locations with multiple utilities. Also, distance between the poles should be the longest feasible consistent with geometric and design line loading considerations.
- Existing poles should be replaced with buried cables when relocation is necessary. Note that this may not be practical, however, for high voltage lines or those with multiple connections.

For existing utilities within the ROW, detailed guidance is provided by Horne [19] and is summarized in Table 7. These guidelines are also reiterated in Transportation Research Board *State of the Art Report 9: Utilities and Roadside Safety* (TRB SAR 9) [20]. Note that the recommendations are split between those applicable to highway agencies and those applicable to utility companies and encompass all those mentioned in the RDG.

Table 7. Summary of Suggested Utility Pole Countermeasures [19]

<table>
<tr><th>Highway Agencies</th><th>Utility Companies</th></tr>
<tr><td rowspan="3">Keep vehicles on the roadway
- Pavement markings
- Delineators
- Skid resistance
- Widen lanes
- Widen, pave shoulders
- Straighten curves</td><td>Locate underground</td></tr>
<tr><td>Increase lateral offset</td></tr>
<tr><td>Locate where less likely to be struck
- Behind ditches, guardrail
- Inside of curves
- Avoid end of lane drop</td></tr>
<tr><td>Safety Devices
- Steel-reinforced safety poles (Breakaway poles)
- Guardrails
- Crash cushions
- Concrete barriers</td><td>Reduce number
- Joint use of poles
- Single side of roadway
- Increased spacing</td></tr>
<tr><td>Warn motorists of obstacles
- Reflective paint, sheeting, markers on poles
- Roadway lighting
- Warning signs
- Rumble strips</td><td>Breakaway poles, guy lines</td></tr>
</table>

TRB SAR 9 [20] also suggests strategies for utility pole crash reduction based on the premise of reducing tort liability on the part of the state transportation agency. The most obviously visible and effective strategy is to determine sites with multiple fatal or injurious collisions and treat poles at those locations. At least 3 years of utility pole crash data is recommended for site identification and prioritization. Although effective and historically common, the authors do note that it is a reactive approach that requires a number of fatal and/or injurious collisions to occur. Another approach is to use statistical models to determine those locations where collisions are most likely and treat utility poles at those locations. As the models developed [6][7] have limited predictive power, the authors suggest coupling the models with a prioritization scheme to ensure effective use of available funds. The final strategy is to document those utilities not in compliance with the RDG and rank based on percentage of compliance. Treatments can then be made on a reasonable number of the highest priority sites each year.

As part of the AASHTO Strategic Highway Safety Plan, Lacy et al. [22] outlines a plan to minimize injuries and fatalities resulting from utility pole collisions (NCHRP Report 500). The countermeasures listed are similar to those presented by Horne [19] but are presented with more of an implementation slant. For instance, the first objective to treat historically high-risk locations is essentially a first step to mitigating a utility pole collision problem while the treatment of a corridor is perhaps more of a long-term goal. Also, the strategies are not split between utility company and highway agency as a concerted effort is stressed by the researchers. Also, the authors classify each strategy into one of three categories: proven (P), tried (T), or experimental (E). Proven strategies are those that have been implemented and evaluations show the strategy to be effective. Tried strategies are those that have been implemented (and may even be labeled as standard approach) but have not been properly evaluated. Experimental strategies are those that have been suggested and are considered promising to try on a small scale.

Table 8. Summary of Pole Collision Reduction Strategies [22]

Objective	Strategy
Treat specific utility poles in high-risk, high-crash locations	Remove poles in hazardous locations (P)
	Relocate poles further from the roadway or to less vulnerable location (P)
	Employ breakaway device (T)
	Shield drivers from hazardous poles (P)
	Improve the ability of the driver to see the pole (E)
	Employ traffic calming measures to reduce speed (T)
Prevent placing utility poles in high-risk locations	Develop, revise, and implement policies to prevent poles from being placed in the recovery area (T)
Treat several utility poles along a corridor to minimize utility pole collisions if a vehicle departs the roadway	Place utilities underground (P)
	Relocate poles in corridor farther from the roadway or to less vulnerable location (P)
	Decrease the number of poles along the corridor (P)

NCHRP Report 500 also provides an eleven step process to implementing the strategies for mitigating utility pole impacts. The process is as follows:

1. Identify and Define the Problem
2. Recruit Appropriate Participants for the Program
3. Establish Crash Reduction Goals
4. Develop Program Policies, Guidelines and Specifications
5. Develop Alternative Approaches to Addressing the Problem
6. Evaluate the Alternatives and Select a Plan
7. Submit Recommendations for Action by Top Management
8. Develop a Plan of Action
9. Establish the Foundation for Implementing the Program
10. Carry Out the Action Plan
11. Assess and Transition the Program

Utility Pole Crash Countermeasures

The following discussion focuses on the state of the art in specific utility pole countermeasures in terms of full-scale crash test performance and field performance. Countermeasures included are as follows:

Breakaway or Energy Absorbing Poles

- Hawkins Breakaway Pole
- FHWA-MA Breakaway Pole
- AD-IV Breakaway Pole
- Shakespeare Composite Energy Absorbing Pole

Longitudinal Barriers

- W-Beam Barriers/End Terminals
- Low Profile Concrete Barrier

Crash Cushions

- TRACC
- REACT
- EASI-Cell Cluster
- QuadGuard

Note that additional information regarding the development and testing of the breakaway utility pole concept can be found in the comprehensive literature review [37].

<u>Hawkins Breakaway Pole</u>

In 1986, Ivey and Morgan [27] proposed a modified slip-base design referred to as the Hawkins Breakaway System (HBS). The HBS consists of a slip base mechanism 3 inches above grade and an upper hinge consisting of a band and strap mechanism that allows the bottom pole segment to rotate clear of the impacting vehicle. Five full-scale crash tests were performed (impact speeds 20 to 60 mph and vehicle weight 1,700 to 4,300 lbs) to test the design against NCHRP 230 [28] standards. The test conditions and results are summarized in Table 9 and Table 10. Note that the impact point for all tests was at the center of the bumper with the exception of Test 4, where the impact point was at the bumper quarter point. All tests produced acceptable occupant risk values. Using injury probability distributions developed by others, the authors calculate that the HBS system results in an average reduction of 91 percent for severe injuries (AIS≥3) when compared to a non-breakaway design.

Table 9. Summary of HBS Crash Tests [27]

Test	Test Vehicle	Vehicle Weight (lb)	Impact Speed (mph)	Delta-V (mph)	Momentum Change (lb-s)
1	79 Honda Civic	1826	39.9	11.5	957
2	79 Honda Civic	1775	19.5	11.3*	915*
3	80 Chevrolet Malibu	3365	40.7	10.8	1655
4	75 Chevrolet Vega	2500	60.0	11.0	1253
5	79 Chrysler Newport	4331	56.8	7.0	1487

* Values are artificially high due to the impulse computed from 0 to 0.5 seconds

Table 10. Summary of HBS Occupant Risk Values [27]

Test	Occupant Impact Velocity (fps)		Occupant Ridedown Acceleration (g)	
	Longitudinal	Lateral	Longitudinal	Lateral
1	12.0	4.2	-1.0	0.5
2	10.1	3.5	-2.1	1.9
3	11.9	6.3	-1.4	1.1
4	15.6	N/A	-1.8	N/A
5	10.7	N/A	-0.8	N/A

In 1989, Kentucky Utilities Company retrofitted 10 utility poles with the HBS system in Lexington [48]. Performance of the poles was satisfactory with respect to environmental loads (withstood wind loads up to 80 mph) and the only maintenance required was periodic straightening of the upper pole segments [20]. Since the poles were not located in an area susceptible to utility pole collisions, no collisions were observed in the 2-year evaluation period [20].

FHWA-MA Breakaway Pole

The FHWA-MA breakaway pole is a modified version of the HBS. Major modifications include lengthening of the upper and lower slip base sleeves (from 17 to 30 inches) to prevent rot, thickening of the slip base flange thickness (3/4 to 5/8 inches) to prevent warping from welding, and increasing the height of the upper hinge to 14.5 feet above the slip base to allow for clearance for most larger vehicles [48]. The research team was unable to locate any published full-scale test results with this revised HBS design.

Field performance of the FHWA-MA is based on a 2-year evaluation of 19 retrofitted poles near the Boston, MA area [48]. A total of 5 hits were reported; all of which resulted in no serious injuries and no breaches in utility services [49]. The average repair time for these hits was 1.5 hours with no safety problems related to repairmen. Similar to the HBS in Kentucky, the FHWA-MA was reported to withstand high winds without failing (while surrounding conventional poles were toppled). Also, wood deterioration from the transverse cuts was found not be an issue [49]. Based on this field performance information along with the satisfactory performance of the HBS in Kentucky, the Federal Highway Administration (FHWA) classified both systems as 'operational' (as opposed to experimental) on January 27, 1993 [50].

In 1995, Virginia installed 5 of the FHWA-MA poles on the eastern shore [48]. No collisions were reported in the evaluation period and there were no reports of significant maintenance costs or problems [20]. Also, as observed in Massachusetts, the poles were reported to withstand several instances of high winds without damage.

<u>AD-IV Breakaway Pole</u>

Alberson and Ivey [29] introduced an improved version of the HBS referred to as the AD-IV (shown in Figure 6). Improvements to the previous system include switching from a six-bolt circular lower slip base connection to a four-bolt square slip base connection and converting the upper connection from a 4-strap mechanism to a 4-strap/4-bolt mechanism. These changes reduced the amount of material used in the base connection, reduced the cost of the upper hinge, and reduced the maintenance costs.

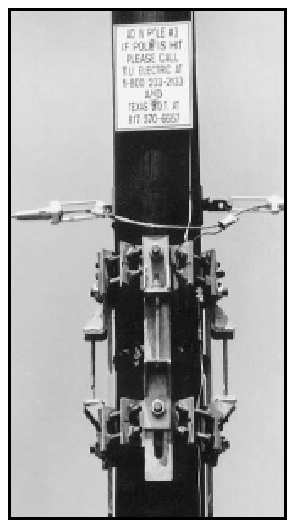


Figure 6. AD-IV Lower Slip Base (Left) and Upper Slip Connection (Right) [20]

The revised design was subjected to three pendulum tests and a single full-scale crash test with an 1,800 lb vehicle impacting at 60 mph and 15 degrees (relative to the strung wires) [29]. Table 11 and Table 12 summarize the results of the single full-scale crash test. Note that the occupant risk values are well within the limiting values of 40 fps for the occupant impact velocity and 20 G for the occupant ridedown acceleration. The AD-IV was found to satisfy the requirements set forth by NCHRP 230 and was approved for use by the FHWA on June 17, 1993 [52].

Table 11. Summary of AD-IV Crash Test [29]

Test Vehicle	Vehicle Weight (lb)	Impact Speed (mph)	Impact Angle (º)	Delta-V (mph)	Momentum Change (lb-s)
80 Honda Civic	1800	59.6	15	16.7	Not Reported

Table 12. Summary of AD-IV Occupant Risk Values [29]

Occupant Impact Velocity (fps)		Occupant Ridedown Acceleration (g)	
Longitudinal	Lateral	Longitudinal	Lateral
19.7	3.1	-2.4	1.4

In 1994, five existing utility poles in Arlington, Texas were retrofit with the AD-IV design [48]. Only one collision was observed with an incorrectly installed pole [20]. Despite the incorrect installation (heavy rains increased the effective height of the slip base), the pole performed correctly and no serious occupant injuries or utility interruptions were reported. Similar to the FHWA-MA and HBS, the ability of the AD-IV breakaway poles to resist high winds is documented.

Shakespeare Composite Energy Absorbing Pole

In 2003, Foedinger et al. [30] developed a fiberglass-reinforced composite utility pole designed to absorb vehicle crash energy in the event of a collision. The Shakespeare composite pole (Figure 4) consists of filament-wound fiberglass-reinforced polyester that is tapered (from bottom to top) along its 45 foot length. The cross-section is octagonal and hollow at the base and transitions to a hollow circular cross-section near the top of the pole. The pole offers significant advantages over traditional wooden poles including weight savings (475 lbs compared to 1000 lbs), increased service life (80 years uniform performance compared to 20-50 years of declining performance), and reduced maintenance (none compared to every 5-7 years).

Figure 7. Shakespeare Energy Absorbing Utility Pole

Based on two bending tests, the composite pole is found to be satisfactory with respect to 2,400-lb load requirement (environmental strength testing set forth in ANSI 136.20) [30]. The loads recorded in the bending tests were 2565 lbs and 2695 lbs. Two test level 2 NCHRP 350 [31] full scale crash tests were performed with an 1800 lb vehicle impacting at 15 degrees and 50 kph (31 mph) and 70 kph (43 mph). Table 13 and Table 14 summarize the full-scale crash test conditions and results. Both tests were satisfactory and the occupant risk values were within prescribed maximums.

Table 13. Summary of Shakespeare Pole TL-2 Crash Tests [30]

Test	Test Vehicle	Vehicle Weight (lb)	Impact Speed (mph)	Impact Angle (º)
1	Geo Metro	1800	31	15
2			43	15

Table 14. Summary of Shakespeare Pole Occupant Risk Values [30]

Test	Occupant Impact Velocity (fps)		Occupant Ridedown Acceleration (g)	
	Longitudinal	Lateral	Longitudinal	Lateral
1	34.8	3.3	-7.6	-2.3
2	35.4	3.6	-0.9	-15.4

The research team did not find any published documentation pertaining to field installations and corresponding in-service evaluations of this device. We have contacted Shakespeare Composites and they have indicated that there have been no field installations as of yet. This will be a potential new technology demonstration project in New Jersey.

Guying Requirements

Very little information exists regarding guy wire requirements for breakaway poles. According to the TRB *State of the Art Report 9* [20], the guy wire locations should be made with full consideration of the influence on impacting vehicles as well as the influence on the support for the main structure. It is also suggested that guy wires within the clear recovery area should utilize a breakaway attachment.

Longitudinal Barriers

A line of utility poles is not typically shielded by a w-beam barrier; however, it may be cost effective to shield a single pole with a combination of a guide rail and end terminal as shown in Figure 8. A listing of FHWA approved extruder terminals are shown in Table 15.

Table 15. Summary of FHWA Approved W-Beam Extruder Terminals

Terminal	Manufacturer	NCHRP Test Level	Approval Reference
ET-2000/ET-2000 Plus	Trinity Industries, Inc	2,3	[63][64][65]
SKT-350	Road Systems, Inc	2,3	[66][67]
FLEAT	Road Systems, Inc	2,3	[68][69]
ArmorFlex X350	Armorflex, Ltd.	3	[70]

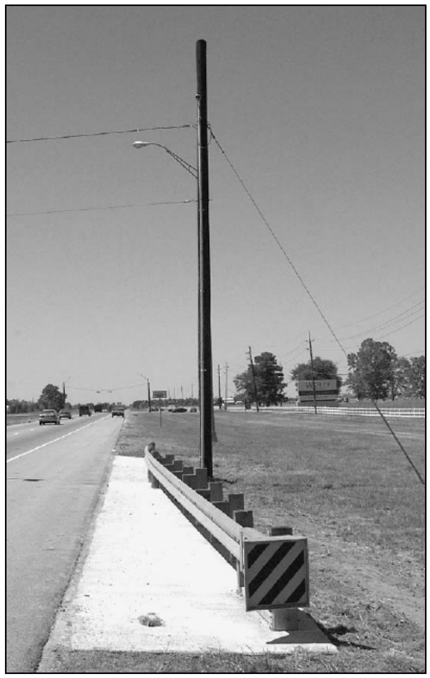


Figure 8. W-Beam Barrier and Extruder Terminal Shielding a Utility Pole [20]

Another longitudinal barrier option is the low profile barrier (Figure 9), a 20 inch high portable pre-cast reinforced concrete barrier. According to TRB SAR 9 [20], the cost of the low profile barrier is approximately 25 dollars per foot.

Figure 9. Low Profile Concrete Barrier [20]

Crash Cushions

A crash cushion is a device intended to dissipate some or all of an impacting vehicle's energy to bring it to a controlled stop. There are several crash cushions tested to NCHRP 350 standards and suitable to shield a utility pole in a high crash risk location. Table 16 is a partial listing of FHWA-approved crash cushions. Figure 10 provides images of two the proprietary crash cushions listed in Table 16.

Table 16. Summary of FHWA Approved Crash Cushions

Terminal	Manufacturer	NCHRP Test Level	Approval Reference
REACT	Energy Absorption Systems	3	[77]
EASI-Cell	Energy Absorption Systems	1	[78]
QuadGuard	Energy Absorption Systems	2,3	[79][80]
TAU-II	Barrier Systems, Inc.	2,3	[81]
HEART Crash Cushion	TTI	3	[82]
TRACC	Trinity Industries	2,3	[83][84]
TrafFix Sand Barrel System	TrafFix Devices, Inc.	3	[85]
Energite III	Energy Absorption Systems	3	[86]

Figure 10. A REACT 350 (left) and QuadGuard (right) Crash Cushion Shielding Concrete Median Barrier Ends

Conclusions

Utility Pole Placement and Crash Mitigation

- Pole placement guidelines exist to minimize the probability of a vehicle impacting a utility pole.

