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Using Linked Data To Evaluate Collisions With Fixed Objects In Pennsylvania

Crash Outcome Data Evaluation System (CODES) Linked Data Demonstration Project

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16. Abstract

This report uses police-reported motor vehicle crash data linked to Emergency Medical Services data and hospital discharge data to evaluate the relative risk of injury posed by specific roadside objects in Pennsylvania. The report focuses primarily on trees and utility poles. Measures of risk include police-reported injury, EMS reported injury and hospital-reported injuries. Trees were found by all measures of risk to pose a greater injury risk than utility poles.

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Executive Summary

Collisions with fixed objects were the most frequent type of motor vehicle crash in Pennsylvania in 1994, accounting for about a third of all reported crashes. These crashes tended to be not only more frequent, but also more dangerous. The fatality and major injury rates for these crashes were double the rates for all other crashes. More than 500 people were killed in fixed object crashes in 1994 and about 2,000 people suffered police-reported major injuries as a result of motor vehicle collisions with fixed objects. The most commonly stuck objects were parked vehicles, embankments, trees, utility poles and guide rails. Trees, utility poles and guide rails together accounted for approximately 47% of all fatalities associated with fixed object collisions and 43% of all major injuries.

Highway designers and others involved in deciding how to spend limited resources for roadside improvements, must be able to understand the relative injury risks posed by specific roadside hazards in order to evaluate alternative engineering treatments, safety interventions and their safety consequences. An important component of developing such an understanding is being able to measure the relative risk of injury associated with collisions with specific roadside objects. Such a measure of expected injury or "severity index" (SI) for common roadside features could be used in comparing alternative safety improvements such as tree removal, utility pole displacement, guide rail installation, and speed limit changes.

The research presented in this document used linked crash data to evaluate the relative risks of injury to motorists posed by trees and utility poles. Using linked data makes it possible to take a variety of approaches to evaluate the relative risks these objects pose and enhances the evaluation. Previous attempts to develop severity indices using only a single outcome measure have yielded inconsistent results and a lack of "user faith" in these indices.

The outcome measures used in the evaluation were based upon police and emergency medical service injury data, hospital charges, hospital-reported injury data and crash vehicle deformity. All outcome measures consistently indicated that trees pose a greater injury risk than utility poles. Victims of collisions with trees were about three times as likely to be killed and were more than twice as likely to suffer a major injury as victims of all other types of fixed object crashes. Victims of collisions with utility poles were only about 10% more likely to be killed than all other fixed object crash victims, but were about 50% more likely to suffer a major injury.

Purpose

Collisions with fixed objects are the most common type of motor vehicle crash in Pennsylvania. In 1994, approximately one third of the approximately 134,000 reported crashes involved collisions with fixed objects such as trees, signs, parked vehicles, utility poles or guide rails. Moreover, these types of crashes tended to result in more severe injuries and deaths than crashes in general. According to police crash reports, the death rate for fixed object crash victims (8/1,000 crash victims) and the major injury rate (31/1,000 crash victims) were double the death rate (4/1,000 crash victims) and major injury (15/1,000 crash victims) rates for all crash victims.

Highway designers and others involved in deciding how to spend limited resources for roadside improvements, must be able to understand the costs of alternative engineering treatments and safety interventions and their projected safety consequences. An important component of developing such an understanding is being able to measure the relative risk of injury associated with collisions with specific roadside objects. Such a measure of expected injury or "severity index" (SI) for common roadside features could be used in comparing alternative safety improvements such as tree removal, utility pole displacement, guide rail installation, and speed limit changes.

While a number of attempts have been made to develop such severity indices for fixed objects, to date the work has been inconsistent. Divergent severity index values for specific roadside objects have been calculated using the same calculation method on different databases (i.e., from different states or data years) as well as using different calculation methods on the same data. A recently published synthesis of knowledge about severity indices and roadside hazards concludes, "despite numerous and progressively more complex research efforts, no clear path has emerged as the best direction for future research efforts.

The purpose of this research is to attempt to evaluate the risks posed by two roadside objects that together account for nearly a quarter of all fixed object crashes and more than 40% of all fixed object crash deaths: trees and utility poles. The research uses a variety of approaches to the evaluation of the risks these objects pose to motorists including both injury-based severity indexes and a non-injury based method of evaluation. The results of all the approaches are compared to give a more comprehensive understanding of the risks these objects pose. The results of this research are intended for use by highway planners and others involved in considering alternative highway safety interventions and for use by researchers in furthering the refinement of fixed object severity indices.

Background

A 1994 study published by the Transportation Research Board,[1] reviewed existing information on the hazards of roadside objects and how this information is used by engineers. This study indicated that there is widespread interest among highway engineers in using a "severity index" (SI) to measure the injury risk posed by common roadside objects. A number of studies have attempted to develop a severity index for roadside objects but there seems to be a lack of "user faith" in the indices currently available. This lack of confidence stems from widely varying values for the same object, estimates based on engineering judgment rather than data, and values based on data from a single state only. The authors of this study conclude:

> "...the severity index has not reached the mature stage of development. Currently, the most widely used values for severity indices are those presented in the *Roadside Design Guide*...To date, no research project has confirmed these severity index values as accurate, authoritative, or representative of those crashes that actually occur on American roadsides."

The Federal Highway Administration recently published the results of a severity index study based upon data from North Carolina and Illinois. This study developed two severity indices based upon the proportion of individuals killed or incurring severe injury and the "societal costs" for driver injury in collisions with given fixed objects under a given set of crash circumstances. The severity index results obtained by this study were "moderately consistent between states and with earlier Texas-based work. However the three states' SI were not consistent with the SIs found in the *Roadside Design Guide*."[2] The authors suggest that future research efforts should be based upon larger sample sizes and better injury severity data.

Comparing crash data in Pennsylvania for years 1991 and 1994 yielded significant differences among death and injury rates for many fixed objects. This is particularly true for those objects with smaller numbers of observations or in which the defined object may include a wide variety of shapes and sizes. Table 1, on the following page, compares crude death and major injury rates, as reported on police crash reports, for a number of common road side objects in 1991 and 1994. As the table illustrates, there seems to be inconsistency in crude death and major injury rates between the two years, although for both years, trees and utility poles accounted for large numbers of deaths and injuries and the injury and fatality rates for these objects are moderately consistent.

The Crash Outcomes Data Evaluation Study (CODES) database is a linked database that brings together police crash report data with emergency medical service data and hospital discharge data. Linked through a probabilistic linkage process, these data offer a much richer perspective and more reliable information in regard to the outcomes of crashes in terms of injuries, interventions and the financial consequences of motor vehicle crashes, compared to non-linked data.