- All utility pole collision mitigation strategies require a method for determining susceptible locations, a method for choosing a countermeasure, and method to evaluate the results. The identification methods typically employ crash records or statistical models or a combination of both, the selection of a countermeasure is typically a cost-effectiveness-based method, while the evaluation typically involves post-countermeasure crash records.

- A myriad of crash mitigation strategies exist including moving the utilities underground, increasing the lateral offset of the poles, shielding with roadside safety hardware, breakaway poles, and delineation. Selection of a particular strategy should be site-dependent.

Utility Pole Collision Countermeasures

- In field trials, steel-reinforced breakaway timber poles were found to be resistant to high winds, less expensive to repair than traditional poles, and not highly susceptible to environmental degradation.

- The Shakespeare Energy Absorbing Composite pole appears to offer significant benefits over traditional wooden utility and breakaway utility poles, especially with respect to life-cycle issues and crashworthiness.

- Breakaway or energy absorbing utility poles are recommended for high risk crash locations where pole relocation or underground line placement is not feasible.

- Various proprietary and non-proprietary devices are available to shield a utility pole including w-beam/extruder terminals, low profile concrete barriers, and crash cushions.

- The small amount of field performance data available suggests satisfactory performance of w-beam/extruder terminal combinations and crash cushions. These devices, however, should only be employed when other countermeasures are not feasible or cost effective.

6. Analysis of New Jersey Utility Accommodation Policy

Summary

In 2005, there were nearly 5,000 crashes in New Jersey from impacts with utility poles – 44 of which resulted in a fatality. Factors such as pole offset, higher than average pole density, speed, traffic volumes, type of facility, and roadway width have all been related to the frequency and severity of utility pole collisions. States such as Washington, Pennsylvania, and New York have already undertaken efforts to safely accommodate utility poles within the right-of-way. Each of these states have identified areas in which utility pole safety improvements were needed and have taken different approaches to solving the problem. This section discusses the NJDOT guidelines and policies for highway design and issues related to utility poles.

Introduction

The existing New Jersey Guidelines on Utility Poles are discussed and compared to national guidelines and recommendations in this section. There are two mechanisms for utility poles to come into consideration in New Jersey. First, utility poles are considered during highway construction or reconstruction and in the instance a utility company requests the installation of a pole on a State Highway. In these cases, there are two main sources of guidance: the New Jersey Utility Accommodation Policy, and the New Jersey Roadway Design Manual. Neither document addresses utility pole placement on existing highways that are not undergoing reconstruction for other reasons. Second, existing utility poles or groups of poles can be identified as part of a safety program, such as the Fixed Object Program, as a result of historical accidents.

The New Jersey Utility Accommodation Policy discusses the use by utility companies of public highway right of way. The document addresses the following: electric companies, telephone companies, sewer lines, water lines, gas lines, electric poles, and cable television. The discussion of this report is limited to issues directly pertaining to utility poles. Typically, utility poles carry some combination of electric power, telephone and cable lines. The accommodation policy places strict limits on the placement of utility poles on restricted access highways. Any utility poles that are placed on restricted access highways are treated on a case by case basis. Therefore, limited access highways are not discussed further. The New Jersey Roadway Design Manual also includes some discussion on utility poles, in the context of including guide rail to protect vehicles from fixed objects.

Pole Placement Guidelines

Section 16:25-5.2 of the New Jersey Utility Accommodation Policy limits utility poles along highway right-of-way to wood construction. However, a utility company can request to use non-wood pole construction, if public safety is not compromised. The number of utility poles is to be limited by encouraging joint use of poles, and by keeping utility poles to a single side of the highway to the extent possible.

Typical Location

Utility poles should be located as close to the right-of-way line as possible. The preferred distance is five feet, which allows the cross arm to stay within the right-of-way. Ideally, utility poles are to be located behind the sidewalk. When this is not possible, poles may be placed between the sidewalk and the curb or gutter line, as close to the sidewalk as possible. The minimum distance between the face of the utility pole and the face of the curb is one and a half feet.

Presence of Guide Rail

Utility poles should always be located behind guide rails. The desired offset from the face of the pole to the back of the guide rail is four feet. The minimum clearances from the face of the pole are one foot from the back of the guide rail and 0.5 feet from the back of the guide rail post. When the offset is less the desirable four feet, post spacing on the guide rail should be increased and double guide rail elements should be provided. Utility poles should not be located within 25 feet of the beginning and end of a guide rail. Utility poles should not be located within 50 feet of crashworthy guide rail end treatments. These distances are summarized in Table 17.

Table 17. Summary of key distances for guide rails

	Desired	Minimum
Offset from guide rail	4 ft.	0.5 ft. from rail post 1.0 ft. from guide rail
Longitudinal from end		25 ft. 50 ft. in presence of crashworthy end treatments.

Vulnerable Locations

Some specific types of vulnerable locations are specifically mentioned. Gore areas, small islands (islands that do not had a longitudinal through roadway length of 100 feet of more), and the outside of sharp horizontal curves (defined by any horizontal curve with a safe speed less than the posted speed) are identified. Any time that a utility pole is on the outside of a horizontal curve, increasing the minimum poles offsets should be considered. Utility poles must have a minimum offset of 40 feet from the edge of the deck of a bridge or from the outside of the parapet (the low protective wall or railing along the edge of a raised structure) of the bridge structure.

Exceptions

The NJDOT will consider utility requests to locate utility poles further from or closer to the right-of-way line based upon the following factors: closeness of building or slopes, existing pole construction type, maintenance requirements, future utility needs, constructability, environmental constraints, public safety, and migrating conditions (parking, auxiliary lanes, or excess lane widths that lessen the accident exposure or severity).

Clearance

Electric power and communication lines are required to comply with the National Electrical Safety Code (NESC), as well as specifications by the New Jersey Accommodation Policy. Specific requirements for clearance are given for both lateral and vertical directions, and are based on phase-to-ground voltage. These required clearances for traffic signals and lighting standards are given in Table 18, the required clearances for highway signs are given in Table 19.

Table 18. Minimum clearances between overhead power lines and highway traffic signals or lighting standards

	Minimum Clearance	
	Lateral Direction	**Vertical Direction**
0-750 volts	NESC	NESC
750 volts – 50 kV	10 feet	10 feet

Table 19. Minimum Clearances between overhead power lines and highway signs, sign standards or sign bridges

	Minimum Clearance	
	Lateral Direction	**Vertical Direction**
0-750 volts	NESC	NESC
750 volts – 50 kV	NESC	10 feet

Highway Reconstruction

Regardless of the initial motivation for highway reconstruction, the Division of Project Planning and Development will request a crash analysis of the area that is being reconstructed. The division will then evaluate design alternatives, and make a recommendation to Project Management for implementation. The desired distance for right of way is fifteen feet from the curb. The minimum distance for right of way is ten feet from the curb. The cost of right of way in New

Jersey is high, so usually only the minimum is used. Typically, utilities are not given a strong consideration in this decision.

The New Jersey Roadway Design Manual section on Guide Rail Design and Median Barriers (Section 8.02.04) states that, when undergoing road reconstruction, corrective action must be taken on utility poles that have been struck three or more times within a three year period. Neighboring poles that have been struck three or more times in a span of three year period will also require corrective action. This clause is taken from the Fixed Object Program, but has been incorporated into the Design Manual. Consistent with the treatment of all fixed objects, relocation of the utility poles and/or improvements of the contributing roadway feature are encouraged, rather than installing guide rails. However, there is allowance for guide rails to be considered.

Furthermore, other types of barriers are encouraged, such as crash cushions are encouraged, where appropriate. However, there is no discussion of specific approaches that are encouraged, or techniques to evaluate or predict the effectiveness of methods.

Fixed Object Program

New Jersey Department of Transportation has a safety program called the Fixed Object Program that identifies fixed objects that have been involved in a number of accidents. Single utility poles, or adjacent utility poles, that are struck three or more times in a three year period are identified by this program.

Comparison of New Jersey Guidelines to National Guidelines

The New Jersey Utilities Accommodation policy focuses solely on pole placement for new construction or reconstruction. In general, the NJ Accommodation policy follows national guidelines closely, if not verbatim. The State of the Art Report Number 9 describes special considerations for utility pole placement at or near intersections. However, there is no mention of specific treatment of intersections in the New Jersey Accommodation Policy.

Another important strategy for reducing utility pole fatalities is to consider the mitigation of existing poles or sites that have been demonstrated to be high risk, either historically, or based on statistical measures to predict high risk, even when that particular section of highway is not under major renovation. The Fixed Object Program identifies utility pole (or adjacent poles) that have been struck three times in three years. An additional check for this situation is explicitly called for in the New Jersey Highway Design Manual for new construction or reconstruction.

The New Jersey Utility Accommodation Policy specifically calls for utility poles to be of single wood pole construction. Both breakaway designs and energy absorbing designs would not likely be considered to be of typical wood construction. However, the definition of single wood pole construction mentions only that poles are greater than ten feet apart, and makes no mention of material.

Recommendations

- Adopt a policy that is specific to Utility Poles for identifying high-risk sites and mitigating these. Policy will consider social cost and accident frequency. Bureau of Safety Programs will monitor accident data and develop a list of high-risk sites each year.

- Require designers to consider cost-benefit analysis based on historical societal cost when considering how much right of way to purchase for highway construction or reconstruction.

- Adopt National Guidelines for intersections.

7. Analysis of Utility Pole Crash Statistics in New Jersey

Objective

The goals of the study presented in this chapter are to (1) determine the characteristics of utility pole crashes in New Jersey, and (2) to identify high risk locations for utility pole crashes.

Approach

The analysis will be based upon the 2003-2005 New Jersey Crash Record system and the 2000-2004 Fatality Analysis Reporting System (FARS).

The New Jersey Crash Record system contains summary records of over 300,000 police-reported accidents each year. The information for each accident is extracted from the NJTR-1 New Jersey Police Accident Report. Injury severity for each person is rated using the KABCO scale. K=killed, A=incapacitating injury, B= moderate injury, C= complaint of pain, O=property damage only. Analysis of state accident data will allow investigation of the frequency and severity of all utility pole impacts which occur in the state.

FARS is a comprehensive census of all traffic related fatalities in the U.S. By Federal mandate, all states including New Jersey must collect and provide NHTSA with records of all traffic related fatalities on their highways. FARS will be used to characterize the nature of the fatal pole impact problem in New Jersey based upon accident data. Analysis of FARS will permit comparison of fatal utility pole crashes in New Jersey with other states.

Results

Figure 11 presents the number of fatal crashes and fatalities in New Jersey from 2000-2004 where the most harmful event in the crash was an impact with a utility pole as reported in FARS. Each year in New Jersey, there are approximately 50 fatalities which result from collisions with utility poles. Because some crashes result in multiple fatalities, the annual number of fatalities is slightly higher than the number of fatal crashes each year. This analysis was based upon cases from FARS in which the most harmful event was an impact with a utility pole.

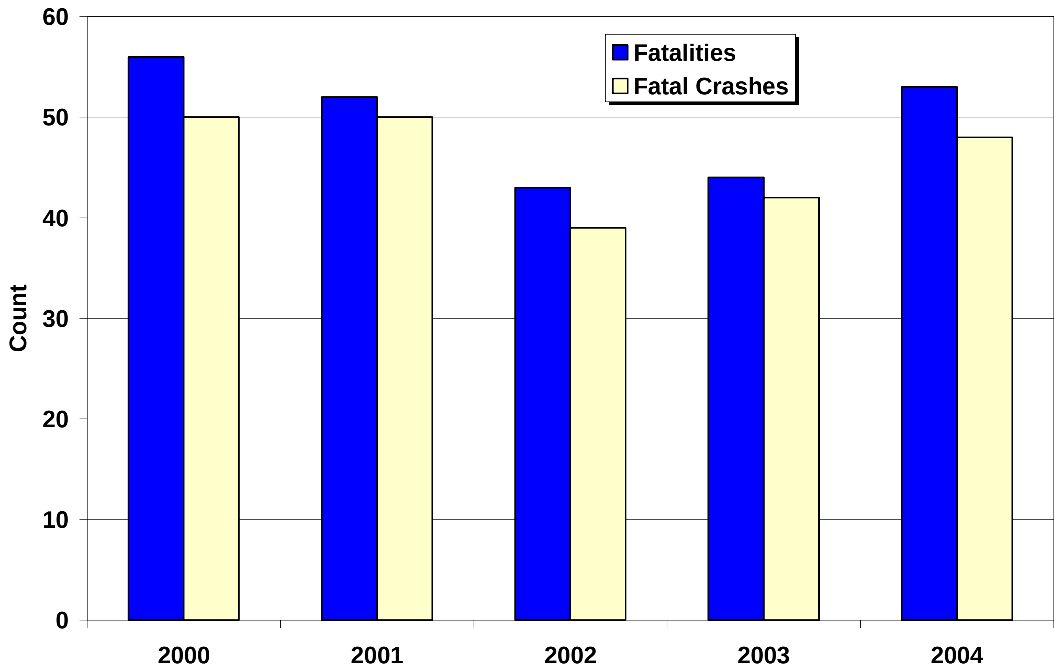


Figure 11. Fatal Utility Pole Crashes in New Jersey (FARS 2000-2004)

Table 20 presents the distribution of all occupants exposed to utility pole crashes by injury severity. The analysis was based upon cases from 2003-2005 NJ Crash Records in which a utility pole impact was one of the events in a crash. Each year, approximately 10,000 vehicle occupants in New Jersey were exposed to crashes involving at least one utility pole impact. Of these occupants approximately 60 persons were fatally injured and 200 persons were incapacitated in utility pole crashes.

Table 20. Utility Pole Crash Injury Severity in New Jersey (NJ 2003-2005)

Occupant Injury Severity	2003	2004	2005
Killed	62	62	57
Incapacitated	206	214	202
Moderate Injury	1,531	1,501	1,368
Complaint of Pain	2,369	2,375	2,381
No Injury	6,244	6,423	6,607
Severity Not Coded	73	54	55
Total	10,485	10,629	, 10,670

Note that the NJ Crash Records report a slightly larger number of fatals than in FARS. Unlike FARS, the NJ Crash Records do not code the most harmful event. Because the utility pole-car interaction may not have been the most harmful event, the number of fatalities involving utility pole impacts recorded in the NJ crash records is similar , but slightly higher than, the number of utility pole-related fatalities reported by FARS.

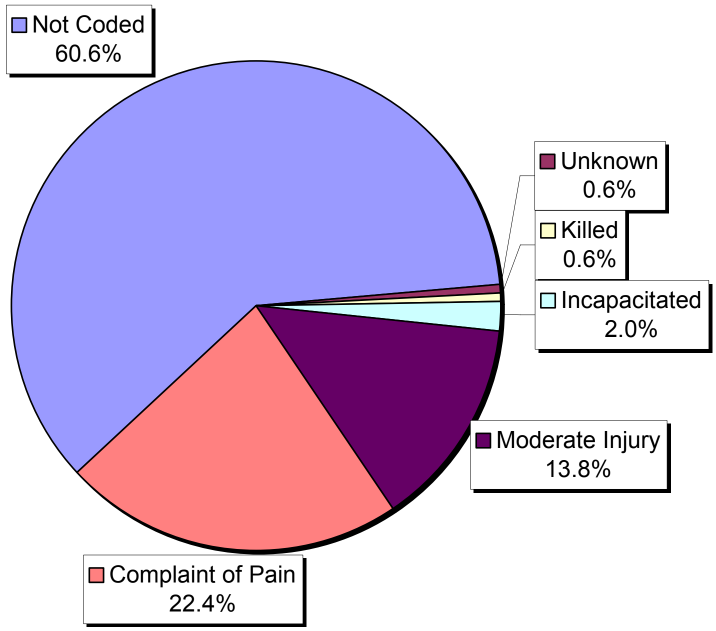


Figure 12. Distribution of Injury Severity in Utility Pole Crashes (NJDOT 2003-2005)

Figure 12 shows the injury severity distribution of police-reported utility pole crashes in NJ. 40% of all occupants exposed to utility pole crashes suffered some level of injury ranging from complaint of pain to death. Fortunately, fatal and incapacitating injuries were rare. Annually, 2.6% of occupants exposed to utility pole crashes received either a fatal or incapacitating injury.

<u>Characteristics of Serious Pole Crashes</u>

Figure 13 presents the distribution of serious pole crashes by road system. For this analysis, serious crashes are defined to be those collisions which resulted in fatal or incapacitating injury. County roads account for most utility pole crashes and most fatalities resulting from utility pole crashes. State highways however are overrepresented in serious utility pole collisions. State highways account for 20% of all utility pole crashes, but 32% of all fatal and incapacitating utility pole crashes.

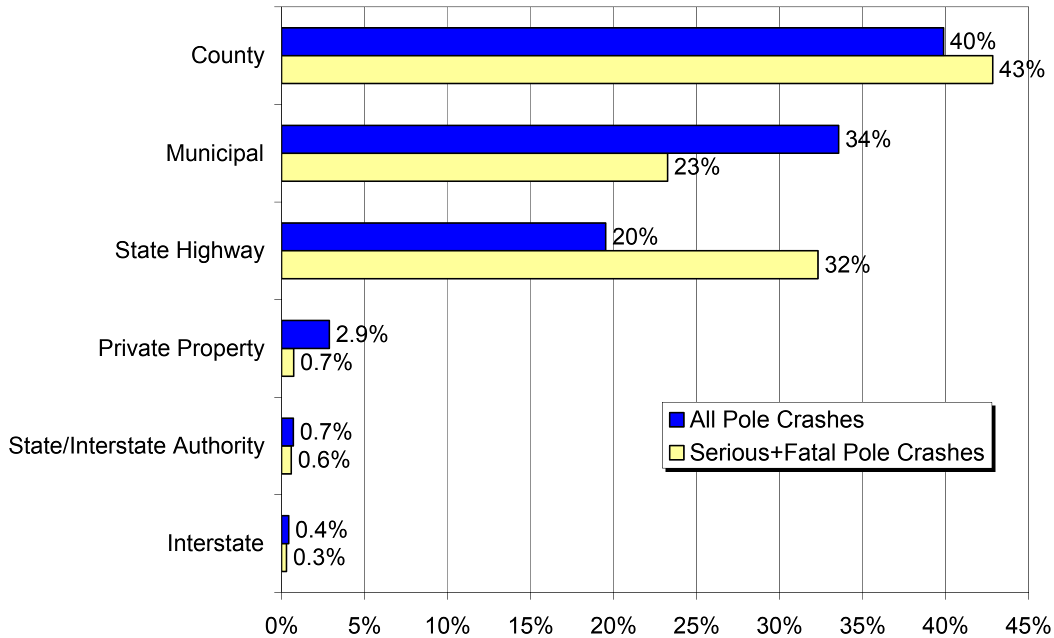


Figure 13. Fatal and Incapacitating Utility Pole Crashes by Road System (NJDOT 2003-2005)

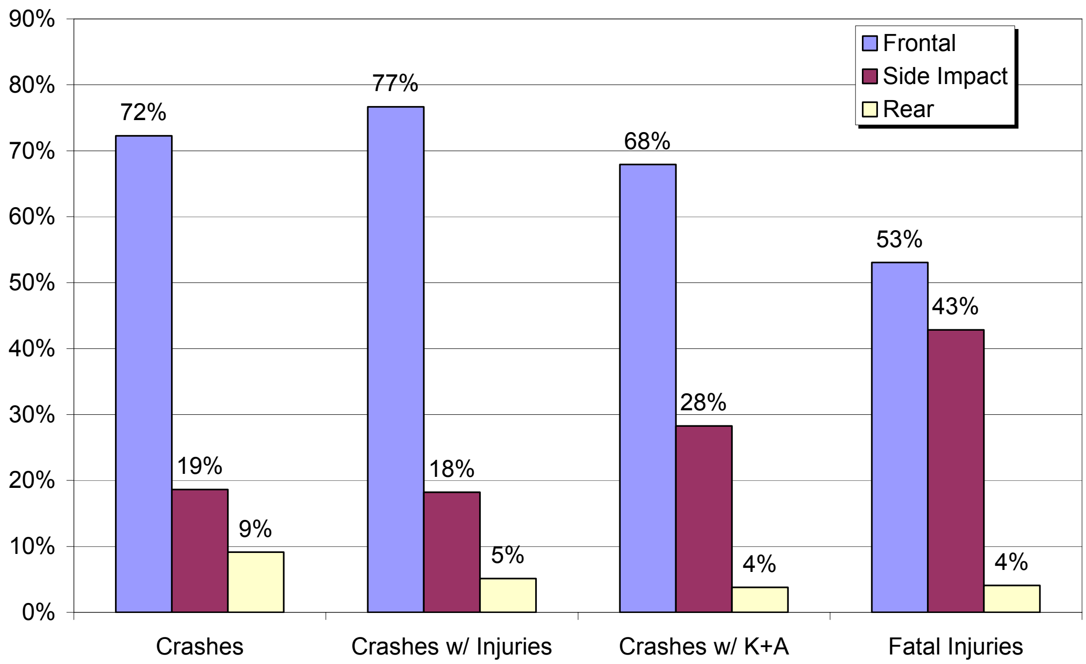


Figure 14. Distribution of Utility Pole Crashes by Crash Mode (NJDOT 2003-2005)

Frontal impacts are most common type of pole impact, but side impacts are the most lethal crash mode. Figure 14 presents the distribution of utility pole crashes by crash mode. Frontal impacts account for 72% while side impacts account for 19% of all utility pole crashes regardless of injury severity. For fatal crashes, however, frontal impacts account for 53% while side impacts account for 43% of all fatal utility pole crashes.

Side impacts are overrepresented in terms of fatality risk. Side impacts are only 19% of all crashes, but result in 43% of all fatal utility pole crashes. One would expect that most poles would be struck by the front of a car. However, if a vehicle loses control and begins to spin, a non-tracking vehicle may actually strike the pole the side or rear. Because the side of a vehicle, unlike the front, has so little structure to protect an occupant, side impacts to poles can be especially dangerous.

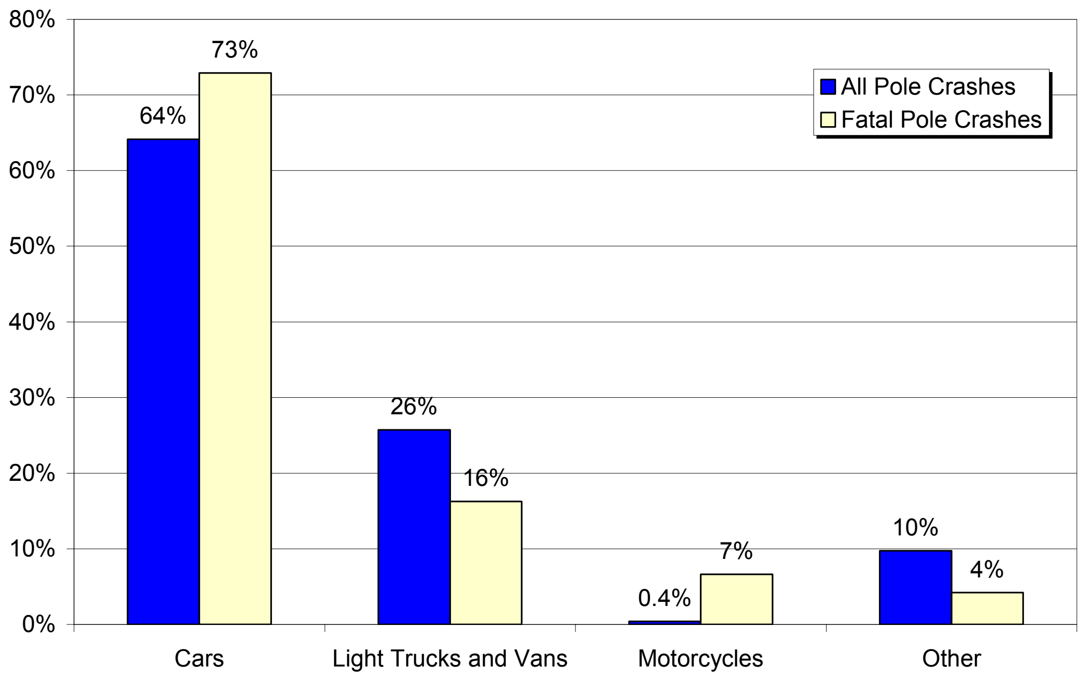


Figure 15. Distribution of Utility Pole Crashes by Vehicle Type (NJDOT 2003-2005)

As shown in Figure 15, cars are the most common vehicle involved in both fatal and non-fatal utility pole crashes, followed by light trucks and vans. Light trucks and vans (LTVs) include SUVs, pickup trucks and vans. Cars are the striking vehicle in approximately 2/3 of the utility pole crashes while light trucks are the striking vehicle in approximately 1/3 of all utility pole crashes. This reflects the composition of registered cars and LTVs in the fleet. Motorcyclists are overrepresented in fatal utility pole crashes. Motorcycles are involved in less than one-half of a percent of utility pole crashes, but were the striking vehicle in 7% of all fatal crashes.

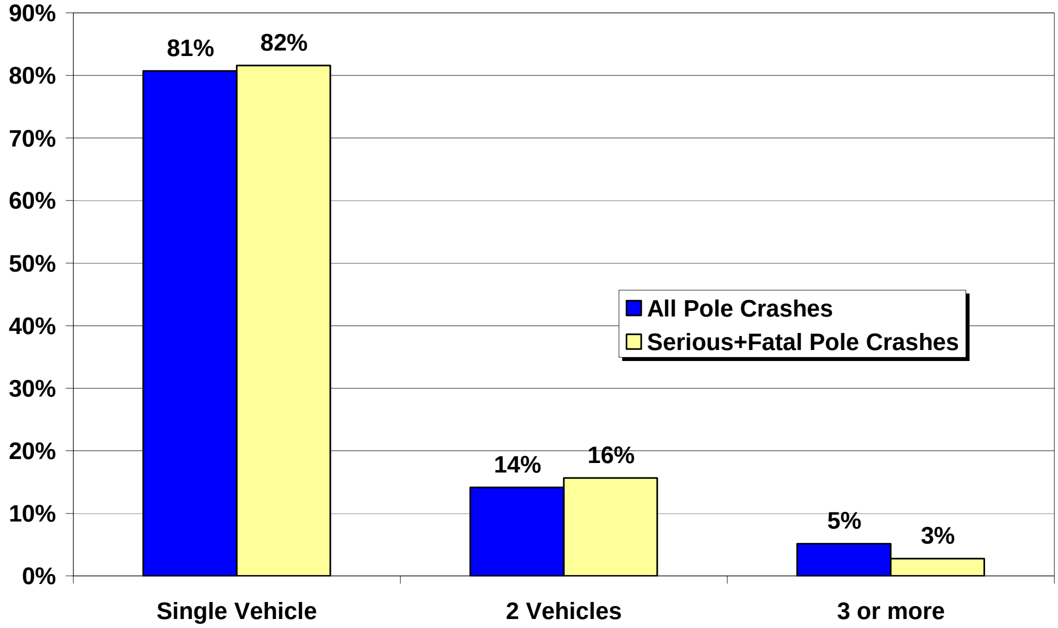


Figure 16. Distribution of Utility Pole Crashes by Number of Vehicles Involved (NJDOT 2003-2005)

Most utility pole crashes are single vehicle-single pole impacts. As shown in Figure 16, over 80% of all utility pole crashes involved only a single vehicle. Likewise, as shown in Table 21, most crashes involved an impact with only a single utility pole. It is interesting to note though that during 2003-2005, over 150 crashes involved impacts with multiple utility poles.

Table 21. Distribution of Utility Pole Impacts per Crash (NJDOT 2003-2005)

Number of Pole Impacts	All Crashes	Fatal Crashes
1	24070	164
2	157	2
3	3	-
4	2	-

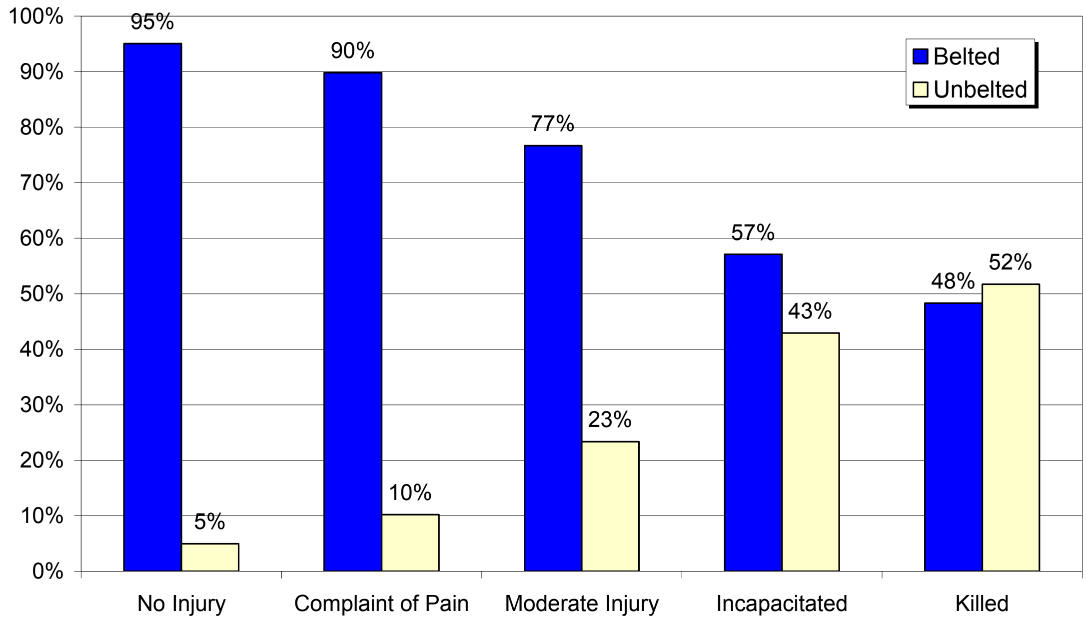


Figure 17. Distribution of Injuries in Utility Pole Crashes by Restraint Use (NJDOT 2003-2005)

Most of the fatally-injured occupants in utility pole crashes were not wearing their safety belts. In the U.S., safety belt use rate is now over 80% [88]. Figure 7 shows that 95% of all uninjured occupants were wearing their seat belts. We see however that as belt use drops off, injury severity increases. Over half of all fatally-injured occupants were not wearing their belts. This figure demonstrates the importance of aggressive enforcement of safety belt laws.

Conclusions

This analysis has investigated New Jersey crash experience in utility pole collisions. The analysis was based on New Jersey Crash Records from 2003-2005 and FARS 2000-2004.

1. Each year in New Jersey, approximately 10,000 vehicle occupants are exposed to crashes involving a utility pole impacts. In these collisions, approximately 50-60 persons were fatally injured and 200 persons were incapacitated.

2. 40% of all occupants exposed to utility pole crashes suffered some level of injury ranging from complaint of pain to death. Fortunately, fatal and incapacitating injuries were rare. Annually, 2.6% of occupants exposed to utility pole crashes received either a fatal or incapacitating injury.

3. County roads account for most utility pole crashes and most utility pole crash fatalities. State highways however are overrepresented in serious utility pole collisions. State highways account for 20% of all utility pole crashes, but 32% of all fatal and incapacitating utility pole crashes.

4. Frontal impacts are most common type of pole impact, but side impacts are the most lethal crash mode. Side impacts are only 19% of all utility pole crashes, but result in 43% of all fatal utility pole crashes. Because energy-absorbing and breakaway poles are designed for frontal impacts, this countermeasure may not be as effective in protecting against side impacts into poles.

5. Motorcyclists are overrepresented in fatal utility pole crashes. Motorcycles are involved in less than one-half of a percent of utility pole crashes, but were the striking vehicle in 7% of all fatal crashes. Because energy-absorbing and breakaway poles are designed for activation by cars, it is unlikely that this countermeasure will be effective in protecting motorcyclists.

8. Identification of High Risk Utility Pole Crash Sites

Objective

This section uses New Jersey accident statistics to identify high risk locations for utility pole impacts on state highways. This analysis is a common component of most state safety initiatives to reduce utility pole crash injuries, and is of enormous value in setting remediation priorities for existing utility pole sites.

Risk Metrics

This section describes the methodology and results of rank ordering utility pole crash sites by risk. The following four priority ranking metrics were considered:

1. Crash Frequency
2. Number of Seriously Injured Persons or Crashes with Serious Injuries
3. 5-4-3-2-1 ranking based on the KABCO scale
4. Social Cost - using FHWA costs of crashes normalized to the cost of a fatality

Crash frequency is simply a count of collisions with a utility pole which have occurred at a given location over a three year period. Ranking by serious injuries tallies the number of persons who have suffered either a fatal or incapacitating injuries in a utility pole crash. Both fatal and incapacitating injuries have equal weights under this scheme. Less severe injuries are not considered.

As shown in Table 22, the 5-4-3-2-1 metric assigns the scores to each injury severity level. A fatality would be given a score of 5, while a crash involving property damage but no injury would only receive a score of 1. The advantage of this metric is that it considers all injury levels and assigns a greater weight to fatalities than to less severe injuries. The concern is that the weighting scheme does not reflect common perceptions of risk. The scale suggests that the NJDOT should view a death as equal to 5 fender-benders.

Table 22. KABCO 5-4-3-2-1 Weighting Scheme

KABCO Code	Injury Severity	Score
K	Killed	5
A	Incapacitated	4
B	Moderate Injury	3
C	Complaint of Pain	2
O	Property Damage Only	1

The Social Cost metric assigns the costs tabulated in Table 23 to each level of injury severity as coded using the KABCO injury scale. The costs are in 2002 dollars as based on FHWA Technical Advisory T 7570.2, "Motor Vehicle Accident

Costs" [89]. Costs / injury in this report are in 1994 dollars. In 2002, USDOT recommended using a figure of $3,000,000 as the cost of a fatality [90]. This 15% increase in costs was based on the GDP Deflator value.

Table 23. KABCO Social Costs

Injury Severity	Cost ($)	Cost normalized to one Fatality
Killed	3,000,000	1.0
Incapacitated	208,000	0.069231
Moderate Injury	42,000	0.013846
Complaint of Pain	22,000	0.007308
Property Damage Only	2,300	0.000769

These costs per injury can be used to compute a cost at each pole impact site. Table 26 which follows contains a column labeled Social Cost. Social Cost is the total costs of all injuries incurred at a particular site. The costs have been normalized to the cost of a single fatality. Hence, costs are in units of Effective Fatality Units or EFUs. To determine the injury costs at a site, each EFU should be multiplied by $3,000,000.