Table 1 Comparison of Death and Injury Rates 1991 and 1994

object	% killed 1991	% killed 1994	% change fatality rate 91 - 94	% major injury 1991	% major injury 1994	% change major injury 91 - 94
bridge support	2.92%	0.52%	-82%	9.94%	5.73%	-42%
bridge wall	0.78%	0.18%	-77%	1.25%	0.91%	-27%
bridge wall end	1.05%	2.50%	138%	6.64%	2.86%	-57%
building	0.29%	0.49%	70%	4.34%	2.79%	-36%
culvert	1.82%	1.25%	-31%	3.15%	4.06%	29%
curb	0.89%	0.49%	-45%	2.75%	2.52%	-8%
ditch	0.98%	0.60%	-39%	3.28%	2.79%	-15%
embankment	0.70%	0.66%	-6%	3.48%	3.09%	-11%
impact attenuator	0.00%	0.00%		13.51%	5.88%	-56%
median barrier	0.34%	0.11%	-68%	2.27%	2.06%	-9%
obstacle on road	0.00%	0.13%		0.45%	0.27%	-41%
overhead structure	4.55%	21.43%	371%	9.09%	7.14%	-21%
sign	0.71%	1.48%	109%	4.16%	3.43%	-18%
snow bank	2.04%	0.28%	-86%	0.00%	1.13%	
construction barrier	0.80%	0.00%	-100%	8.00%	1.59%	-80%
traffic island	0.42%	0.00%	-100%	3.81%	2.17%	-43%
tree	2.09%	1.92%	-8%	6.66%	5.48%	-18%
utility pole	0.95%	0.83%	-12%	5.40%	4.60%	-15%
mail box	1.62%	0.75%	-54%	4.18%	3.76%	-10%
rock	1.22%	0.89%	-27%	2.43%	3.11%	28%
fence	1.07%	0.66%	-38%	3.60%	1.99%	-45%
wall	0.83%	0.69%	-17%	4.64%	3.00%	-35%
shrubs	0.34%	0.19%	-43%	3.84%	3.32%	-13%
fire hydrant	0.00%	0.74%		3.30%	1.12%	-66%
guide rail	0.97%	0.71%	-27%	2.92%	2.09%	-28%
guide rail end	0.00%	3.82%		4.46%	5.41%	21%

Source: Pennsylvania CODES databases, 1991 and 1994

Whether crash victims suffer a major injury or fatality depends upon a number of mitigating or aggravating factors such as whether or not a passenger restraint system was used, seat position within the vehicle, and vehicle speed. Sometimes, however, attempts to control for these confounding factors can introduce even more bias into the evaluation of risks these objects pose. For example, police reports of injury severity, safety belt usage, and estimated vehicle speed may be inaccurate or unreliable. The more one attempts to control for such confounding data by including potentially inaccurate data, the more dubious becomes the statistical analysis. This research attempts to show the benefits of using linked crash data to enhance the crash reported information related to trees and utility poles.

Scope of the Problem

In 1994, approximately 134,000 motor vehicle crashes were reported to the Pennsylvania Department of Transportation involving 350,492 individuals. Approximately, 42,300 (32%) of these crashes were described by the crash investigator as "hit fixed object."

Of the 350,492 individuals involved in reported crashes, 65,250 victims were involved in fixed object crashes. The great majority of these crash victims (60,065 victims) were occupants of single vehicles that collided with fixed roadside features such as trees, guide rails or embankments. Among the occupants of single vehicle collisions with fixed objects 482 crash victims died, and 1,858 were reported by the police as incurring "major injuries." About 43% of these crash victims were reported by the police to have incurred some degree of injury. Table 2 indicates police reported injury severity for these crash victims.

Table 2 Police Reported Injury Severity 1994 Single Vehicle Fixed Object Crashes vs. All Crashes

police-reported injury severity	number of single vehicle crash victims	percent of all single vehicle fixed-object crash victims	number of all crash victims	percent of all crash victims
no injury	31,186	51.9%	215,649	61.6%
killed	482	0.8%	1,477	0.4%
major injury	1,858	3.0%	5,381	1.5%
moderate injury	5,729	9.5%	18,409	5.3%
minor injury	17,874	29.9%	90,592	25.8%
unknown injury	2,936	4.9%	18,684	5.3%
TOTAL	60,065	100%	350,492	100%

Source: Pennsylvania CODES database, 1994

The most frequently struck objects were embankments, utility poles, trees, guide rails and parked vehicles. Embankments, utility poles and trees accounted for nearly half of all single vehicle fixed object collisions.

Table 3 on the following page indicates the number of crash victims who were occupants of vehicles colliding with specific objects.

More than 95% of the crash victims were occupants of passenger cars or light trucks and 70% of crash victims were also drivers of the crash vehicle. Approximately 80% of fixed object crashes occurred on roads with a speed limit of at least 35 MPH. and about 30% of all fixed object crashes occurred on 55-MPH highways.

About 58% of fixed object crashes occurred on state highways, 33% on municipal or county roads, and 9% occurred on Interstate highways including the Pennsylvania Turnpike.

Table 3. Objects Struck in Single Vehicle Fixed Object Crashes 1994

object	number of crash victims	percent of all single vehicle fixed object crash victims
embankment	9,392	15.6%
utility pole	8,415	14.0%
tree	6,533	10.9%
guide rail	5,081	8.5%
parked vehicle not towed	3,410	5.7%
median barrier	3,042	5.1%
snow bank	3,019	5.0%
curb	2,975	5.0%
parked vehicle -towed	2,899	4.8%
ditch	2,382	4.0%
shrub	1,691	2.8%
sign	1,638	2.7%
fence	1,192	2.0%
mailbox	1,001	1.7%
other	982	1.6%
wall	955	1.6%
object on roadway	816	1.4%
culvert	736	1.2%
rock	723	1.2%
building	688	1.1%
bridge wall	597	1.0%
guide rail end	343	0.6%
bridge wall end	316	0.5%
fire hydrant	300	0.5%
traffic island	252	0.4%
bridge support	211	0.4%
parked vehicle - towing unknown	153	0.3%
temporary construction barrier	132	0.2%
unknown object	91	0.2%
overhead structure	63	0.1%
impact attenuator	37	0.1%
TOTAL	60,065	100.0%

Source: Pennsylvania CODES database 1994

The Linked Data Set Used for Analysis

This research is based upon data collected during 1994 by the Pennsylvania Department of Transportation (PADOT), the Pennsylvania Department of Health (PADOH), and the Pennsylvania Health Care Cost Containment Council (PHC4). The PADOT data used was from the *Pennsylvania Accident Reporting System*. The PADOH data was from a statewide database of emergency medical service run reports. The data from PHC4, was the hospital discharge data set. The data from these three sources were linked together using probabilistic linkage. Each of the individual data sets and the linked data set are described in *Appendix I* to this document.

The overall 1994 crash data set included records for 350,492 crash victims involved in approximately 134,000 crashes. Approximately 52,000 of these crash records linked to an Emergency Medical Service "trip ticket," while about 6,000 crash records were linked to a hospital discharge record. These linked records represent an estimated 42% of EMS patients involved in motor vehicle crashes and about one third of all persons hospitalized for crash-related injuries with External Cause of Injury Codes (E-codes) indicating a motor vehicle crash was the cause of the injuries.

Linked data were used in these analyses because linked data offer an advantage over crash data alone in a number of ways including:

- data elements not captured on the crash report (e.g., EMS-reported crash vehicle deformation) are available,

- more reliable and detailed data in regard to injury outcomes (e.g., hospital-reported diagnostic codes) are included,

- longer term crash outcomes (e.g., the hospital discharge status) are possible, not simply the victim's status at the crash scene,

- financial information such as hospital charges are available, and

- linked data makes it possible to cross-check the validity and reliability of crash data collected in more than one dataset such as safety belt usage.