The metrics can be applied either to the number of injured persons or to the number of crashes. The two methods may assign different priorities to sites if there were multiple fatalities or persons injured in a crash. For example, the number of fatalities at a site may be different than the number of fatal crashes at a site. In this analysis, we provide both sets of priority rankings.

Methodology for Ranking by Injured Person

Using each scheme, we rank ordered all crashes involving utility poles based on NJ data from 2003-2005. Each crash location was identified by (a) the milepost (MP) for all crash locations broken down into 1/10 mile increments, and (b) the direction of travel. Each of the ranking metrics described above was computed for each crash involving a utility pole, and aggregated by crash location.

After applying this methodology to the NJ 2003-2005 accident data, the result was a spreadsheet of over 13,000 crash locations. The ranking metrics described above were computed for each of the 13,000 sites, and then sorted by risk. Table 24, Table 25, and Table 26 present the top 25 sites as ranked by each metric. Note that several locations may be tied using these metrics. The full 13,000 site spreadsheet has been provided electronically to the Project Panel.

Table 24. Highest Risk NJ Pole Crashes Ranked by 5-4-3-2-1 Score (2003-2005)

Crash Location	Mile Post	Direction of Travel	County	Number Occupants killed	Number Occupants incapacitated	Number Occupants with moderate injury	Number Occupants with complaint of pain	Number Occupants with no injury	Number Occupants with unknown injury	Number of PDO Pole Crashes	Number of Pole Crashes	Score (5-4-3-2-1)	Priority (5-4-3-2-1)
DIXONTOWN RD	1.5	East	BURLINGTON	0	0	18	14	3	0	0	1	82	1
US 22	51.5	West	UNION	0	3	4	2	3	0	3	8	31	2
US 30	43.5	West	ATLANTIC	0	0	0	14	0	0	0	1	28	3
NJ 347	0.6	North	CAPE MAY	2	3	0	0	1	0	0	1	22	4
ROUTE 513	42.3	South	MORRIS	1	0	2	4	3	0	2	8	21	5
NJ 4	8.1	West	BERGEN	0	2	2	0	6	0	4	6	18	6
US 30	2.4	East	CAMDEN	0	0	1	7	2	0	1	5	18	6
US 9	74.6	South	OCEAN	2	2	0	0	0	0	0	1	18	6
US 1	11.2	North	MERCER	0	0	3	3	3	0	2	4	17	7
US 46	44.7	East	MORRIS	1	0	2	2	4	0	2	7	17	7
I-295	0.8	West	SALEM	1	2	1	0	0	0	0	1	16	8
NJ 29	23	South	HUNTERDON	0	4	0	0	0	0	0	1	16	8
NJ 38	2.4	West	CAMDEN	1	2	1	0	0	0	0	1	16	8
ROUTE 528	26.9	West	OCEAN	0	0	2	5	0	0	0	2	16	8
ROUTE 549 SPUR 2	3.1	North	OCEAN	0	1	4	0	0	0	0	1	16	8
US 30	48.8	East	ATLANTIC	0	4	0	0	0	0	0	2	16	8
ESSEX COUNTY 621	0.8	North	ESSEX	0	1	3	1	2	0	0	4	15	9
ROUTE 524	19.2	West	MONMOUTH	1	0	2	2	1	0	0	1	15	9
US 1 TRUCK	2.2	East	HUDSON	0	1	2	2	2	0	1	2	15	9
US 22	46.5	West	SOMERSET	0	0	5	0	0	0	0	1	15	9
PARK ST	2	West	ESSEX	0	0	4	1	0	0	0	1	14	10
ROUTE 522	7.3	West	MIDDLESEX	2	1	0	0	0	0	0	1	14	10
SOMERSET COUNTY 651	0.6	South	SOMERSET	0	0	2	3	4	0	2	7	14	10
US 1	11.4	North	MERCER	0	1	3	0	2	0	1	3	14	10
US 1	64	North	BERGEN	0	2	2	0	0	0	0	2	14	10

Table 25. Highest Risk NJ Pole Crash Sites Ranked by Number of Killed and Incapacitated Occupants (2003-2005)

Crash Location	Mile Post	Direction of Travel	County	Number Occupants killed	Number Occupants incapacitated	Number Occupants with moderate injury	Number Occupants with complaint of pain	Number Occupants with no injury	Number Occupants with unknown injury	Number of PDO Pole Crashes	Number of Pole Crashes	Score (K+A)	Priority (K+A)
NJ 347	0.6	North	CAPE MAY	2	3	0	0	1	0	0	1	5	1
US 9	74.6	South	OCEAN	2	2	0	0	0	0	0	1	4	2
NJ 29	23	South	HUNTERDON	0	4	0	0	0	0	0	1	4	2
US 30	48.8	East	ATLANTIC	0	4	0	0	0	0	0	2	4	2
US 22	51.5	West	UNION	0	3	4	2	3	0	3	8	3	3
I-295	0.8	West	SALEM	1	2	1	0	0	0	0	1	3	3
NJ 38	2.4	West	CAMDEN	1	2	1	0	0	0	0	1	3	3
ROUTE 522	7.3	West	MIDDLESEX	2	1	0	0	0	0	0	1	3	3
BERGEN COUNTY 102 I	0.5	East	BERGEN	1	2	0	0	0	0	0	1	3	3
MIDDLESEX COUNTY 675 I	1.8	South	MIDDLESEX	1	2	0	0	0	0	0	1	3	3
NJ 35	29.6	East	MONMOUTH	1	2	0	0	0	0	0	1	3	3
OCEAN COUNTY 641	0.9	West	OCEAN	1	2	0	0	0	0	0	1	3	3
US 22	56.7	East	UNION	0	3	0	0	1	0	1	2	3	3
US 322	30.2	West	GLOUCESTER	1	2	0	0	0	0	0	2	3	3
US 9	41.5	North	ATLANTIC	1	2	0	0	0	0	0	1	3	3
NJ 4	8.1	West	BERGEN	0	2	2	0	6	0	4	6	2	4
US 1	64	North	BERGEN	0	2	2	0	0	0	0	2	2	4
US 22	50	West	UNION	0	2	2	0	0	0	0	2	2	4
NJ 4	3.8	West	BERGEN	2	0	1	0	0	0	0	1	2	4
NJ 73	32.6	North	CAMDEN	2	0	1	0	0	0	0	2	2	4
ROUTE 514	40.5	West	UNION	1	1	0	2	0	0	0	1	2	4
US 46	41.5	East	MORRIS	1	1	0	2	0	0	0	2	2	4
BURLINGTON COUNTY 656	1.6	North	BURLINGTON	0	2	0	2	0	0	0	1	2	4
NJ 31	1.1	South	MERCER	0	2	0	2	0	0	0	3	2	4
OCEAN COUNTY 601	2.4	South	OCEAN	0	2	1	0	1	0	1	2	2	4

Table 26. Highest Risk NJ Pole Crash Sites Ranked by Social Cost (2003-2005)

Crash Location	MilePost	Direction of Travel	County	Number Occupants killed	Number Occupants incapacitated	Number Occupants with moderate injury	Number Occupants with complaint of pain	Number Occupants with no injury	Number Occupants with unknown injury	Number of PDO Pole Crashes	Number of Pole Crashes	Social Cost (EFUs)	Priority (EFUs)
NJ 347	0.6	North	CAPE MAY	2	3	0	0	1	0	0	1	2.208	1
US 9	74.6	South	OCEAN	2	2	0	0	0	0	0	1	2.138	2
ROUTE 522	7.3	West	MIDDLESEX	2	1	0	0	0	0	0	1	2.069	3
NJ 4	3.8	West	BERGEN	2	0	1	0	0	0	0	1	2.014	4
NJ 73	32.6	North	CAMDEN	2	0	1	0	0	0	0	2	2.014	4
CHESTNUT AVE	0.4	West	CUMBERLAND	2	0	0	0	1	0	1	2	2.001	5
NJ 3	0.1	South	PASSAIC	2	0	0	0	0	0	0	1	2.000	6
NJ 35	54.3	North	MIDDLESEX	2	0	0	0	0	0	0	1	2.000	6
NJ 72	16.5	South	OCEAN	2	0	0	0	0	0	0	1	2.000	6
US 206	35.6	North	BURLINGTON	2	0	0	0	0	0	0	1	2.000	6
US 9	101.4	North	OCEAN	2	0	0	0	0	0	0	1	2.000	6
I-295	0.8	West	SALEM	1	2	1	0	0	0	0	1	1.152	7
NJ 38	2.4	West	CAMDEN	1	2	1	0	0	0	0	1	1.152	7
BERGEN COUNTY 102 I	0.5	East	BERGEN	1	2	0	0	0	0	0	1	1.138	8
MIDDLESEX COUNTY 675 I	1.8	South	MIDDLESEX	1	2	0	0	0	0	0	1	1.138	8
NJ 35	29.6	East	MONMOUTH	1	2	0	0	0	0	0	1	1.138	8
OCEAN COUNTY 641	0.9	West	OCEAN	1	2	0	0	0	0	0	1	1.138	8
US 322	30.2	West	GLOUCESTER	1	2	0	0	0	0	0	2	1.138	8
US 9	41.5	North	ATLANTIC	1	2	0	0	0	0	0	1	1.138	8
ROUTE 514	40.5	West	UNION	1	1	0	2	0	0	0	1	1.084	9
US 46	41.5	East	MORRIS	1	1	0	2	0	0	0	2	1.084	9
BURLINGTON COUNTY 616	4.9	West	BURLINGTON	1	1	0	1	1	0	0	2	1.077	10
MORRIS COUNTY 607	1.1	North	MORRIS	1	1	0	0	0	0	0	1	1.069	11
NJ 17	10	North	BERGEN	1	1	0	0	0	0	0	1	1.069	11
NJ 3	3.4	East	PASSAIC	1	1	0	0	0	0	0	1	1.069	11

Methodology for Ranking by Crash

In a separate analysis, utility pole crashes were ranked by the most severe injury that incurred in the accident. As in the ranking by injured person, the ranking was based on NJ Crash Statistics from 2003-2005. This analysis used the following three metrics:

- Ranking by 5-4-3-2-1. This metric assigns 5 to a fatal crash, 4 to a crash where the most severe injury was an incapacitating injury and so forth.
- Ranking by number of fatal or incapacitating crashes. Crashes in which a person was seriously injured – either killed (K) or incapacitated (A).
- Ranking by Crash Frequency

Each metric has advantages and disadvantages. We recommend use of the 5-4-3-2-1 metric and crash frequency metric. The 5-4-3-2-1 metric provides a balance between crash severity and crash frequency. The Crash Frequency metric may highlight crash sites with a potential utility pole problem. A location with a high crash frequency, but no fatalities, may simply have been fortunate - the next crash could result in serious injuries.

After applying this methodology to the NJCRASH 2003-2005 data, the result was a second 13,000 spreadsheet of crash locations. This spreadsheet was provided electronically to the Project Panel. Table 27, Table 28, and Table 29 present the top 20-30 locations using each metric. Note that several locations may be tied using these metrics. For example, in the ranking by number of fatal or incapacitating crashes, only 3 scores were observed – 0, 1, or 2. This lack of differentiation between crash sites is one drawback of using fatal or incapacitating crashes as a risk metric.

Conclusions and Recommendations

1. After evaluating the relative ranking of each of these metrics, our recommendation is that NJDOT should use two metrics in parallel. The Social Cost metric proves an excellent measure of sites requiring immediate remediation while the Crash Frequency metric provides targets for a longer-term remediation plan. Following is the justification for these two metrics:

- <u>Social Cost metri</u>c - Because the social cost metric uses injury costs, it assigns a greater risk to sites where there have been a number of fatal or incapacitating injuries. These are targets for near-term remediation.

- <u>Crash Frequency metric</u> - identifies sites with a frequent, although not necessarily fatal, collision problem. Because of their high crash frequency, these may be sites where we have simply been fortunate that a serious or fatal collision has not occurred. These are targets for long-term remediation possibly as part of an ongoing program of highway risk remediation.

2. Using all methods, U.S. Highway 22 is ranked as having a serious utility pole impact problem. In the next chapter, the report describes field visits to utility pole impact sites on this highway to determine factors leading to the elevated crash risk. Our preliminary conclusion is that this highway, especially the stretch between MP 46 and MP 56, should be considered for remediation of the pole impact problem.

Table 27. Highest Risk NJ Pole Crash Sites Ranked by 5-4-3-2-1 Crash Score (2003-2005)

Crash Location	Mile Post	Direction of Travel	County	Number of Fatal Pole Crashes	Number of Incapacitating Pole Crashes	Number of Pole Crashes - Moderate Injury	Number of Pole Crashes - Complaint of Pain	Number of PDO-only Pole Crashes	Number of Pole Crashes	Score (5-4-3-2-1)	Priority (5-4-3-2-1)
ROUTE 513	42.3	South	MORRIS	1	0	2	3	2	8	19	1
US 22	51.5	West	UNION	0	1	3	1	3	8	18	2
US 46	44.7	East	MORRIS	1	0	2	2	2	7	17	3
SOMERSET COUNTY 651	0.6	South	SOMERSET	0	0	2	3	2	7	14	4
US 30	2.9	West	CAMDEN	0	1	2	1	2	6	14	4
ESSEX COUNTY 621	0.8	North	ESSEX	0	1	2	1	0	4	12	5
NJ 4	8.1	West	BERGEN	0	1	1	0	4	6	11	6
NJ 18	39.2	South	MIDDLESEX	0	0	1	2	3	6	10	7
NJ 35	52.3	South	MIDDLESEX	0	0	2	1	2	5	10	7
US 130	36.6	South	BURLINGTON	0	0	3	0	1	4	10	7
US 22	52.6	East	UNION	1	0	0	2	1	4	10	7
US 30	2.4	East	CAMDEN	0	0	1	3	1	5	10	7
ROUTE 513	42.3	North	MORRIS	0	0	1	1	4	6	9	8
US 1	39.2	South	UNION	0	0	2	1	1	4	9	8
US 1	41.5	South	UNION	1	1	0	0	0	2	9	8
US 22	35.9	West	SOMERSET	1	0	1	0	1	3	9	8
US 30	2.8	West	CAMDEN	0	0	1	2	2	5	9	8
US 30	54	East	ATLANTIC	0	0	2	1	1	4	9	8
US 322	30.2	West	GLOUCESTER	1	1	0	0	0	2	9	8
US 40	60.3	East	ATLANTIC	0	0	0	4	1	5	9	8
US 9	35.5	South	ATLANTIC	0	0	2	1	1	4	9	8
US 9	98.7	North	OCEAN	0	0	1	1	4	6	9	8
BROOK LAKE RD	0.4	East	MORRIS	0	0	1	0	5	6	8	9
KLOCKNER RD	1.3	South	MERCER	0	0	2	1	0	3	8	9
NJ 24	10	West	UNION	0	0	0	4	0	4	8	9
NJ 3	0.5	West	PASSAIC	0	0	1	2	1	4	8	9
NJ 3	2.6	East	PASSAIC	1	0	1	0	0	2	8	9

Crash Location	Mile Post	Direction of Travel	County	Number of Fatal Pole Crashes	Number of Incapacitating Pole Crashes	Number of Pole Crashes - Moderate Injury	Number of Pole Crashes - Complaint of Pain	Number of PDO-only Pole Crashes	Number of Pole Crashes	Score (5-4-3-2-1)	Priority (5-4-3-2-1)
NJ 31	1.1	South	MERCER	0	1	0	2	0	3	8	9
NJ 34	2.6	North	MONMOUTH	0	0	2	1	0	3	8	9
NJ 73	32.6	North	CAMDEN	1	0	1	0	0	2	8	9
NJ 88	3.5	West	OCEAN	0	0	2	0	2	4	8	9
ROUTE 501	35.4	South	HUDSON	0	0	0	4	0	4	8	9
ROUTE 508	4.5	West	ESSEX	0	1	1	0	1	3	8	9
ROUTE 514	19.8	West	SOMERSET	1	0	1	0	0	2	8	9
ROUTE 528	16	West	OCEAN	0	0	2	0	2	4	8	9
SOMERSET COUNTY 623	0.8	North	SOMERSET	0	1	0	1	2	4	8	9
US 1	11.4	North	MERCER	0	1	1	0	1	3	8	9
US 1	42.5	North	UNION	0	1	0	2	0	3	8	9
US 30	43	East	ATLANTIC	0	1	0	2	0	3	8	9
US 30	48.8	East	ATLANTIC	0	2	0	0	0	2	8	9
US 322	29.3	East	GLOUCESTER	1	0	1	0	0	2	8	9
US 322	38.3	West	ATLANTIC	0	2	0	0	0	2	8	9

Table 28. Highest Risk NJ Pole Crash Sites Ranked by Number of Fatal or Incapacitating Crashes (2003-2005)

Crash Location	Mile Post	Direction of Travel	County	Number of Fatal Pole Crashes	Number of Incapacitating Pole Crashes	Number of Pole Crashes - Moderate Injury	Number of Pole Crashes - Complaint of Pain	Number of PDO-only Pole Crashes	Number of Pole Crashes	Score (K+A) Crashes	Priority (K+A) Crashes
US 1	41.5	South	UNION	1	1	0	0	0	2	2	1
US 30	48.8	East	ATLANTIC	0	2	0	0	0	2	2	1
US 322	30.2	West	GLOUCESTER	1	1	0	0	0	2	2	1
US 322	38.3	West	ATLANTIC	0	2	0	0	0	2	2	1
ATLANTIC COUNTY 608	2.5	East	ATLANTIC	0	1	0	0	0	1	1	2
ATLANTIC COUNTY 629	5.1	West	ATLANTIC	0	1	0	0	0	1	1	2
ATLANTIC COUNTY 634	5.3	South	ATLANTIC	0	1	0	0	0	1	1	2
ATLANTIC COUNTY 637	0.4	East	ATLANTIC	0	1	0	0	0	1	1	2
ATLANTIC COUNTY 647	3	West	ATLANTIC	0	1	0	0	0	1	1	2
ATLANTIC COUNTY 662	4.8	South	ATLANTIC	0	1	0	0	0	1	1	2
ATLANTIC COUNTY 669	0.3	East	ATLANTIC	0	1	0	0	0	1	1	2
ATLANTIC COUNTY 685	1.8	North	ATLANTIC	0	1	0	0	0	1	1	2
BELLEVUE AVE	1.1	West	ESSEX	0	1	0	0	0	1	1	2
BERGEN COUNTY 102 I	0.5	East	BERGEN	1	0	0	0	0	1	1	2
BERGEN COUNTY 102 I	0.8	West	BERGEN	1	0	0	0	0	1	1	2
BERGEN COUNTY 110 II	5	West	BERGEN	0	1	0	0	0	1	1	2
BERGEN COUNTY 17	1.8	North	BERGEN	0	1	0	0	0	1	1	2
BERGEN COUNTY 38	0.2	South	BERGEN	0	1	0	0	0	1	1	2
BERGEN COUNTY 40 I	1.8	East	BERGEN	0	1	0	0	0	1	1	2
BERGEN COUNTY 53	2.4	South	BERGEN	0	1	0	0	1	2	1	2
BERGEN COUNTY 55	4.2	North	BERGEN	0	1	0	0	0	1	1	2
BERGEN COUNTY 55	5	South	BERGEN	0	1	0	0	0	1	1	2
BERGEN COUNTY 56 I	1.9	West	BERGEN	1	0	0	0	0	1	1	2
BERGEN COUNTY 56 I	3.5	West	BERGEN	0	1	0	0	0	1	1	2
BERGEN COUNTY 56 III	3.6	West	BERGEN	0	1	0	0	0	1	1	2
BERGEN COUNTY 57	1	North	BERGEN	0	1	0	0	0	1	1	2

Table 29. Highest Risk NJ Pole Crash Sites Ranked by Crash Frequency (2003-2005)

Crash Location	Mile Post	Direction of Travel	County	Number of Fatal Pole Crashes	Number of Incapacitating Pole Crashes	Number of Pole Crashes - Moderate Injury	Number of Pole Crashes - Complaint of Pain	Number of PDO-only Pole Crashes	Number of Pole Crashes	Score Number Crashes	Priority Number Crashes
ROUTE 513	42.3	South	MORRIS	1	0	2	3	2	8	8	1
US 22	51.5	West	UNION	0	1	3	1	3	8	8	1
SOMERSET COUNTY 651	0.6	South	SOMERSET	0	0	2	3	2	7	7	2
US 46	44.7	East	MORRIS	1	0	2	2	2	7	7	2
BROOK LAKE RD	0.4	East	MORRIS	0	0	1	0	5	6	6	3
NJ 18	39.2	South	MIDDLESEX	0	0	1	2	3	6	6	3
NJ 4	8.1	West	BERGEN	0	1	1	0	4	6	6	3
ROUTE 513	42.3	North	MORRIS	0	0	1	1	4	6	6	3
US 30	2.9	West	CAMDEN	0	1	2	1	2	6	6	3
US 9	98.7	North	OCEAN	0	0	1	1	4	6	6	3
NJ 18	36.2	South	MIDDLESEX	0	0	0	1	4	5	5	4
NJ 35	52.3	South	MIDDLESEX	0	0	2	1	2	5	5	4
US 130	46.3	West	BURLINGTON	0	0	0	1	4	5	5	4
US 202	74.5	North	BERGEN	0	0	0	0	5	5	5	4
US 30	2.4	East	CAMDEN	0	0	1	3	1	5	5	4
US 30	2.8	West	CAMDEN	0	0	1	2	2	5	5	4
US 40	60.3	East	ATLANTIC	0	0	0	4	1	5	5	4
ESSEX COUNTY 621	0.8	North	ESSEX	0	1	2	1	0	4	4	5
GARDEN STATE PARKWAY	161.8	South	BERGEN	0	0	1	1	2	4	4	5
GLOUCESTER COUNTY 603	3.3	East	GLOUCESTER	0	0	1	1	2	4	4	5
MERCER COUNTY 634	2.1	West	MERCER	0	0	1	1	2	4	4	5
MIDDLESEX COUNTY 605	0.2	North	MIDDLESEX	0	0	0	1	3	4	4	5
MORRIS COUNTY 661	0.4	South	MORRIS	0	0	1	0	3	4	4	5
NJ 17	14.4	South	BERGEN	0	0	1	0	3	4	4	5
NJ 20	1.2	South	PASSAIC	0	0	1	0	3	4	4	5
NJ 24	10	West	UNION	0	0	0	4	0	4	4	5
NJ 27	31.5	East	UNION	0	0	1	1	2	4	4	5

Crash Location	Mile Post	Direction of Travel	County	Number of Fatal Pole Crashes	Number of Incapacitating Pole Crashes	Number of Pole Crashes - Moderate Injury	Number of Pole Crashes - Complaint of Pain	Number of PDO-only Pole Crashes	Number of Pole Crashes	Score Number Crashes	Priority Number Crashes
NJ 3	0.5	West	PASSAIC	0	0	1	2	1	4	4	5
NJ 33	2.8	West	MERCER	0	0	0	1	3	4	4	5
NJ 70	0	West	CAMDEN	0	0	0	1	3	4	4	5
NJ 82	1.3	East	UNION	0	0	0	1	3	4	4	5
NJ 88	3.5	West	OCEAN	0	0	2	0	2	4	4	5
PASSAIC COUNTY 681	3.5	South	PASSAIC	0	0	1	0	3	4	4	5
PASSAIC COUNTY 693	6.5	North	PASSAIC	0	0	0	2	2	4	4	5
ROUTE 501	35.4	South	HUDSON	0	0	0	4	0	4	4	5
ROUTE 502	23	West	BERGEN	0	0	0	1	3	4	4	5
ROUTE 504	8	East	PASSAIC	0	0	0	1	3	4	4	5
ROUTE 504	12.1	East	PASSAIC	0	0	0	0	4	4	4	5
ROUTE 527	20.7	South	MONMOUTH	0	0	0	0	4	4	4	5
ROUTE 528	16	West	OCEAN	0	0	2	0	2	4	4	5
ROUTE 530	6.1	West	BURLINGTON	0	0	0	0	4	4	4	5
ROUTE 541	23	South	BURLINGTON	0	0	0	1	3	4	4	5
SOMERSET COUNTY 623	0.8	North	SOMERSET	0	1	0	1	2	4	4	5
US 1	11.2	North	MERCER	0	0	1	1	2	4	4	5
US 1	37.1	North	MIDDLESEX	0	0	0	2	2	4	4	5
US 1	39.2	South	UNION	0	0	2	1	1	4	4	5
US 130	36.6	South	BURLINGTON	0	0	3	0	1	4	4	5
US 22	0.6	East	WARREN	0	0	0	0	4	4	4	5
US 22	52.6	East	UNION	1	0	0	2	1	4	4	5
US 22	53.8	East	UNION	0	0	1	1	2	4	4	5
US 30	54	East	ATLANTIC	0	0	2	1	1	4	4	5
US 30	54.1	East	ATLANTIC	0	0	0	3	1	4	4	5
US 9	35.5	South	ATLANTIC	0	0	2	1	1	4	4	5

9. Site Visits of High Risk Utility Pole Crash Locations

Several locations were chosen for site visits. In general, sites were identified because they had a significant number of accidents, one or more fatalities or type A injuries, or were near other sites of interest. A summary of selected sites that were visited is given in Table 30. The speed limit and ADT were obtained from New Jersey Straight-Line diagrams.

Table 30. Summary of Utilty Pole Site Visit Locations

Route	Mile Post	Speed Limit (MPH)	Average Daily Traffic (Veh/Day)	Accidents	Total Cost	Cost/Accident
9	41.5	35	9,388	1	$3,415,400	$3,415,400
18	39.2	45	96,128	6	$92,200	$15,367
22	36	55	87,729	3	$129,100	$43,033
	43.8	50	61,952	1	$3,000,000	$3,000,000
	51.5	45	61,914	9	$842,100	$93,567
	52.6	45	61,914	6	$3,378,300	$563,050
30	2.9	45	73,666	6	$317,200	$52,867
38	2.4	50	54,549	1	$3,456,900	$3,456,900
	2.6	50	54,549	2	$3,210,000	$1,605,000
49	3.5	40	13,600	2	$4,600	$2,300
	6.2	50	14,500	2	$85,300	$42,650
	7.0	50	14,500	3	$251,500	$83,833
	12.5	35	9,000	1	$3,000,000	$3,000,000
73	32.6	50	41,252	2	$6,461,500	$3,230,750
168	7.7	40	28,171	2	$46,100	$23,500
	9.9	45	22,694	1	$21,900	$21.900

Route 22, Milepost 36

Mile Post 36 on Route 22 had three utility pole accidents from 2003-2005. These are summarized in Table 31. The posted speed limit is 55 MPH, and the ADT is 87,729 vehicles per day. Measurements of specific poles near this mile post are given in Table 32. Note that Poles 65613BW and 68223BWT are before and after a turn off. The position of both of these poles is potentially troublesome.

Table 31. Summary of accidents at MP 36.0 on Route 22

Occupant Injury	Number	Cost
Killed	0	-
A	0	-
B	2	$83,000
C	2	$43,800
PDO	1	$2,300
Total Accidents	3	$129,100
Cost/Accident		$43,033

Table 32. Summary of measurements of specific poles near MP 36.0 on Route 22

Pole ID	Pole Diameter	Curb Offset	Travel Lane Offset
65614BW (West)	13.4”	2’6”	5’
65613BW (West)	13.4”	8”	N/A
68223BWT (West)	13.4”	5’/5’	N/A
63064BWT (East)	10.5”	5’6”	17’
63063BWT (East)	11.2”	5’6”	17’

Figure 18. US 22 MP 36 Westbound: Pole 65614BW

Figure 19. US 22 MP 36 Westbound: Pole 65613BW

Figure 20. US 22 MP 36 Westbound: Pole 68223BWT

Figure 21. US 22 MP 36 Eastbound: Pole 63064BWT

Figure 22. US 22 MP 36 Eastbound: Pole 63063BWT

Route 22, Milepost 43.8

Mile Post 43.8 on Route 22 had one utility pole accident from 2003-2005. This is summarized in Table 33. The posted speed limit is 50 MPH, and the ADT is 61,952. Measurements of specific poles near this mile post are given in Table 34. The two directions of traffic are separated by a New Jersey shape concrete barrier. Utility poles along this section of road are very close to the curbs.

Table 33. Summary of accidents at MP 43.8 on Route 22

Occupant Injury	Number	Cost
Killed	1	3,000,000
A	0	-
B	0	-
C	0	-
PDO	0	-
Total Accidents	1	$3,000,000
Cost/Accident		$3,000,000

Table 34. Summary of measurements of specific poles near MP36.0 on Route 22

Pole ID	Pole Diameter	Curb Offset	Travel Lane Offset
62144NPB (West)	10.5"	2'6"	4'
62091NPB (West)	10.5"	1'	4'
61128NPB (East)	12.1"	1'3"	N/A
62263NPB (East)	15"	2'6"	10'

Figure 23. US 22 MP 43.8 Westbound: Pole 62144NPB

Figure 24. US 22 MP 43.8 Westbound: Pole 62091NPB

Figure 25. US 22 MP 43.9 Westbound: Pole 61128NPB

Figure 26. US 22 MP 43.8 Westbound: Pole 62263NPB

Route 22, Milepost 51.5

Mile Post 51.5 on Route 22 had nine utility pole accidents from 2003-2005. These are summarized in Table 35. The posted speed limit is 45 MPH, and the ADT is 61,914. Measurements of specific poles near this mile post are given in

Table 36. The overhead image shows that there is a fairly complex traffic pattern, and a large number of poles in the immediate area. The curbs along this section of road are not well defined. There is a stump of a pole near the current pole PS1066. The picture suggests that the original location of the pole was closer to the road than the current location.

Table 35. Summary of accidents at MP 51.5 on Route 22

Occupant Injury	Number	Cost
Killed	0	-
A	3	$623,100
B	4	$166,000
C	2	$43,800
PDO	4	$9,200
Total Accidents	9	$842,100
Cost/Accident		$93,567

Table 36. Summary of measurements of specific poles near MP 51.5 on Route 22

Pole ID	Pole Diameter	Curb Offset	Travel Lane Offset
60634MSB (West)	12.1”	10’	18’
61491MSB (West)	12.1”	3’	8’
60701MSB (East)	15”	3’6”	N/A
PS1066 (East)	15”	4’6”	15’

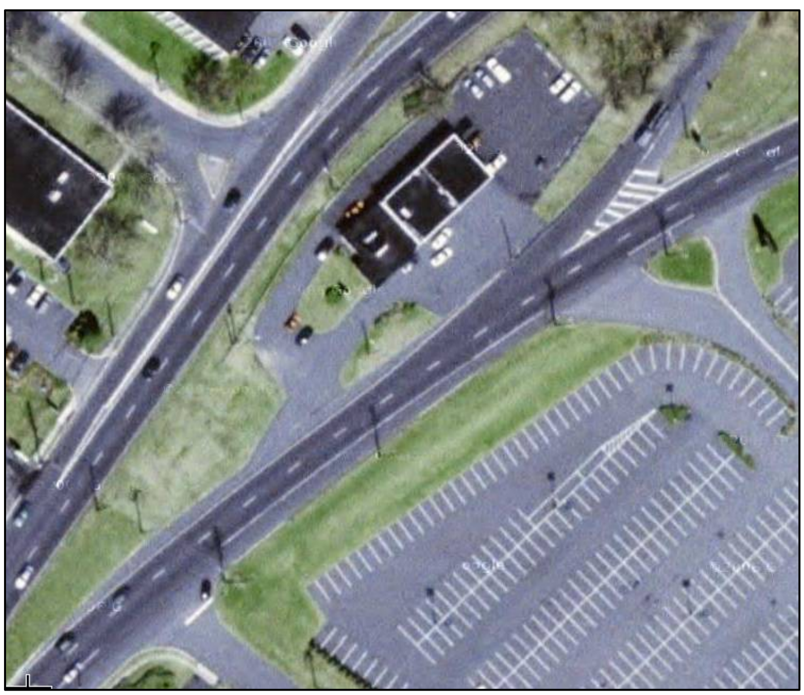


Figure 27. Overhead view of MP 51.5 on Route 22

Figure 28. US 22 MP 51.5 Westbound: Pole 60634MSB

Figure 29. US 22 MP 51.5 Westbound: Pole 61491MSB

Figure 30. US 22 MP 51.5 Eastbound: Pole PS1066

Figure 31. Comparison with curb and road: Pole PS1066

Figure 32. Stump near current pole PS1066

Route 22, Milepost 52.6

Mile Post 52.6 on Route 22 had six utility pole accidents from 2003-2005. These are summarized in Table 37. The posted speed limit is 45 MPH, and the ADT is 61,914. The two directions of traffic are separated. Measurements of specific poles near this mile post are given in Table 38. Note Figure 35, showing pole PS537 on an island, and Figure 36, showing two poles, and a stump, suggesting a pole was originally located much closer to the road.

Table 37. Summary of accidents at MP 52.6 on Route 22

Occupant Injury	Number	Cost
Killed	1	$3,000,000
A	1	$207,700
B	3	$124,500
C	2	$43,800
PDO	1	$2,300
Total Accidents	6	$3,378,300
Cost/Accident		$563,050

Table 38. Summary of measurements of specific poles near MP 52.6 on Route 22

Pole ID	Pole Diameter	Curb Offset	Travel Lane Offset
BT60015SF (West)	12.1”	2’	10’
P537 (West)	12.1”	4’	10’
JC383BSF (East)	12.1”	8’6”	18’
JC163SF (East)	12.1”	1’	14’

Figure 33. Overhead view of MP 52.6 on Route 22

Figure 34. US 22 MP 52.6 Westbound: Pole BT60015SF

Figure 35. US 22 MP 52.6 Westbound: Pole PS537

Figure 36. US 22 MP 52.6: Poles JC383BSF, JC383ASF and stump

Figure 37. US 22 MP 52.6: Pole JC163SF

10. Methodology for Cost-Benefit Evaluation of Breakaway or Energy Absorbing Poles

This section describes a cost-benefit methodology for evaluating the use of breakaway or energy absorbing utility poles.