Methodology

A variety of crash circumstance and outcome descriptors were developed from data within the crash, EMS and hospital discharge sections of the *CODES '94* database. Variables to describe independent factors and the circumstances of the crash that may have contributed to the crash outcome, (e.g., whether or not a safety belt was in use, vehicle speed, etc.) were also created in the database. Statistical testing of the data was used to examine the relationship between the type of object struck and the crash outcome. Creation of these independent and crash outcome variables is discussed in *Appendix II* of this document.

Measures of Risk

Various types of measures of risk were applied to the two objects under study. The methods used to estimate relative risks are described in general terms on the following pages. The results of the application of each measure to the two objects under study are described in the ***Results*** section of this document.

Crude morbidity and mortality rates

Unadjusted mortality rates and injury rates were developed using police and EMS reported information on injury. These rates were then compared to the mortality and injury rates for all crash victims and for victims of all fixed object crashes. Simple odds ratios were then calculated to compare injury and mortality rates for specific objects with all fixed objects. These unadjusted mortality and injury rates do not take into account any other factors that may have contributed to the crash outcome, such as whether or not a safety belt was in use or the crash vehicle speed. They are simply the proportion of individuals killed or seriously injured in collisions with specific objects. Odds ratios for the risk of the death or "major injury or worse" were calculated. This type of analysis serves as a rough gauge of the relative severity of the objects in question.

Morbidity and mortality rates with control for contributing factors

Logistic regression analysis was used to control for various mitigating factors that may have played a role in the injury outcome. The factors controlled for were restraint usage, age, sex, seat position, seat position in relation to impact, and vehicle speed.

While this approach attempts to control for contributing factors to the outcome, the more one attempts to control for these factors the greater may be the error caused by using invalid or unreliable data. The crash and EMS data are often collected under difficult field conditions.

Hospital charges

Hospital charges can serve as a proxy measure of injury severity. More severely injured crash victims can be expected to incur higher hospital charges. However, some of the most seriously injured do not incur high hospital charges because they may die shortly after admission. Neither are hospital charges a good indicator of risk of death, because individuals killed at the scene or dead on arrival at the hospital are not included in the hospital discharge data.

Contingency tables were constructed to compare average hospital charges for the two objects under study. Linear regressions were performed on the data to examine hospital charges for crash victims while controlling for age, sex, seat position, restraint usage and vehicle speed.

Injury Severity Score

Diagnostic codes within the hospital portion of the linked data set were converted to Injury Severity Scores (ISS) using ICDMAP-90 software. Average scores were calculated for all crash victims, all fixed object crash victims and for tree and utility pole crash victims. Linear and logistic regression analyses were applied to the data to examine differences in the average ISS for victims of collisions with trees and utility poles.

Vehicle deformation

The injury outcome of an accident is related to a great variety of contributing factors such as safety belt use, vehicle speed and other crash circumstances. Certain factors, such as safety belt usage, are very strongly correlated with the level of injury. However, attempts to control for these contributing factors may introduce unreliable data into the calculation of the risk posed.

The amount of "injury" to the vehicle (i.e., vehicle deformation) may serve as a good proxy measure of relative risk. The relationship between vehicle deformation and injury outcome was explored and found to be very strongly associated with the injury outcome. Logistic regression analysis using vehicle deformation as the outcome variable was then carried out on the data. The advantage of this method is that the data used are independent of all person-related factors such as seat position, injury outcome, and restraint use.

Case Selection

The analyses are based upon the 1994 Pennsylvania CODES database (*CODES '94*). The entire database representing the universe of reported crash victims is used for several analyses and sub-samples of observations were drawn from the *CODES '94* linked database depending on the type of analysis.

An important subsample of the *CODES '94* data consisted of all occupants of single passenger car or light truck crashes in which the crash was described as "hit fixed object." These sample selection criteria excluded all crash victims involved in multiple-vehicle crashes, pedestrians, and occupants of other vehicle types such as motorcycles or heavy trucks. Records for those who were involved in other types of crashes (e.g., non-collisions, head-on crashes, hit pedestrian, etc.) were also excluded. This left a total of 57,507 records for crash victims that met the above criteria. From this sample of 57,507 records, crash records for victims whose crash record linked to an EMS record (11,626 records) and hospital records (1,076) records were included in the analysis.

An analysis of all 1994 EMS data indicated that approximately 125,000 motor vehicle crash victims were transported by ambulance in 1994. Approximately 52,000 of these EMS records (42%) linked to a crash record. The 11,626 linked EMS records included in the analysis represent approximately 9% of all EMS-transported crash victims and 20% of all fixed object crash victim records that met the selection criteria described above.

Analysis of all 1994 hospital discharge data indicated that approximately 17,500 motor vehicle crash victims were hospitalized in Pennsylvania in 1994. Records for approximately 6,000 of these hospital patients linked to crash records. The 1,076 hospital records included in the analysis represent approximately 6% of all hospitalized motor vehicle crash victims and 2% of all fixed object crash victims that met the selection criteria described above.

For those analyses that examined vehicle deformation, a subsample of the data was prepared to represent only a single record for a single crash. This was accomplished by selecting only crash records for drivers. Including only records for drivers left a total of 39,538 crash records. Including only those records that linked to an EMS record left a total of records for 7,771 crashes. The various methods, of estimating risk (e.g., crude mortality rates, vehicle deformation, etc.) were then calculated for trees, utility poles and guide rails using the relevant subset of data.

Results

Crude Death and Injury Rates

Crude death and injury rates for trees and utility poles were calculated by examining the proportion of individuals involved in collisions with specific objects who were killed or injured and comparing these with death and injury rates for all crash victims and for all fixed object crash victims. No attempt was made in this initial analysis to control for such contributing factors as restraint use, seat position, or vehicle speed.

Police crash reports of death and injury were used to calculate the death and injury rates for specific objects and for all crashes. Table 4 compares the crude death and injury rates for victims of collisions with trees and utility poles with all crash victims and all fixed object crash victims.

Table 4 Crude Death and Injury Rates

outcome measure	all crash victims n=350,492	fixed object crash victims n=57,507	victims of collisions with trees n=6,580	victims of collisions with utility poles n=8,522
% killed	0.4%	0.7%	1.8%	0.8%
% with major injury or worse	1.9%	3.6%	7.0%	5.1%
% with any injury	33.0%	43.0%	44.0%	50.0%