Analysis of Zegeer Equation

The Zegeer equation was developed to predict utility pole accident rates for average offsets between 2 and 30 feet, ADT between 1,000 to 60,000, and pole density between 10 and 90 poles per mile. The equation relates accident rate (accident/mile/year) to the average daily traffic (ADT), pole density (Density) and average pole offset (Offset). This model has been compared to accident rate data from four different states, and found to be a reasonable overall predictor of accident rates.

$$\frac{Accidents}{Mile \cdot Year} = 8.84x10^{-5}\left(ADT\right) + \left(\frac{0.0354xDensity}{Offset^{0.6}}\right) - 0.04$$

Where

ADT	= Annual Daily Traffic [vehicles/day]
Density	= Pole Density [utility poles/mile]
Offset	= Pole Offset [feet]

Note that the Zegeer equation makes no predictions regarding accident severity. Also, the Zegeer equation is non-linear, and slightly different accident rates are predicted when the equation is used on an average pole offset, and when the equation is used on each pole and then averaged. Finally, factors such as road curvature are not included in this equation, although this may be an important factor under some conditions.

Accident rate predicted by Zegeer Equation

A plot of predicted accident rate plotted against pole density for two different values of ADT and two different average offset values is shown in Figure 38. Note that the bold, solid line representing ADT = 60,000 and offsets of 2 ft represents the upper bound for which the Zegeer equation is felt to be valid. While the accident rates reflected in this curve are relatively high values, there are numerous 0.1 mile sections of highway in New Jersey that have a historical accident rate above this.

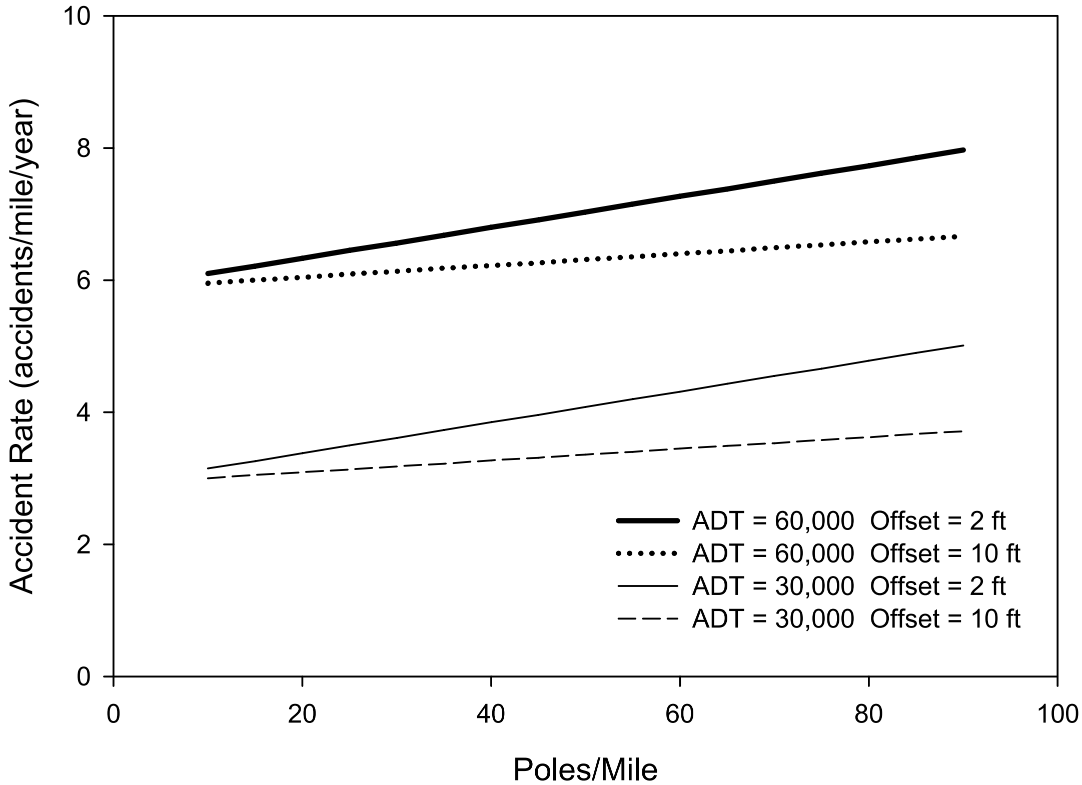


Figure 38. Accident rates predicted by Zegeer equation for various parameters

Injury Costs

The U.S. Department of Transportation has assigned values to various injury severities to allow cost-benefit analyses to be performed. The costs of injury using the KABCO scale are presented in Table 39, in both 1994 and 2002 dollars [89]. In 2002, USDOT recommended using a figure of $3,000,000 as the cost of a fatality [90]. This 15% increase in costs was based on the GDP Deflator value.

Table 39. Injury Costs using the KABCO Scale for Injury Severity

Type		**1994 cost**	**2002 cost**
K	Killed	$2,600,000	$3,000,000
A	Incapacitating	$180,000	$207,700
B	Evident	$36,000	$41,500
C	Possible	$19,000	$21,900
PDO	Property Damage Only	$2,000	$2,300

Effect of Posted Speed Limit on Cost of Accidents

There is a relation between the speed limit of the road and the accident severity. A rational policy for utilizing breakaway or energy absorbing poles should place poles where accidents tend to have the largest societal cost. Therefore, an analysis was performed to evaluate the relationship between societal cost of accidents and the posted speed limit.

Two hundred accidents were selected for the study. For each accident, the societal cost was calculated using the values given in Table 39. The posted speed limit for each site was identified using New Jersey straightline diagrams. The distribution of the corresponding speed limits is shown in Figure 39.

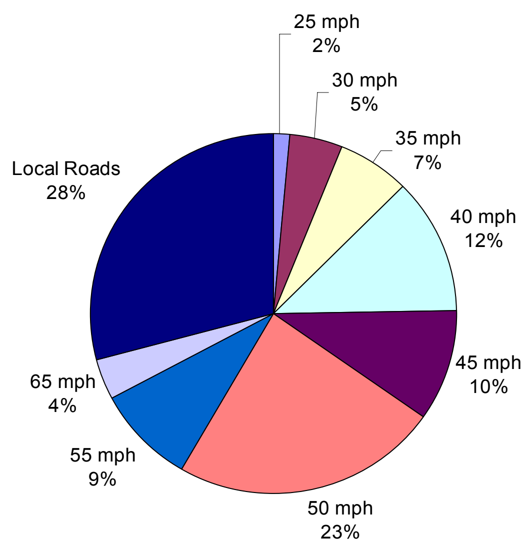


Figure 39. Posted speed limit at 200 accident sites

Next, a cumulative density function plot was developed for all 200 accidents. This is shown by the blue line in Figure 40. For this plot, local roads were considered to have a speed limit of 25 MPH. The x-axis is a plot of societal cost for an accident. The y-axis is the probability that one of the 200 accidents resulted in a societal cost less than or equal to the cost on the x-axis. Then, a cumulative density function was developed for all of the accidents that occurred in locations with posted speed limits from 40 to 65 MPH, 45 to 65 MPH and 50 to 65 MPH.

Comparison of these plots suggest that utility pole accidents along sections of highway that have speeds posted at 45 MPH and greater are more likely to result in societal costs greater than $40,000 per accident than the set of all highways. Note that the plot for 40 to 65 MPH is nearly coincident with the plot for 25 to 65 MPH for societal costs greater than $40,000 per accident, while there is a significant difference between these plots for the lower societal costs. These observations suggest that highways with posted speed limits of 45 MPH and greater should be targeted for policies to prevent fatalities resulting from impacts with utility poles.

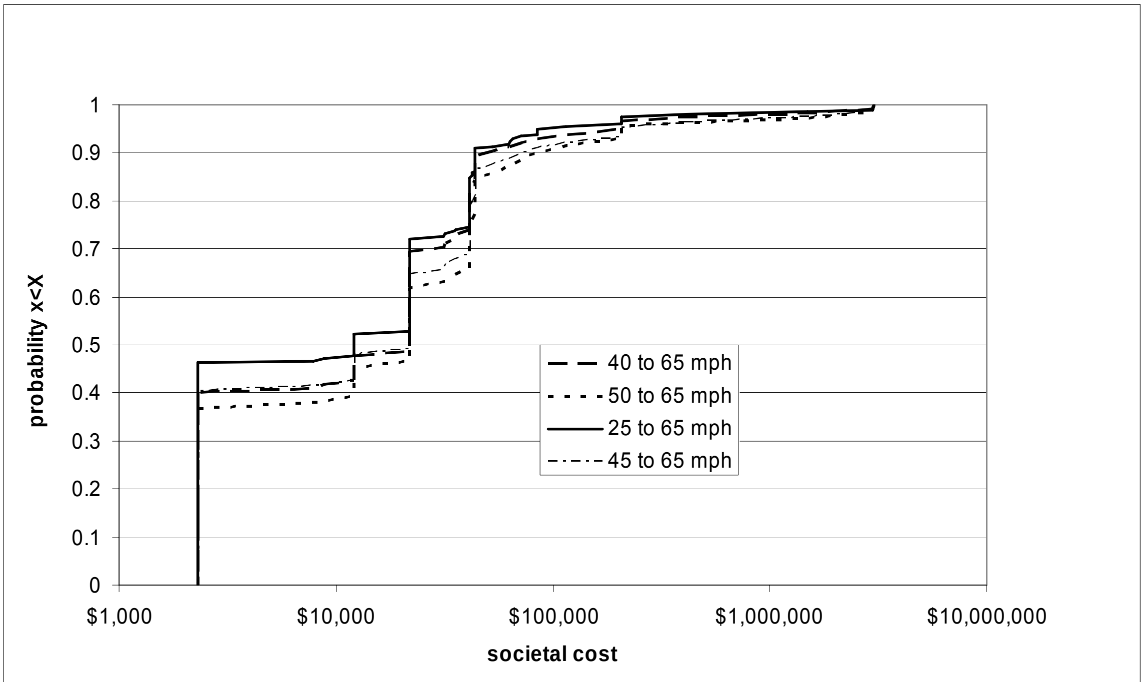


Figure 40. Probability of Incurring a Social Cost as a function of the posted speed limit

Life Cycle Costs of a Utility Pole

Several aspects of the life cycle cost calculation for utility poles are considered in the calculation which follows. The underlying assumptions are discussed below:

1. The lifetime of a pole is dictated by highway renovations rather than a gradual decay of the pole.

2. Approximately 75% of poles that are known to be struck by a vehicle are replaced.

3. 100% of breakaway or energy absorbing poles struck by a car will need to be replaced.

4. The cost of replacing or moving an existing pole can vary greatly, depending on many factors including the size of the pole and the service of the pole. Costs as low as $1000 to move a pole have been reported. The values described by Frank Pinto [93], from NJ DOT of $5000 for typical service and $15,000 for a transmission line are in line with those found in the literature.

5. Average societal cost in terms of harm to people of a vehicle striking a utility pole can be calculated by adding the total societal cost of all the utility pole accidents in a three year span in New Jersey, divided by the number of utility pole accidents. This results in an average societal cost/utility pole strike of $56,883/accident. Note that the high society cost of fatalities that occur in a relatively few number of accidents results in an average cost that is significantly greater than the median cost.

6. An estimate of the effect of energy absorbing or breakaway poles on the societal cost per accident can be developed by making some assumptions regarding how accident severity is affected by the energy absorbing or breakaway utility poles.

7. Breakaway or energy absorbing poles are likely to be very effective at preventing or reducing severe and fatal injuries for head-on collisions involving cars, but less effective for side collisions. Breakaway or energy absorbing poles are not likely to be effective at reducing the severity of injuries sustained by motorcyclists. Approximately 38% of fatalities involving utility poles are head-on collisions, while approximately 50% of the fatalities involve side impacts. The remaining approximately 12% of fatalities involving utility poles involved motorcyclists. These assumptions and statistics are used to predict a revised accident cost that would result from the implementation of breakaway or energy absorbing poles. It is assumed that energy absorbing poles would reduce all actual head-on fatalities to A injuries, and all actual head-on A injuries to B injuries. It is further assumed that energy absorbing poles would reduce 50% of all actual side collision fatalities to A injuries, and 50% of all actual side collision A-injuries to B injuries. Finally, motorcycle fatalities and A injuries are not assumed to be reduced. The resulting modified injuries are shown in Table 41. The resulting modified societal cost is $38,831/accident.

Table 40. Summary of Injuries Sustained in Utility Pole Collisions in 2003-2005

Injury Type	Cost/Injury	Number of Injuries	Total Cost
K	$3,000,000	139	$417,000,000
A	$207,700	466	$96,788,200
B	$41,500	3023	$125,454,500
C	$21,900	4765	$104,353,500
PDO	$2,300	7856	$18,068,800
Total	$56,883	16,249	$924,284,200

Table 41. Assumed Injuries with Energy Absorbing Poles

Injury Type	Cost/Injury	Number of Injuries	Total Cost
1	$3,000,000	51	$154,290,000
2	$207,700	260	$53,999,923
3	$41,500	3317	$137,638,070
4	$21,900	4765	$104,353,500
5	$2,300	7856	$18,068,800
Total	$38,831	16,249	$630,969,493

Economic Analysis

A payback period for an initial investment, P yielding an annual return A can be evaluated by solving for the number of years, n, for which the annual return has a present worth equal to P. For a time span of n years, the return A that has the same present worth as P can be solved using Equation 1.

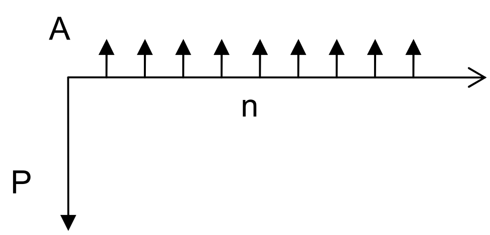


Figure 41. Schematic cash flow diagram

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$ **Equation 1**

For non-zero values of i, the solution for n is

$$n = \frac{-\ln\left(1 - \frac{iP}{A}\right)}{\ln(1+i)}$$ **Equation 2**

For i = zero, the simple payback period is P/A.

A ten year payback period with i = 0.05, is established when

$P = A[7.72]$.

Toward a cost-effective policy for utilizing breakaway or energy absorbing poles

Calculation of Break even ADT-Offset Values

It is assumed that the additional cost of installing breakaway or energy absorbing poles during highway construction or reconstruction is $1862.45, which represents the difference in the price of wood and energy absorbing 40 foot poles. However, the cost per accident (societal and utility) is $120,844 per accident less when breakaway or energy absorbing poles are in place.

Based on these values, the accident rate required for a break even cost can be calculated by

$$\frac{\$1862.45}{pole} * density\left(\frac{poles}{mile}\right) = 7.72 * \frac{\$20,844}{accident} * break\ even\ accident\ rate$$

Using the numbers stated above, the break even accident rate is 0.41 accidents/mile/year.

Next, the Zegeer equation can be inverted to solve for the relationship between offset and ADT that predicts this breakeven accident rate. The result is shown in Figure 42.

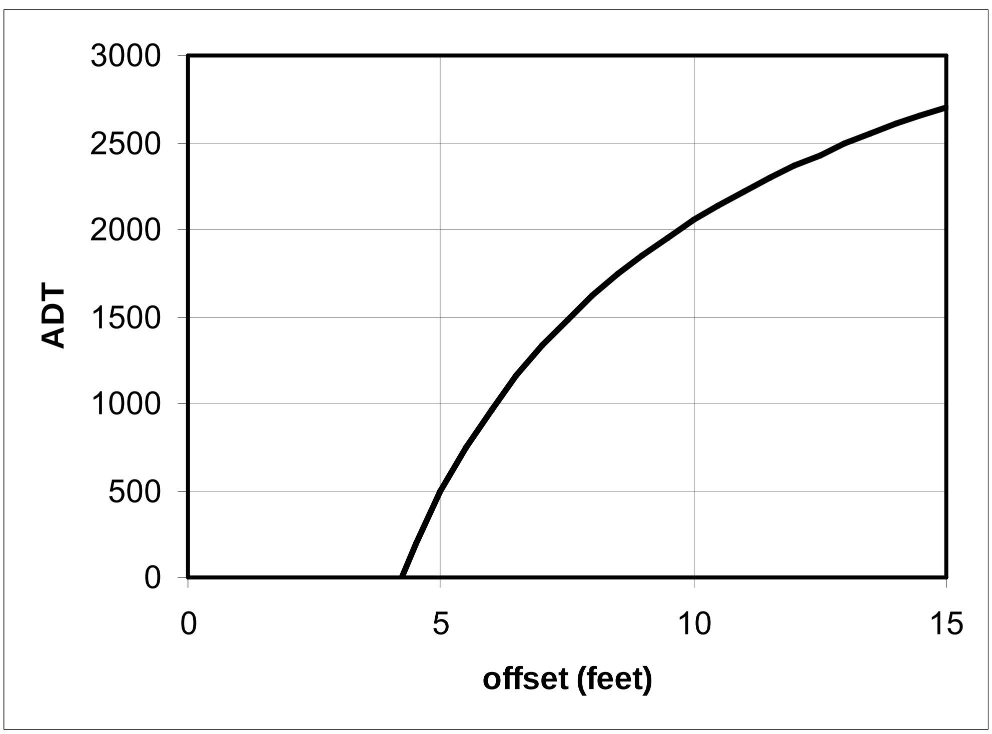


Figure 42. Values of offset and ADT that result in break even accident rate

Based on these relationships, one can argue that energy absorbing or breakaway poles for sections of highway in New Jersey that meet the three requirements summarized in Table 42. Note that requirement 1 will be met for nearly all state highways in New Jersey.