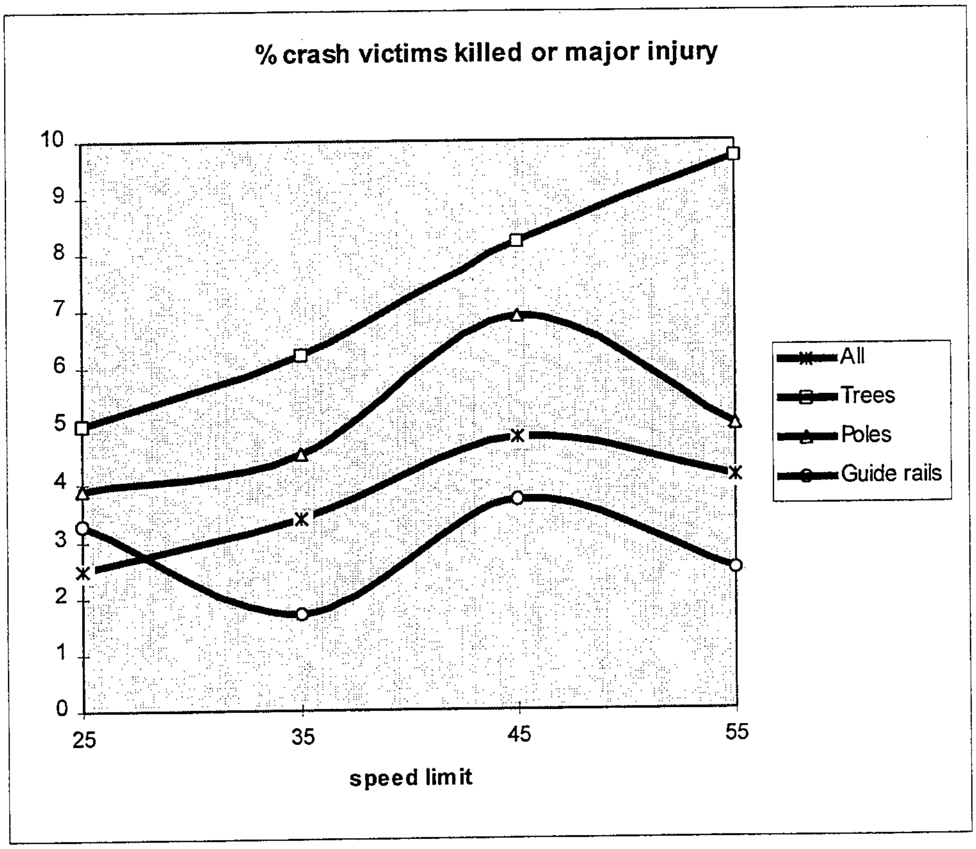
Source: Pennsylvania Accident Reporting System database, 1994

From the unadjusted death injury rates it appears that the percentage of crash victims who die or suffer serious injury in collisions with trees and utility poles is greater than the percentage who die or are seriously injured from any type of crash or for any type of fixed object crash.

Figure 1 depicts the crude death and injury rate for trees, and utility poles, guide rails and all fixed object crashes as a function of posted speed limits. As the graph illustrates, the crude death and injury rate for trees and utility poles is higher than the death and injury rate for all fixed object crashes regardless of speed, while the crude death and injury rate for guide rails remains less than the crude death and injury rate for all fixed object victims.

An interesting feature of Figure 1 is that the rate of major injury or worse seems to peak at around a speed limit of 45 MPH for most objects, except trees, and then diminishes slightly at 55 MPH. This may be because at higher speeds the object struck may shear off or the vehicle may vault over the object, resulting in a lower crash velocity. Another theory is that the best designs of guide rails and utility poles might be more commonly found along roads with a posted speed of 55 MPH.

Figure 1 Crude Mortality by Object Struck and Posted Speed Limit



The crude death and injury data was used to calculate the relative risk of death and for defining the broader group of "major injury or worse" (i.e., death or major injury) crash victims. The relative risk is simply the proportion of those with the specified outcome divided by the proportion of those without the specified outcome for each object. For example the relative risk for death due to a collision with a tree is calculated as follows:

(deaths from tree collisions/all tree collisions) ÷ (deaths non-tree collisions/all non-tree collisions)

The relative risk of collisions with trees and utility poles is presented in Table 5. A relative risk of greater than 1 indicates that the object poses a greater risk than the risk posed by all other objects combined. A relative risk of less than one indicates that the object poses less of a risk than all other objects combined.

Table 5 Relative Risk of Death or Major Injury or Worse Comparing all Fixed Object Crash Victims

object	relative risk of death	relative risk of major injury of worse
trees	3.06	2.19
utility poles	1.07	1.45

Source: Pennsylvania CODES database, 1994

This analysis indicates that trees pose a greater risk for both death and major injury while utility poles are shown to pose only a marginally greater risk of death than other objects. The relative risk for "major injury or worse" for collisions with trees is lower than the relative risk of death, while for utility poles the relative risk for "major injury or worse" is greater than the relative risk for death. The foregoing indicates that trees pose a greater serious injury hazard than utility poles.

It is possible that more reliable injury indicators may be found on the EMS portion of the linked records. One of the EMS measures of injury outcome is the report of patient condition from the EMS record. Emergency medical personnel report whether the injuries incurred are of a "life-threatening nature." Table 6 indicates the relative risks posed by trees and utility poles for life-threatening injuries indicated on those EMS records that linked to a crash record.

Table 6 Relative Risk for Life Threatening Injuries

object struck	life threatening injuries	relative risk for life threatening injuries
all objects n=11,626	7.7%	
trees n=1,949	13.5%	2.1
utility poles n=802	6.9%	not statistically significant at 0.05 level

Source: Pennsylvania CODES database, 1994

Logistic Regression Analysis

Logistic regression is a statistical method of measuring the likelihood of an event occurring (or not occurring) while controlling for factors that may contribute to whether or not the event occurs.

Logistic regressions were carried out on the data using a variety of injury outcome descriptors and accounting for a wide variety of possible contributing factors. These logistic regression models used police and EMS reports of injury or death as the outcome variable while controlling for potentially contributing factors including seat belt use, speed limit, impact point, seat position, seat position in relation to impact point, vehicle wheel base, age and sex of the crash victim and highway type. While controlling for all these variables, only seat belt use and seat position in relation to impact point appeared to have a strong influence on the injury outcome.

The logistic regressions yielded odds ratios that indicated how much more (or less) likely an individual was to incur a specified injury outcome if the collision was with a tree or utility pole while controlling for such factors as restraint usage and seat position. According to all of the logistic regression models, trees represented the greater danger to motorists. While controlling for seat belt usage and seat position within the vehicle, individuals involved in collisions with trees are about 3.1 times as likely to die as all fixed object crash victims and about 2.1 times as likely to incur a major injury or worse. Table 7 compares the odds ratios for various injury outcomes for trees and utility poles while controlling for seat belt use and seat position.

Table 7 Odds Ratios for Injury Outcomes Controlling for Restraint Usage and Seat Position in Single Vehicle Fixed Object Crashes

object	odds ratio for police-reported death	Odds ratio for police-reported major injury or worse	odds ratio for any police, EMS or hospital-reported injury	odds ratio for EMS-reported life threatening injury
trees	3.1 (p. <.01)	2.1 (p . <005)	1.4 (p . <005)	2.1 (p . <01)
utility poles	NSS*	1.3 (p . <01)	1.4 (p. <03)	NSS*
* not statistically significant p <.05				

Source: Pennsylvania CODES database, 1994

While the results obtained through logistic regression modeling begin to show that utility poles do seem to pose a greater risk than is found when using crude death and injury rates, they also indicate that other factors such as seat belt use and seat position in relation to the impact point of the vehicle are important co-variates. The implications, nonetheless, for these results are that trees represent the greater serious injury hazard to motorists. The results also indicate that other factors, particularly seat belt use and seat position, are very important determinants of injury outcome. Severity indices based upon injury outcome should therefore have reliable information in regard to these person characteristics in order to accurately model the risk of injury.

Hospital Charges

Hospital charges may also serve as an indicator of injury severity. Individuals that are more seriously injured can reasonably be expected to spend longer in the hospital than the less severely injured with the possible exception of the most severely injured patients who may die shortly after admission. In order to attempt to measure the risk posed by trees and utility poles, average hospital charge was calculated for all linked hospital records involving patients in fixed object crashes.

The analysis showed that those involved in collisions with trees tended to have higher average charges.

Table 8 compares average hospital charges for those involved in collisions with specific roadside objects. These results support the hypothesis that trees are more dangerous than utility poles.

Table 8 Average Hospital Charges for Fixed Object Crash Victims

object struck	number of linked hospital records	average hospital charge[1]	number of linked & unlinked records	average hospital charge[2]
all crashes	6,078	$18,579	350,492	$322
all fixed objects	1,947	$18,293	60,065	$559
Trees	281	$22,076	6,570	$944
utility poles	390	$15,679	8,522	$718

[1] average hospital charge linked records only
[2] average hospital charge linked and unlinked records

Source: Pennsylvania CODES database, 1994

Linear regression is a statistical method to analyze how a continuous outcome variable, such as hospital charges, varies in relation to independent variables such as the type of object struck or whether or not a seat belt was in use. A linear regression model was applied to the data using hospital charges as the dependent variable. Independent variables used in the model included age, sex, seat position, safety belt use, speed limit, whether or not the vehicle rolled over, and the type of object struck. The linear regression analysis of hospital charges indicated that hospital charges were about $900 greater than average if the object struck was a tree, and about $166 greater if the object struck was a utility pole, although these results were not statistically significant (i.e., *p-value* less than 0.05).

Injury Severity Score

One of the primary advantages of using linked crash data for the analysis was the availability of clinically reported injury data. Hospitals record diagnostic information according to a standardized classification system known as the International Classification of Diseases 9th Edition Clinical Modification (ICD-9-CM). Hospitals in Pennsylvania record a primary diagnostic code and up to eight secondary diagnostic codes for all patients.

These ICD-9-CM diagnostic codes were converted into Injury Severity Scores using ICDMAP-90 software. This software program uses artificial intelligence and input from injury coding experts to translate ICD-9 codes into Abbreviated Injury Score (AIS) and Injury Severity Scores (ISS). The ISS is a generally recognized standard measure for anatomic injury assessment, although many researchers prefer the maximum AIS. According to the ISS system, the higher the score the more severe the injury.

The average ISS score for all crash records that linked to a hospital record was 8.3. For victims of single vehicle fixed object collisions the average ISS score was also 8.3. For victims of passenger car or light truck collisions with utility poles the average ISS score was 8.0, while the average ISS score victims of passenger car or light truck collisions with trees was 9.7. While the ISS is not an interval-level measure (e.g., the difference between an ISS of "0" and "16" is not the same as the difference between an ISS of "16" and "32"), the higher average ISS score for victims of collisions with trees supports the hypothesis that these victims are on average more severely injured than victims of collisions with utility poles. The average ISS scores should not be used, however, to estimate the relative injury risk posed by trees.

Linear regression controlling for safety belt usage and seat position in relation to vehicle impact point indicated that the ISS increased by approximately 1.7 if the crash was a collision with a tree. The same regression analysis indicated that ISS decreased by approximately 1.6 if the crash was a collision with a utility pole.

Various ISS thresholds have been used by injury researchers to define major and minor injury. Research carried out on crash data from Australia suggests that patients with an ISS score of 9 or greater should be considered to be severely injured. Other research carried out on head injury victims in the United Kingdom used an ISS of 16 or greater to define a severe injury. Both these thresholds were used to create dichotomous variables in the linked data to identify severely injured patients. Logistic regression was carried out on the data using these dichotomous variables for severe injury as the dependent variable while controlling for safety belt usage, seat position and the type of object struck.

Both logistic regressions indicated that victims of collisions with trees were much more likely to be severely injured than all other fixed object crash victims. The logistic regressions indicated that victims of collisions with utility poles were slightly less likely to be severely injured than all fixed object crash victims but the results were not statistically significant at a level less than .05.

Table 9 summarizes the analyses of injury outcomes using the ISS score as the measure of injury outcome. All of the analyses using the ISS as a measure of injury outcome consistently indicated that trees represent a greater injury severity risk than utility poles.

Table 9 Injury Severity Score Outcome Measures

Measure		
average ISS all linked crash records	8.3	n = 6,078
average ISS single vehicle fixed object crash victims	8.4	n = 1,686
average ISS single vehicle tree collisions	9.7	n = 256
average ISS single vehicle utility pole collisions	8.0	n = 361
linear regression parameter estimate for tree collisions	1.7	p-value 0.05
linear regression parameter estimate for utility pole collisions	-1.6	p-value 0.04
odds ratio for ISS greater or equal to 16 for tree collisions	1.5	p-value 0.003
odds ratio for ISS greater or equal to 16 for utility pole collisions	0.9	p-value 0.38
odds ratio for ISS greater or equal to 9 for tree collisions	1.4	p-value 0.04
odds ratio for ISS greater or equal to 9 for utility pole collisions	0.9	p-value 0.60

Source: Pennsylvania CODES database, 1994

Crash Vehicle Deformity as Measure of Risk

Another approach to measure the risk of specific objects is to look at the amount of "injury" to the vehicle itself rather than to the vehicle occupants. If the relationship between vehicle deformation and injury outcome is strong, crash vehicle deformation may serve as a good indicator of the risk posed by various objects, in that it will be independent of person-specific characteristics. If vehicle deformation were to be used as a measure of injury risk, it would be necessary to first examine the value of vehicle deformation as a predictor of injury. This was the first step in this part of the analysis.

Police accident reports include information in regard to vehicle deformation but this information is simply the police officer's judgment as to whether or not the deformation was "severe," "moderate," "light," or none. A more objective measure of crash vehicle damage may be the recorded on the EMS trip ticket that indicates whether or not a deformation of a specific number of inches (20 inches) to the crash vehicle was incurred. Of those records that were linked to an EMS record approximately 20% of crash vehicles had incurred a twenty or more inch deformity. The information on estimated crash velocity as measured by crash vehicle deformation from EMS data may be more reliable than police-reported data as this information is used by EMS crews in triage decisions, and appears to be more quantitative and thus less subjective.

Several caveats must be kept in mind in using vehicle deformation as a measure of injury risk however. A 20+ inch deformation to the rear quarter panel of a crash vehicle would probably present less of an injury risk than a 20+ inch deformation to the passenger compartment of the vehicle. Secondly, there have been no studies that compare EMS estimates of crash velocity with detailed calculations of crash vehicle velocity. Despite these caveats, EMS-reported crash vehicle deformation appears to be a good predictor of injury severity as described in the following section.

The Relationship Between Vehicle Deformation and Injury

A series of logistic regression analyses were run on the data to examine the relationship between vehicle deformation and the risk of injury or death. A variety of injury outcome measures were used and the analyses controlled for a variety of combinations of potentially contributing factors. All of these logistic models indicated consistently that a vehicle deformation of 20 inches or greater was much more likely to result in death, serious injury or any injury at all. In controlling for belt use, speed limit, seat position, and age and sex of the crash victim, only belt use and seat position in relation to the impact point were strongly associated with the likelihood of death or serious injury.

All of the logistic regressions (i.e., controlling for restraint use, seat position, speed limit, age and sex) showed that the odds of being killed in a collision were between 5.4 and 6.6 times greater if a 20 inch deformity was incurred. The likelihood of police reported injury being reported as "major injury or killed" was between 5.3 and 6.9 times greater if a twenty inch deformation was incurred. The likelihood of the injuries being described by EMS personnel as being "life threatening" in nature was 6.9 to 7.7 times greater if a twenty inch deformation was reported. The likelihood of any injury at all (i.e., minor injury through death) being reported by either police or EMS personnel was 2.3 times greater if a twenty inch deformation of the crash vehicle occurred. In summary, vehicle deformation was found by all measures to be a very good predictor of injury outcome, and a particularly good predictor of more serious injury outcomes.