Table 42. Proposed requirements for breakaway or energy absorbing utility poles

Requirement	Parameter	Threshold
1	ADT	500 or greater
2	Speed limit	45 MPH or greater
3	Offset	5 feet or less

11. Conclusions

The Problem

Vehicle impacts with utility poles are one of the most unforgiving types of crashes to which motorists are exposed. The rigid design of a utility pole, which allows the pole to survive the high winds of a storm, unfortunately makes the pole particularly unyielding in a traffic accident. Vehicles which undergo pole impacts suffer large, frequently devastating, deformation of the occupant compartment which too frequently leads to serious or fatal injuries.

The State of New Jersey has a particularly urgent utility pole problem. New Jersey is only 22nd among the states in number of traffic fatalities, but surprisingly ranks 8th in number of fatalities resulting from utility pole impacts. Each year in New Jersey, approximately 10,000 vehicle occupants are involved in a utility pole crash. Unfortunately each year, these collisions result in 50-60 deaths and 200 persons who are incapacitated.

Objective

The goal of this research program was to investigate and recommend methods to mitigate the fatalities and injuries that result from traffic crashes with utility poles in New Jersey. The specific objective was to develop recommended procedures which will enable a designer to select the countermeasures which are most appropriate for reducing the frequency or severity of vehicle impacts with utility poles at a specific site.

Current National Practices

Both AASHTO and TRB have established recommended guidelines and practices for reducing utility pole crash frequency and severity:

<u>Utility Pole Placement and Crash Mitigation</u>

- Utility pole crash mitigation strategies include moving the utilities underground, increasing the lateral offset of the poles, shielding with roadside safety hardware, breakaway poles, and delineation. Selection of a particular strategy should be site-dependent.

- All utility pole collision mitigation strategies require a method for determining susceptible locations, a method for choosing a countermeasure, and a method to evaluate the results. The identification methods typically employ crash records or statistical models or a combination of both, the selection of a countermeasure is typically a cost-effectiveness-based method, while the evaluation typically involves post-countermeasure crash records.

Performance of Breakaway and Energy Absorbing Utility Poles

- Breakaway or energy absorbing utility poles are recommended for high risk crash locations where pole relocation or underground line placement is not feasible.

- In field trials, steel-reinforced breakaway timber poles were found to be resistant to high winds, less expensive to repair than traditional poles, and not highly susceptible to environmental degradation.

- New fiberglass-reinforced composite utility poles appear to offer significant benefits over the traditional wooden utility poles, especially with respect to life-cycle issues and crashworthiness.

Government-Utility Initiatives and Experience

- Numerous states, cities, and even some electric companies have undertaken initiatives to reduce utility pole collisions.

- Successful utility pole crash mitigation programs start by eliminating historically hazardous areas followed by a continued monitoring of crash data.

- The most effective programs include collaboration with the applicable utility industries. Successful cooperative initiatives include PennDOT's cost sharing with utility owners, the partnership of Jacksonville Electric Authority and TTI, and the Clear Roadside Committee in Georgia.

Legal Issues

- State DOTs can minimize tort suits involving utility poles by the use of "hold-harmless" clauses (when granting utility permits) and purchasing insurance.

- To further reduce liability, state DOTs should develop methods to classify and mitigate utility hazards. These should include mitigating historically active sites, employ statistical models to determine sites with highest collision probabilities, and documenting deviances from the Roadside Design Guide.

Review of New Jersey Utility Accommodation Policy

The New Jersey Utility Accommodation policy focuses solely on pole placement for new construction or reconstruction. In general, the NJ Accommodation policy follows national guidelines closely, if not verbatim. One exception is pole placement at or near intersections. TRB State of the Art Report Number 9 describes special considerations for utility pole placement at or near intersections. There is no corresponding mention of specific treatment of intersections in the New Jersey Accommodation Policy.

One important strategy for reducing utility pole fatalities is to consider the mitigation of existing high risk poles or sites. To our knowledge there is currently no mechanism in New Jersey to remediate high risk utility pole sites which are not undergoing reconstruction. The Fixed Object Program identifies utility pole (or adjacent poles) that have been struck three times in three years. We are not aware of any formal program to act on knowledge of these high risk sites unless the site is scheduled for reconstruction. An additional check for utility pole hazards is explicitly called for in the New Jersey Highway Design Manual for new construction or reconstruction.   Again, these checks are not applied to existing high risk sites not planned for reconstruction.

Analysis of Utility Pole Crashes in New Jersey

The research program has investigated New Jersey crash experience in utility pole collisions based on New Jersey Crash Records from 2003-2005 and FARS 2000-2004. Following are the findings:

- Each year in New Jersey, approximately 10,000 vehicle occupants are exposed to crashes involving a utility pole impacts. In these collisions, approximately 50-60 persons were fatally injured and 200 persons were incapacitated.

- 40% of all occupants exposed to utility pole crashes suffered some level of injury ranging from complaint of pain to death. Fortunately, fatal and incapacitating injuries were rare. Annually, 2.6% of occupants exposed to utility pole crashes received either a fatal or incapacitating injury.

- County roads account for most utility pole crashes and most utility pole crash fatalities. State highways however are overrepresented in serious utility pole collisions.   State highways account for 20% of all utility pole crashes, but 32% of all fatal and incapacitating utility pole crashes.

- Frontal impacts are most common type of pole impact, but side impacts are the most lethal crash mode. Side impacts are only 19% of all utility pole crashes, but result in 43% of all fatal utility pole crashes. Because energy-absorbing and breakaway poles are designed for frontal impacts, this countermeasure may not be as effective in protecting against side impacts into poles.

- Motorcyclists are overrepresented in fatal utility pole crashes. Motorcycles are involved in less than one-half of a percent of utility pole crashes, but were the striking vehicle in 7% of all fatal crashes. Because energy-absorbing and breakaway poles are designed for activation by cars, it is unlikely that this countermeasure will be effective in protecting motorcyclists.

Identification of High Risk Utility Pole Crash Sites

Four different metrics were used to rank order 13,000 utility pole crash sites by their risk to NJ motorists: 1) Crash Frequency, (2) Number of Serious Injured Persons, (3) 5-4-3-2-1 ranking based on the KABCO scale, and (4) Social Cost. After evaluating the relative ranking of each of these four metrics, our recommendation is that we use two metrics in parallel. The Social Cost metric proves an excellent measure of sites requiring immediate remediation while the Crash frequency metric provides targets for a longer-term remediation plan. Following is the justification for these two metrics:

- <u>Social Cost metri</u>c - Because the social cost metric uses injury costs, it assigns a greater risk to sites where there have been a number of fatal or incapacitating injuries. These are targets for near-term remediation.

- <u>Crash Frequency metric</u> - identifies sites with a frequent, although not necessarily fatal, collision problem. Because of their high crash frequency, these may be sites where we have simply been fortunate that a serious or fatal collision has not occurred. These are targets for long-term remediation possibly as part of an ongoing program of highway risk remediation.

Identification of High Risk Utility Pole Crash Sites

Based both upon the accident ranking and a site visit, U.S. Highway 22 is ranked as having a very serious utility pole impact problem. This highway, especially the stretch between MP 46 and 56, should be considered for remediation of its utility pole crash problem.

Cost-Benefit Calculation of Breakaway or Energy Absorbing Poles

Breakaway or energy-absorbing poles are less dangerous than traditional timber poles, but are also more expensive. This research program has developed a methodology for evaluating the cost vs. benefit of installing these more benign utility pole designs, and presents recommendations for their use based upon site characteristics.

12. Recommendations

This research program has investigated New Jersey crash experience in utility pole collisions, and makes the following recommendations to reduce both the number of crashes and severity of crashes into utility poles.

Recommendation 1: Mitigate Existing High Risk Utility Pole Crash Sites

Both AASHTO and TRB recommend an ongoing comprehensive crash reduction program periodically analyzes crash data to identify, prioritize, and mitigate locations where pole crash risk is high. New Jersey should adopt this national guideline, and initiate a formalized to regularly identify and remediate high risk utility pole crash sites. Remediation should not be limited to sites planned for or undergoing reconstruction.

- <u>Identification of High Risk Sites</u>. The NJ Bureau of Safety Programs should conduct a yearly analysis of New Jersey crash data to determine new high risk pole crash locations and track previous high risk locations. The analysis should focus on injury-producing as well as fatal collisions.

- <u>Prioritize High Risk Sites</u>. Sites should be prioritized based on two priority ranking metrics: (1) social cost and (2) crash frequency. The Social Cost metric proves an excellent measure of sites requiring immediate remediation while the Crash frequency metric provides targets for a longer-term remediation plan. This report provides the computational details for both of these metrics

- <u>High Risk Site Mitigation</u>. High risk pole crash sites should be mitigated based on crash-based priority. Countermeasures should be selected on a site-by-site basis using a benefit-cost analysis.

A comprehensive accident analysis has been conducted as part of this research project which has ranked the worst utility pole crash sites in New Jersey for both State and local roads. This ranking can be the starting point to initiate a utility pole accident mitigation program for implementation by the NJDOT on the State Highway system.

For those frequent utility pole hits that have been identified off the State Highway system, the NJDOT should develop a plan to disseminate this information to the utility companies, counties, municipalities, and toll authorities having jurisdiction.

Recommendation 2: Update the NJ Utility Accommodation Policy

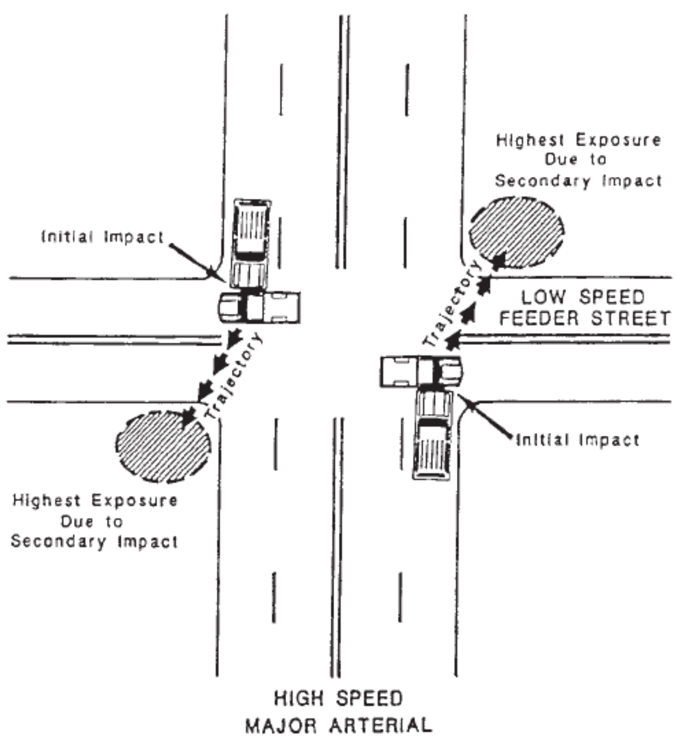
The New Jersey Utility Accommodation Policy and Roadway Design Guidelines should be updated to reflect current national best practices as recommended by AASHTO and TRB. Specifically,

- Adopt a policy that is specific to Utility Poles for identifying high-risk sites and mitigating these. The policy should consider social cost and accident frequency. The Bureau of Safety Programs should monitor accident data and develop a list of high-risk sites each year.

- Require designers to consider cost-benefit analysis based on historical accident experience using both a societal cost metric and a crash frequency metric when considering how much right of way to purchase for highway construction or reconstruction.

- Adopt National Guidelines for placement of poles near intersections. Specifically, include the following paragraph and figure in the NJ Utility Accommodation Policy:

  Where critical traffic conflicts can be foreseen, especially at intersections of high-speed roadways, pole placement may be designed to avoid the most critical secondary collisions. For example, if the major roadway is in a north–south direction and the minor roadway is east–west, the most critical quadrants for a secondary collision (collision of a vehicle with a pole after an initial two-vehicle collision) are the northeast and southwest quadrants. Thus, the preferred placement for poles at this intersection would be in the northwest and/or southeast quadrants, as indicated in the figure below.



Intersection zones having highest exposure to secondary collisions.

Recommendation 3: Investigate US Highway 22 as a candidate for utility pole crash mitigation

Using all four methods, U.S. Highway 22 is ranked as having a very serious utility pole impact problem. Our conclusion is that this highway, especially the stretch between MP 46 and 56, should be considered for remediation of the pole impact problem.

Recommendation 4: Install Shakespeare composite energy absorbing poles as a new technology demonstration project in New Jersey

We recommend that Shakespeare composite energy absorbing poles be installed as a new technology demonstration project for a limited number of sites with a utility pole crash problem. Appropriate sites should be selected using the cost-benefit methodology developed as part of this research effort.

Recommendation 5: Develop NJDOT design standard to allow for breakaway utility poles to be installed at high risk locations

Upon the completion of a successful demonstration project, consider revising NJDOT Design Manual to Install Breakaway or Energy-Absorbing Pole Installations at high risk locations, which could include horizontal curves with a safe speed less than the posted speed; or where design exceptions have been approved for substandard radius, cross slope, and shoulder width; or high posted speed limits with small pole offsets where utility companies are replacing poles that have been previously hit.

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Appendix A: Summary of Utility Pole Accident Literature

Summary of Published Crash Statistics Relating to Utility Pole Collisions

Study	Publication Year	Location(s)	Data Collection Years	Total Number of Utility Pole Crashes	% of all FO Crashes	% of Fatal FO Crashes	% Fatal	% Injury	Other Findings/General Notes
Graf et al.	1976	All	1971-1972	49,364	18.37	16.86	1.17	45.67	Suggests utility pole collisions one of most frequently struck objects and national utility pole collisions ~5% of all fatalities and ~15% of all fixed object fatalities. Presents only basic statistics as other objectives include highlighting complexity of the problem and recommending solutions.
		Kansas		4,436	22.25	13.06	1.06	43.03	
		Massachusetts		12,583	27.40	25.21	1.17	46.71	
		Michigan	1972	10,159	16.08	13.29	0.85	46.57	
		Oklahoma	1971-1972	1,639	9.74	6.45	0.98	36.61	
		Pennsylvania		20,547	16.72	20.87	1.37	45.89	
Jones and Baum	1978	All	1975	1,291	21.1	*	*	50.5	Data was collected from 20 urban-suburban areas amongst the locations listed. Site visits were conducted. Regression analysis was used to examine relation between road and pole characteristics on utility pole crashes. Total number of poles, pole offset, and speed limit are found to explain the largest portion of the variation in the available data.
		Macon, GA		*	44.8	*	*	*	
		Knoxville, TN		*	34.8	*	*	*	
		Columbus, OH		*	30.9	*	*	*	
		Nashville, TN		*	24.4	*	*	*	
		Erie & Niagra County, NY		*	21.9	*	*	*	
		San Diego, CA		*	17.5	*	*	*	
Jones	1980	Knoxville, TN	1968 (6 month period)	37	*	*	5.4	54.05	Data shown is from 4 locations in the Knoxville area. The remainder of the paper describes a before-and-after study on a 2-mile section of major arterial (included in the numbers shown). Utility poles were relocated from 6 inches to 6 feet behind the curb and steel poles were used to increase pole spacing. Prior to relocation, there were 5 fatalities and 68 personal injuries from 1963 through 1968. In a 4 year period after the improvements, there were no fatalities or reported injury crashes (1975-1979)
Mak and Mason	1980	Washington (DC), Kentucky, Salt Lake City, San Francisco, Los Angeles, Dallas, and San Antonio	January 1976 to October 1979	1,099	*	*	1.5	47.1	Perhaps most comprehensive study (includes poles of all types). Goals were to identify extent of the pole collision problem, relate collisions to roadway, vehicle and pole characteristics, and evaluate performance of breakaway devices.
Good et al.	1987	Melbourne, Australia	July 1976 to March 1977	879	*	*	3	27	Crashes were randomly selected. Authors developed a model to predict utility pole crashes based on site characteristics. Roughly half of the crashes occurred during dark hours, 68% were at non-intersection sites, and wet roadways were found to be a factor (collision 4 times as likely).
Zeeger et al.	1988	Michigan	1983	*	*	25.44	0.8	45	Main objectives of this study were to develop a method to characterize roadside hazard level, determine the influence of roadway characteristics on roadside crashes, and estimate the benefits of a given improvement. Data collected from 2-lane rural roads only. Utility poles found to have highest percentage of serious + fatal crashes of the examined roadside objects.
		Utah	1980-1985	*	*	10.87	1.2	39	
		Washington	1980-1984	*	*	14.1	1.6	47	
Turner and Barnett	1989	Huntsville, AL	January 1985 thru June 1987	458	*	*	1.6	39.7	Crash statistics are to support authors recommendations for existing (retrofit) and future utility pole placement. The researchers conducted site visits for all the collisions. Roughly half of utility pole collisions are found to occur at night and on straight and level roadways. Curves, however, were found to be overrepresented in terms of fatalities (ratio of 6 to 1). Wet roadway conditions are not found to be a factor. About 90% of collisions are found to occur within 10 feet of the roadway edge.
Troxel et al.	1991	National (FARS, NASS)	1980 - 1985	35,996	*	26	*	*	Focuses on side impact collisions with roadside objects only. Tall, narrow objects found to pose significantly greater hazard (trees most hazardous with utility poles second). Authors estimate that utility pole collisions are ~22% of all fixed object side impact collisions but represent 26% of all fixed object side impact fatalities.
Allen and Weiss	1998	Pennsylvania	1994	8,522	14.8	*	0.8	50	Main objectives of the study are to investigate the relative risk of various roadside objects with a focus on trees and utility poles. Tree impacts are found to be more hazardous than utility pole impacts. Utility pole impacts are 10% more likely to be fatal and 50% more likely to result in serious injury (compared to all other fixed object collisions).
Marquis	2001	Maine	1994 - 1998	7,544	*	*	0.7	54	Crash statistics were to support development of improved utility pole policy. Fatal utility pole collisions were found to be overrepresented on rural and curved roadways. Study also provided survey results from 24 State DOTs.
Lindly	2003	Alabama	1996 - 2000	3,364	*	*	2.1	41.3	Crash statistics are to support development of utility pole safety program. Other findings include 1% of crashes on state routes were utility pole crashes but these crashes accounted for 2.4% of fatalities on state routes. Also, utility poles occur more frequently on rural roads and less frequently at intersections.
Holdridge et al.	2004	Washington	1993-1996	848	8.7	11.3	0.71	38.7	Note that counts include **all** types of poles. The authors examined various fixed objects using nested logit models. Utility poles are found to increase propensity toward fatal collisions. Study considers driver injury only.