The Relationship Between Vehicle Deformation and Specific Objects Struck

Logistic regressions used the occurrence of a twenty inch deformity as the outcome variable and controlled for speed limit, vehicle wheel base, the change in velocity, and impact point. These logistic regressions indicated that there were statistically significant relationships in the likelihood of incurring a twenty-inch deformation and the type of object struck. A contributing factor found to be statistically significant was whether or not the collision was a frontal impact.

Those crash vehicles in which a ΔV of 20 MPH or greater was listed as a contributing factor were approximately 4.4 times as likely to incur a twenty inch deformation, while those in frontal impacts were approximately 1.3 times as likely to incur a 20 inch deformation. Table 10, below indicates the odds ratios for incurring a twenty-inch deformation for trees and utility poles.

Table 10 Odds Ratios for 20 Inch Crash Vehicle Deformation in Single Vehicle Fixed Object Crashes

object	Overall Odds ratio	odds ratio for crashes ΔV>20 MPH	odds ratio for frontal impact crashes
trees	1.83	4.6	1.3
utility poles	1.68	4.6	1.4

Source: Pennsylvania CODES database, 1994

Discussion

This research highlights the difficulties encountered in using any single outcome variable alone to measure the risk posed by specific roadside objects. Injury data collected under difficult field conditions may pose questions of validity and reliability, yet overall there appears to be a remarkably consistent relationship between collisions with certain objects and the injury outcome. Regardless of the approach to measurement of risk, trees were consistently shown to pose a greater injury risk than utility poles. Each object type is discussed in detail below.

Trees

All risk measures used in this research showed that trees pose a high risk to motorists involved in fixed object crashes. The crude death and injury rates for 1991 and 1994 showed that tree collisions were among the most dangerous both in terms of total numbers of collisions, death and injury rates, and total deaths and injuries.

Victims of tree collision crashes were about three times as likely to die and twice as likely to suffer major or life-threatening injuries as all fixed object collision crash victims. These relationships held true while using crude death and injury rates as the outcome variable and while controlling for restraint use, vehicle speed, and seat position within the vehicle. The greater risk posed by trees was further confirmed by the average hospital charges for individuals hospitalized as a result of a motor vehicle crash into a tree and the amount of vehicle deformation incurred in these collisions. Hospital charges for these patients were about 7% higher than average charges for all fixed object crash victims. Vehicles colliding with trees were about 80% more likely to incur a twenty or more inch deformation as all fixed object crash vehicles.

An interesting relationship between trees and speed limit was also discerned. Most fixed objects seem to pose the greatest injury risk at speed limits around 45 MPH and the risk then diminishes slightly at 55 MPH. This may be because at higher speeds less rigid objects such as signposts and utility poles may shear off resulting in a lower rate of crash deceleration, or as in the case of guide rails, the vehicle may simply vault over the rail. Trees on the other hand, appear to become even more dangerous at the 55-MPH speed limit.

Why trees pose such a greater injury risk is probably related to several factors including their pole-like nature, mass, and rigidity. Objects with a pole-like nature tend to concentrate the crash energy to a much higher degree in a small area. Pole-like objects such as trees, utility poles, guide rail ends and fire hydrants are about twice as likely (odds ratio 1.98) to incur a twenty inch deformation, while lateral objects such as guide rails, walls, buildings and parked vehicles were only about half as likely (odds ratio .53) to incur a twenty inch deformation. Despite their pole-like nature, trees are also extremely rigid. Utility poles, signposts and other pole-like objects may give way more readily than trees. Trees undoubtedly pose one of the greatest injury risks faced by the motoring public.

Utility Poles

Utility poles also represent a serious danger to motorists. According to most risk severity measures used in this analysis, utility poles appeared to pose a slightly greater than average risk of death and for most measures a substantially greater risk of serious injury.

Individuals involved in collisions with utility poles are about 7% more likely to die than all fixed object crash victims, but about 30% to 40% more likely to incur major or life threatening injuries. The hospital charge data showed that hospital charges victims of collisions with utility poles were on average about 2% greater than average hospital charges for all fixed object crash victims. The crash vehicle data showed that collisions with utility poles are almost as likely to result in a twenty-inch deformation of the crash vehicle as collisions with trees.

Overall the data indicate that utility poles appear to pose a somewhat greater hazard than average fixed object crash risk for serious injury and a slightly greater than average risk for death. The analyses showed consistently that utility poles pose a lower risk than trees, however, utility pole collisions are among the most frequent types of fixed object collisions. Safety interventions might focus on reducing the likelihood of collisions as well as modifying the design of the poles themselves. These interventions might include moving poles farther away from the travel way or placing guide rails in front of the poles.

Severity Indices

The research illustrated the benefits of using multiple indices for measuring risk posed by fixed objects. Statistical testing yielded results that are consistent with engineering judgment (i.e., trees are more dangerous than utility poles) and offers quantification of the risks posed by these objects.

For some purposes, crash vehicle deformity may prove to be a more appropriate measure of the risk posed by roadside objects in that the outcome measure is independent of all person-specific factors such as restraint usage or seat position. The appropriateness of this outcome as a measure of risk severity should be further substantiated by running the same analysis on subsequent years of linked crash data. If the data from subsequent years yields results that are consistent with the 1994 data, crash investigators may want to consider capturing this data on future crash reports.

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Appendix I

Description of Data

The data used in this analysis was collected by the Pennsylvania Department of transportation, the Pennsylvania Department of Health, and the Pennsylvania Health Care Cost Containment Council. Data for 1994 from these three sources were linked using probabilistic linkage technology. Each of the three separate databases are briefly described below as well as the linked crash data set that was created.

The Pennsylvania Accident Reporting System (ARS)

All motor vehicle crashes in Pennsylvania in which an individual is injured, a vehicle is towed from the scene or in which $1,000 in property damage has been incurred are reportable by law to the Pennsylvania Department of Transportation (PADOT). Accident reports are completed by the investigating police officer and forwarded to PADOT on paper where they are filtered for logic and validity and then entered into the Accident Reporting System database. The data collected includes information in regard to the crash itself (e.g., date, time, location, harmful events, etc.), the vehicles involved (e.g., vehicle type, axles, VIN, body type etc.), the crash victims (e.g., age, sex, injury severity, restraint use, etc.), the crash location (e.g., intersection type, traffic control devices, speed limit, etc.), the sequence of events which occurred during the crash, contributing factors, road attributes, and extended description of the crash.

The 1994 ARS database included information on approximately 134,000 reported crashes and 350,498 crash victims.

EMS Data

The Pennsylvania Department of Health maintains a database of information collected by emergency medical service personnel for every EMS response in the Commonwealth. EMS personnel fill out a machine-readable form for every patient for whom there has been an EMS response. This form (or "trip ticket") includes information on the date and time of dispatch, the emergency interventions rendered, the type and location of the EMS incident, source of injury, injury severity, contributing factors and demographic information about the patient. This information is then forwarded to regional EMS Councils where it is filtered for logic and validity and then entered into a standardized database (EMSCAN). The data from the 16 regional councils are forwarded to the Pennsylvania Department of Health.

The 1994 EMSCAN database included data from 1.39 million EMS responses. Approximately 125,000 of these records indicated that the EMS call was in response to a motor vehicle crash.

Hospital Discharge Data

All Pennsylvania hospitals are required to submit discharge data on a quarterly basis to the Pennsylvania Health Care Cost Containment Council (PHC4). The data submitted included the standard administrative data from the Universal Billing Form 92 (UB 92) as well as severity adjustment information which is abstracted from clinical records. The data collected by PHC4 includes information in regard to diagnoses, procedures, charges, length of hospital stay, patient demographic information, discharge status, physician services and severity of illness.

The 1994 discharge database included information on approximately 1.8 million hospital discharges. Approximately, 18,900 of these records indicated that a motor vehicle crash was the reason for hospitalization.

The Linked Data Set

The three datasets described above were linked together using probabilistic linkage to create a data set, which is referred to as the CODES '94 database. This database contains a single record for each individual involved in a reported crash in Pennsylvania in 1994. All crash records include all information from the ARS database in regard to individual characteristics, the vehicle in which they were riding (if any), the crash circumstances, the events and crash location information. The records which linked to EMS records include information in regard to the emergency medical interventions rendered, the types and severity of injuries incurred, and contributing and extenuating factors that may have been involved in the patient outcome. Those records that linked to the hospital discharge data set include information in regard to diagnoses, procedures, hospital charges and length of hospital stay, discharge status, and external causes of injury.

The EMS database for 1994 contained records for approximately 1.3 million patients transported by ambulance. Of these 1.3 million records, approximately 132,000 were possibly a response to a motor vehicle crash (either reported as a crash, evidence of an injury, or the incident happening along a highway). Approximately 7,000 of these records linked to one another (i.e., they were responding to the same patient). These EMS records were internally linked leaving a total of approximately 125,000 EMS records. Of the 125,000 EMS potential responses to crashes, approximately 52,000 (42%) records linked to a crash record.

The hospital discharge database included records for approximately 1.8 million hospital discharges in 1994. Approximately 18,900 of these records had External Source of Injury Codes (E-codes) that indicated that a motor vehicle crash might have been the reason for the hospitalization. Another 111,000 hospital records also included trauma-related diagnostic codes. All primary and secondary diagnostic codes (ICD-9-CM), DRGs, and Major Diagnostic Categories were examined.

Any record that indicated the possibility of trauma was included in the hospital records that were matched to the crash/EMS file. Of the approximately 125,000 hospital discharges that indicated trauma, about 6,000 high quality linked records were found. Thus for about one third of the estimated 18,500 hospitalized crash victims, a corresponding crash record was found.

About 2,500 of the 6,000 linked hospital records were also linked to an EMS record. The blocking and matching variables that seemed to be most effective in linking the hospital discharge records were age, sex, date of admission, time of admission, location (e.g., did the crash occur in the same county as the hospital), and the receiving facility identification number.

In comparing the crash records that linked with those that did not link, the principal differences between the linked and unlinked records was in those variables thought to be strongly associated with a higher likelihood of injury. For example, a higher portion of those individuals whose crash records linked to either EMS records or hospital discharge records were not wearing safety belts. This difference is belt usage rates between the linked and unlinked records is to be expected, however, as one would normally expect more non-belt users to be injured (and thus link to an EMS or hospital record) than non-belt users.

For those variables which one would not expect to be associated with likelihood of injury (e.g., date of crash, county of crash, insurance status of crash vehicle, license status of crash vehicle driver), the linked and unlinked records have nearly identical frequency distributions.

For those variables thought to have a weaker association with the likelihood of injury (e.g., age of crash victim, type of vehicle), the differences between the linked and unlinked crash records is less pronounced.

In comparing those EMS records which linked to crash records with those EMS records that did not link, the only significant differences between the linked and unlinked EMS records were the unlinked EMS records had a higher proportion of missing data elements such as the date of the crash, and the age and sex of the crash victim.

Appendix II

Description of Dependent

And

Independent Variables

The analyses described in this document were based upon statistical testing of linked crash data. In order to perform the analyses it was necessary to create variables in the data set that described the crash outcomes and the independent factors that may have contributed to the outcome. These were created by transforming existing data within the linked database to a format appropriate for the particular type of statistical test being applied.

A brief description of key variables and how they were transformed is described below.

Object Characteristics

The contingency tables revealed that several roadside objects seem to account for a very disproportionate share of both collisions, deaths and injuries.

Embankments were the most frequently struck objects accounting for more than 15% of all crashes and crash victims. Together with trees, utility poles and guide rails, these four objects accounted for 50% of all fixed object collisions and about 66% of all deaths and injuries. Trees alone accounted for about 27% of the 435 deaths. Trees appear to be most deadly because they are not only among the most frequently struck objects, but also have substantially higher death rates than most other objects.

While collisions with overhead structures appear to be most deadly with fully one-fifth of the 30 crash victims dying these types of crashes are exceedingly rare (There were only 18 crashes of this type recorded in 1994.). Immovable pole-like objects seem to pose the greatest danger to motorists not only because they are much more frequently struck but also because they appear to be more deadly when they are struck. More than 1% of all victims of collisions with guide rail ends, wall ends, trees, and signal posts died. These same objects appear to pose a significant risk of severe injury.

A series of variables were created in the data set to indicate whether or not the crash was a collision with any of the 31 fixed collision objects described on the police crash report. Other variables were created to describe whether or not the object was "pole-like" or "lateral" in nature. Pole like objects included trees, utility poles, wall ends, guide rail ends, signal and signposts, fire hydrants, and bridge supports. Lateral objects included parked vehicles, curbs, ditches, embankments, buildings, walls, impact attenuators, snow banks, construction barriers, fences, and guide rails.

Other Independent Factors

Simply examining the proportion of killed or severely injured crash victims of course ignores other factors such as seat belt use, age of the crash victim, or vehicle speed that may have affected the outcome of the crash. In order to control for these other factors, variables describing these possible-contributing factors were created. Contingency tables were constructed with these variables and as a series of logistic regression models were performed to examine to what degree other independent factors may account for injury and crash outcome.

Previous research on injury outcomes of crashes indicates that a number of independent factors are related to the outcome of a motor vehicle crash. Among these factors are passenger restraint system usage, vehicle speed, seat position, vehicle size, and the age and sex of the crash victim. Logistic regression is a statistical method used to evaluate the inter-relation of multiple factors (i.e., independent) in contributing to a dichotomous outcome (or dependent) variable. A dichotomous outcome variable is one that can only have one of two possible values such as "killed" or "not killed."

Variables to describe these independent and dependent variables were created in the data set and logistic regressions were then performed using these independent and dependent variables.

The following independent variables were created in the data set.