Appendix B: Excerpt from TRB SAR 9

Some specific situations deserve special safety considerations. Brief discussions of some situations are presented here.

Curves

On urban arterials, especially those with crowned cross sections, consideration should be given to placing a pole line on the inside instead of on the outside of curves. As indicated in Figure 2*a*, poles on the outside of a curve usually have a higher exposure to vehicle impacts. This is particularly important for situations in which there is a single curve after a long straight section of roadway or in which one curve is substantially more severe than other curves in close proximity. However, for winding roadways with sequentially occurring curves in opposite directions, it normally would not be cost-effective for the pole line to cross the road repeatedly to achieve inside curve placement.

When a pole line is placed on the inside of a severe curve (e.g., a curve with a radius of less than 1,700 ft), it may be necessary to place strain poles on the outside of the curve, as indicated in Figure 2*b.* These strain poles should be of a size that is adaptable to a breakaway design. Pole guys and strain poles should be used only if they can be designed in such a way that the fallen pole guy wire will not pose a hazard to traffic. A preferred alternative to the use of breakaway strain poles and down guy wires is the use of a compression strut (push brace or stub pole), as indicated in Figure 2*c.*

Lane Drops and Roadway Narrowing

Placement of poles downstream of a lane drop or the area where the roadway narrows should be discouraged. This is especially important when it can be reasonably foreseen that an inattentive or physically impaired driver might not be able to accurately perceive the lane drop or lane narrowing. These situations are presented in Figures 3 and 4. Another cause of this problem is a traffic conflict, where a driver is prevented by another vehicle from changing lanes or moving laterally. If it is impractical to span the critical zone without a pole, consideration should be given to the use of a guardrail or crash cushion.

Traffic Island

Placement of poles on a traffic island should be strongly discouraged. Islands are an element of traffic control at an intersection and are usually located within the boundaries of the traveled way. As such, they are likely to be occasionally traversed by errant vehicles. This traversal should not be prevented by a utility pole placed as indicated in Figure 5. If placement of a utility pole on an island is a practical necessity, consideration should be given to protecting errant vehicles with a crash cushion.

Medians

Placement of poles in medians, as indicated in Figure 5, should be strongly discouraged. Medians are safeguards against head-on collisions and, as such, provide space for errant vehicles to regain control or space for installation of median barriers. A pole or pole line in a median should be considered only if vehicles can be completely shielded from the poles by median barriers. Luminaires are often placed in protected positions on top of median barriers.

Use of Existing Safety Structures

Where guardrails, bridge rails, and crash cushions exist, consideration should be given in pole placement to take advantage of the shielding influence of these structures. An example is presented in Figure 6. During new highway or street construction, coordination of safety structure design and utility facility design should be pursued to reduce the influence of unshielded poles.

Traffic Conflicts

Where critical traffic conflicts can be foreseen, especially at intersections of high-speed roadways, pole placement may be designed to avoid the most critical secondary collisions. For example, if the major roadway is in a north–south direction and the minor roadway is east–west, the most critical quadrants for a secondary collision (collision of a vehicle with a pole after an initial two-vehicle collision) are the northeast and southwest quadrants. Thus, the preferred placement for poles at this intersection would be in the northwest and/or southeast quadrants, as indicated in Figure 7.

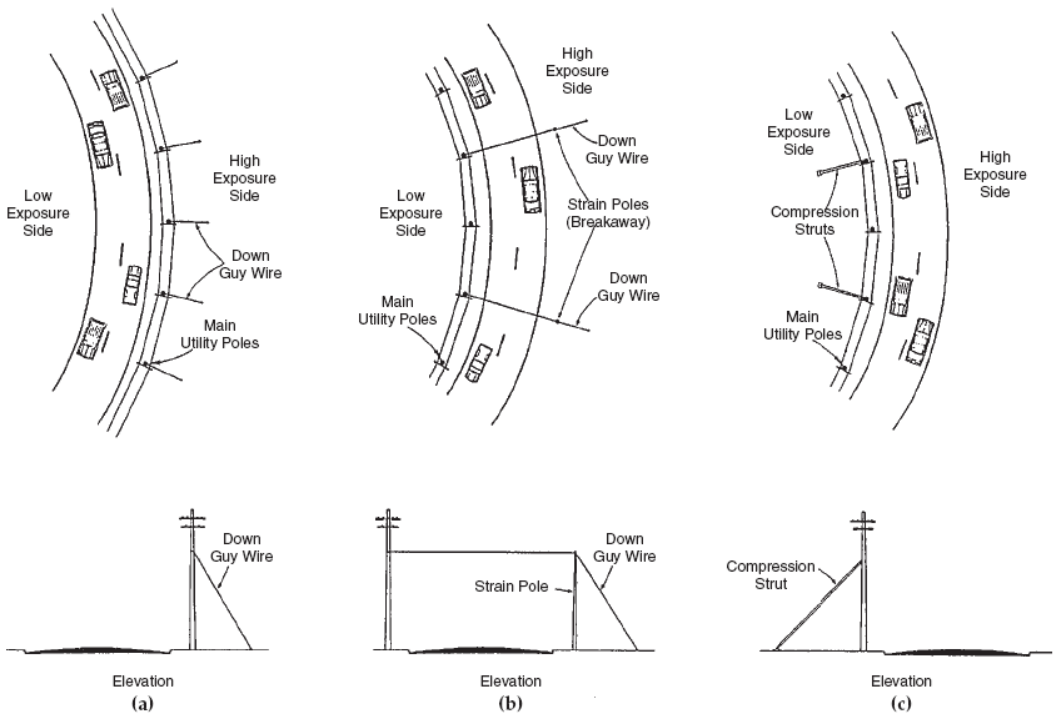

FIGURE 2 Location of utility poles on curves: (*a*) poles on outside of curve; (*b*) poles on inside of curve with breakaway strain poles; (*c*) poles on inside of curve with compression struts.

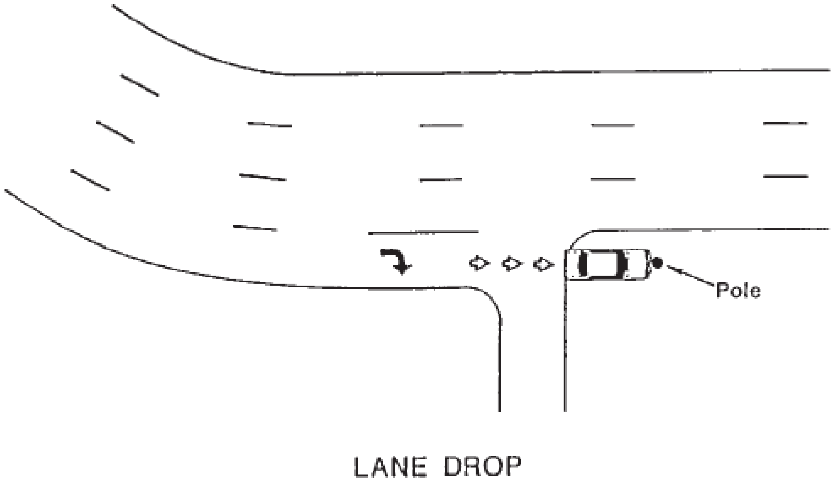

FIGURE 3 Exposure of vehicle to utility pole downstream of lane drop.

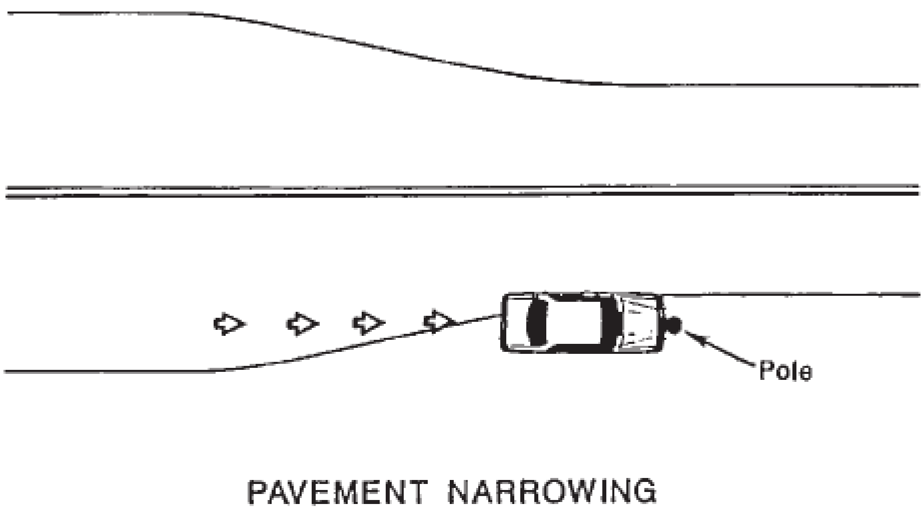

FIGURE 4 Placement of pole downstream of roadway narrowing.

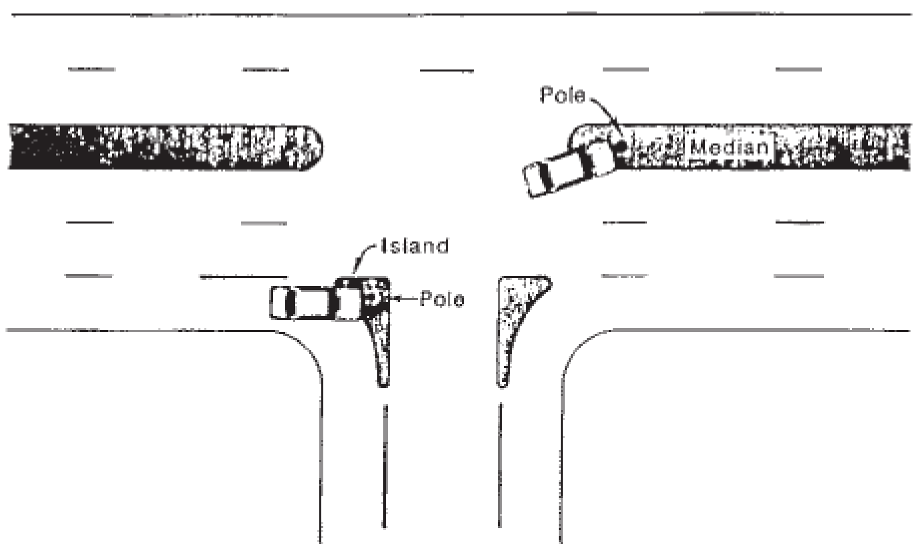

FIGURE 5 Inappropriate location of poles within a traffic island or median.

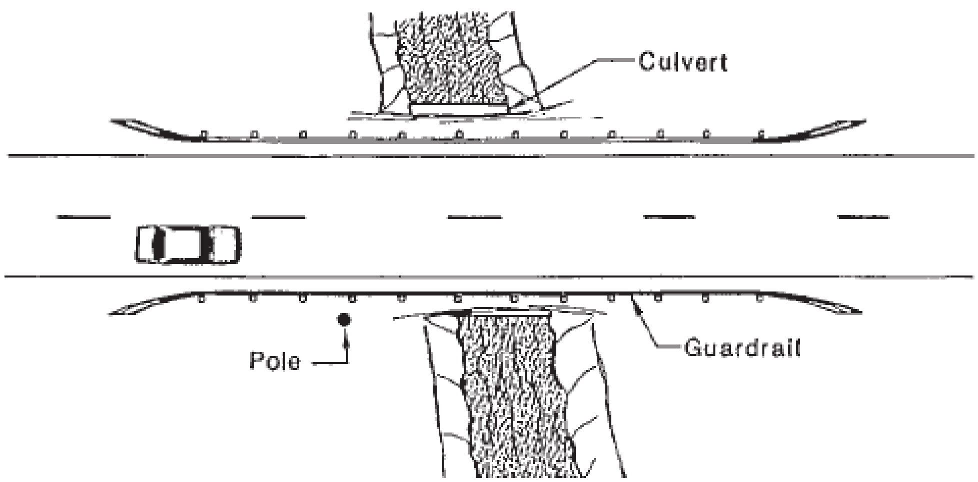

FIGURE 6 Pole shielded from traffic by an existing guardrail.

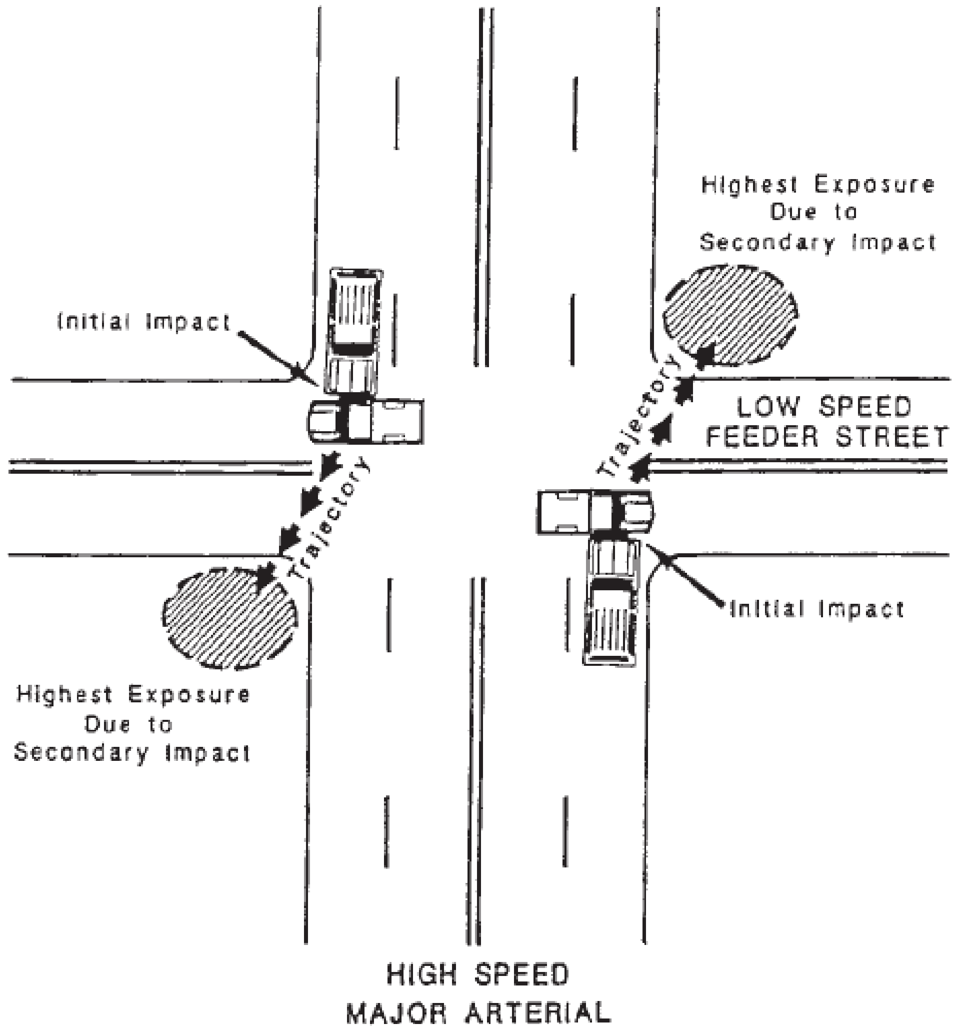

FIGURE 7 Intersection zones having highest exposure to secondary collisions.