Restraint Usage

Police reported crash information was examined to determine the types of active and passive restraint systems in place and whether or not these restraint systems were used or deployed for the crash victim. Five categories of restraint usage were established as follows:

1. safety belt only in use
2. safety belt in use and airbag deployed
3. airbag deployed without safety belt
4. no active or passive restraint system in use or deployed
5. unknown passenger restraint system

A series of four dichotomous variables based on this methods of classification were then created in the database as follows:

Variable name	Coding
Beltonly	1=safety belt only in use 0=no restraint system in use missing=other restraint combination
Bagonly	1=airbag only deployed

	0=no restraint system in use missing=other restraint combination
Beltnbag	1=safety belt in use and airbag deployed 0=no restraint system in use missing=other restraint combination
Nobelt	1=no active or passive restraint 0=any other combination of active and passive restraint

Age
This independent variable was created from the age as recorded on the police crash report. Additional variables were created to identify those over the age of 65 and those under the age of six. These variables were coded as follows:

Variable Name	Coding
Age	age of crash victim as recorded on police crash report
Over65	1=individual age 65 or older 0=individual under 65 years old
Under6	1=child age 5 or younger 0=individual over the age of 5

Sex
Males represent a disproportionate share of all crash victims and this is reflected in the data for single vehicle fixed object crashes. Approximately 68% of all crash victims were male. A separate variable was created from information on the crash report to indicate whether the crash victim was male or not.

Crash Vehicle Wheel Base
A continuos numeric variable was created in the data set to correspond to the crash vehicle wheelbase as recorded on the police crash report. Crash vehicle wheelbase was used as a measure of vehicle size. Small vehicles, it was hypothesized, would absorb less crash energy and thus be less crash-worthy, while larger vehicles might result in greater crash forces. Two other dichotomous variables were also created to indicate if the vehicle wheelbase was greater or less than one standard deviation of the average wheelbase for all crash vehicles. These vehicles were coded as follows:

Variable Name	Coding
CWB	Crash vehicle wheelbase in inches. Smallest value 799, largest value 1299
LWB (large wheel base)	1=wheel base > 1200 inches 0=wheel base < 1199 inches
SWB (small wheel base)	1=wheel base < 900 0=wheel base > 899

Crash Vehicle Speed

The crash data includes data on the speed of the crash vehicle as estimated by the investigating police officer. This variable however was considered by the data-collecting agency to be high unreliable. The speed limit of highway of the crash vehicle was thought to be more reliably collected and probably would serve as a good indication of the speed of the crash vehicle. Speed limits are recorded in five mile per hour increments between 5 and 55 MPH in 1994. Additional variables were also created in the data set to indicate whether the crash occurred on a high-speed highway or not.

The linked EMS data also included a data field that indicated whether or not a speed change of 20 MPH or 40 MPH had occurred. Variables were created in the data set to indicate whether or not the crash had occurred on a high speed road or not and also whether or not a speed change of 20 MPH or 40 MPH had been incurred. The variables were coded as follows:

Variable Name	Coding
splim	speed limit on highway of crash (5 MPH increments)
speed35	1=speed limit 35 MPH or greater 0=speed limit less than 35 MPH
speed45	1=speed limit 45 MPH or greater 0=speed limit less than 45 MPH
speed55	1=speed limit 55 MPH or greater 0=speed limit less than 55 MPH
delta20	1=speed change of 20 MPH or greater 0=no speed change of 20 MPH or greater
delta40	1=speed change of 40 MPH or greater 0=no speed change of 40 MPH or greater

Seat Position
The crash data records information on the seat position of all crash victims. This information was recoded to indicate whether or not the individual was an occupant of the front or back seat, the driver or a passenger and whether or not they were sitting on the same side as the principal point of impact. The following variables were created in the data:

Variable Name	Coding
driver	1=driver 0=not driver
fseat	1=front seat occupant or driver 0=not front seat occupant or driver
bseat	1=back seat occupant 0=not back seat occupant
sameside	1=occupant of same side of vehicle as impact point 0=not on same side as impact point
oppside	1=occupant on opposite side of vehicle as impact point 0=not on opposite side of impact point

Impact Point
The crash data includes information on the principal impact point of the vehicle with the fixed object. These points are indicated by twelve points of the clock around the vehicle with the "12" being the front center of the vehicle and the "6" being the back center of the vehicle. These impact points as recorded on the crash report were used to create new variables, which indicated whether or not the collision was a frontal collision, or a side impact. As was mentioned above these data were also used to create variables indicating the crash victim's seat position in relation to the point of impact.

These variables were coded as follows:

Variable Name	Coding
front	1=frontal impact 0=not frontal impact
side	1=side impact 0=not side impact

Crash Outcomes
A number of variables were created in the data set to describe the outcomes of the crash in terms of injury or death to the crash victim or damage to the crash vehicle. Data from the police crash report as well as from the linked EMS and hospital data were used to create this outcome descriptor. These outcome variables are described below.

Killed
This variable was created by examining police reports of injury severity as well as EMS data and hospital discharge data. This variable was coded as follows:

1=Killed
0=Not Killed

Major Injury or Worse
This variable was created by examining police reports of injury severity as well as EMS data. If police reported injury was either killed or major injury or if the EMS data reported the injuries to be "life-threatening" or if hospital discharge status indicated that the patient died, then this variable was coded as a "1." Otherwise it was coded as a "0."

Hospital Charges
The hospital discharge data includes information on total hospital charges. This field was used as a proxy measure of injury severity. In these analyses, all observations for individuals who died were excluded from the analysis. In addition, those observations that were more than one standard deviation greater or less than average hospital charges were excluded to control for outlier charges.

Vehicle Deformation

EMS records include data that indicates whether a twenty-inch or greater deformation of the crash vehicle was incurred in the crash. EMS personnel use this data in triaging crash victims. This information was used to create a dichotomous variable that indicated whether or not a twenty-inch deformation had been incurred.

Appendix III

Number of Collisions by Object and County

Table 11 Collisions by County and Object Struck

County	Trees	Utility Poles	County	Trees	Utility Poles
ADAMS	45	71	LACKAWANNA	47	86
ALLEGHENY	163	724	LANCASTER	112	298
ARMSTRONG	25	29	LAWRENCE	50	62
BEAVER	69	116	LEBANON	56	60
BEDFORD	15	31	LEHIGH	89	132
BERKS	159	191	LUZERNE	108	170
BLAIR	44	43	LYCOMING	53	52
BRADFORD	36	24	MCKEAN	15	11
BUCKS	244	306	MERCER	44	58
BUTLER	80	65	MIFFLIN	16	28
CAMBRIA	58	74	MONROE	212	76
CAMERON	4	1	MONTGOMERY	238	469
CARBON	39	35	MONTOUR	11	6
CENTRE	55	31	NORTHAMPTON	104	134
CHESTER	191	268	NORTHUMBERLA	29	25
CLARION	28	26	PERRY	28	37
CLEARFIELD	56	16	PIKE	59	30
CLINTON	19	19	POTTER	12	4
COLUMBIA	33	11	SCHUYLKILL	87	75
CRAWFORD	66	38	SNYDER	20	13
CUMBERLAND	75	91	SOMERSET	44	43
DAUPHIN	90	103	SULLIVAN	5	2
DELAWARE	98	228	SUSQUEHANNA	29	15
ELK	13	12	TIOGA	26	21
ERIE	96	142	UNION	16	22
FAYETTE	88	103	VENANGO	33	30
FOREST	14	3	WARREN	28	13
FRANKLIN	63	108	WASHINGTON	126	82
FULTON	7	9	WAYNE	44	29
GREENE	29	18	WESTMORELAND	178	204
HUNTINGDON	29	18	WYOMING	27	16
INDIANA	30	44	YORK	114	229
JEFFERSON	30	29	PHILADELPHIA	151	297