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NHTSA Technical Report

The Crash Outcome Data Evaluation System (CODES)

NHTSA
People Saving People

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This document is an accompaniment to the Report to Congress on "Benefits of Safety Belts and Motorcycle Helmets, based on data from The Crash Outcome Data Evaluation System (CODES)," December, 1995.

16. Abstract

The CODES Technical Report presents state-specific results from the Crash Outcome Data Evaluation System project. These results confirm previous NHTSA studies and show that safety belts and motorcycle helmets are effective in reducing fatalities and injuries. The Report also shows that safety belt and motorcycle use in the seven CODES states (Hawaii, Maine, Missouri, New York, Pennsylvania, Utah, and Wisconsin) could save millions of dollars in direct medical costs. The CODES project represents the first time that occupant-specific medical outcome and cost data for all occupants involved in motor vehicle crashes were available for highway safety evaluation. The technical report provides detailed descriptions of the crash, EMS, emergency department, hospital discharge and other state data files used to generate the population-based information for the Report to Congress. It describes the background of the CODES project, the selection of the seven states, the formation of the CODES advisory committees within each state (crucial to a project which depended on the cooperation of various data owners and data users) and the concepts of probabilistic linkage. Variations and similarities among the states are discussed regarding the availability of state data, file preparation, linkage variables, the linkage process and resulting linkage rates, and validation of the linkage results. It elaborates on the uniform research model used and discusses the outcome variables, additional risk factors used as covariates, models used in the logistic regressions, and methods of computing weighted averages of odds ratios and effectiveness. It compares odds ratios to risk ratios and 'effectiveness' and presents state-specific results for the safety-belt analyses of injury and cost of injury. Finally, the document gives digests of other state-specific analyses, covering topics such as: data quality, additional linkages to improve the results, data outliers (extreme values, as in inpatient charges), alcohol and drug use, age factors, types of safety belts, and geographic patterns in crash characteristics.

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INTRODUCTION

Over the years, NHTSA studies have shown that safety belts are 40-50 percent effective in preventing mortality and 45-55 percent[1] effective in preventing morbidity. As a result, fatal and non-fatal injuries have gradually decreased. However, injuries resulting from crashes continue to be a major public health problem responsible for $83 billion in societal costs excluding property damage. Direct health care costs of $14 billion comprise a significant part of these societal costs.[2] To reduce these costs, the focus must shift from monitoring just the occurrence of injuries to a more systematic approach to injury control that includes prevention, acute care, and rehabilitation. Priorities need to address the reduction of the occurrence and severity of injuries and their health care costs.

Intermodal Surface Transportation Efficiency Act (ISTEA)

Congress indicated its concern about rising health care costs in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. Section 1031, part (b) of ISTEA called for a study of the benefits of safety belts and motorcycle helmets:

> 1)IN GENERAL. -- The Secretary shall conduct a study or studies to determine the benefits of safety belt use and motorcycle helmet use for individuals involved in motor vehicle crashes and motorcycle crashes, collecting and analyzing data from regional trauma systems regarding differences in the following: the severity of injuries; acute, rehabilitative and long-term medical costs, including the sources of reimbursement and the extent to which these sources cover actual costs; government, employer, and other costs; and mortality and morbidity outcomes. The study shall cover a representative period after January 1, 1990.

With these requirements, Congress expanded its focus beyond fatal injuries to include the severity of non-fatal injuries and their costs. Five million dollars were provided to the National Highway Traffic Safety Administration for the study with the results to be reported to Congress by February, 1996.

Format of the Report

The Report to Congress focused on the benefits of safety belts and helmets. Benefits in terms of mortality, morbidity, severity, and cost were generated by each state and then combined for the Report. The state specific results are reported in this technical report which also provides a detailed description of the state data files, the linkage process, and the mandated research model used to generate the information for the Report to Congress. In addition, the state specific analyses performed by each state and the importance of linked data for injury control purposes are discussed.

The Introduction includes a discussion of the options for the study design and summarizes the requirements each applicant met for funding for the Report to Congress. The second section discusses the concepts of linkage. In the third section, details are provided about each grantee and the necessary collaboration between the owners and users of state data. The fourth and fifth sections describe the crash and injury data resources and how the data files were prepared for linkage. The sixth and seventh sections discuss the linkage process and the mandated research model. They are followed by two sections which present the results of the analyses of the benefits of safety belts and helmets. Following a summary of the results of the mandated model, the remaining sections present the state specific applications of the linked data, discuss some analytical issues, and highlight the significance of CODES. Included in the final section are recommendations about state data and the importance of linking these data to generate outcome information for highway safety.

Background

In designing the study to meet the congressional mandate, NHTSA considered the population upon which the study would be based and the availability of information relevant to specific analytical requirements called for in the legislation. Choice of a study population is important because the desired effect of most injury control countermeasures, including safety belts and helmets, is to cause a reduction in the occurrence and severity of injuries, i.e., reducing the fatal or severe injury to moderate, minor or none at all. If the study population includes only injured persons, the obvious successes (those who use the countermeasure and receive no injury) and those not affected (those who do not use the countermeasure and receive no injury) are not available to provide a basis for comparison. The same is true if the study population includes only fatalities or even the most seriously injured, such as those persons treated at trauma centers. Again, the lack of information about the uninjured makes it impossible to measure the downward shift from injured to not injured and to evaluate both the failures and successes resulting from the use of safety measures.

In an individual state, the comprehensive source of information about all persons involved in motor vehicle traffic crashes (including those involving passenger cars, vans, light trucks and motorcycles) is the statewide database created from crash reports filed by police agencies. Police officers, who investigate the crash at the scene, complete a report which includes information about the crash, vehicles, and persons involved. Selected data from these reports are entered into an electronic database from which most states produce an annual report describing the crashes occurring in that state. The availability of the database in electronic format makes the data readily available for statistical analysis.

Crash data, however, do have some limitations. They do not contain medical information on the outcome of the crash or information on the financial consequences to the injured victims. Thus, by themselves, they were not able to satisfy the ISTEA requirements.

A potential source of medical and financial outcome data was the injury data collected at the time of treatment. These data, collected locally at the scene, en route, at the emergency department, in the hospital, and after discharge, are the richest source of information on the nature, cause, and costs of injury resulting from motor vehicle crashes. If they could be linked together and with the crash data, then each data set linked would provide outcome information for the previous set and so on making it possible to describe the injury event from the time of onset, through the medical care system to final disposition. Thus, linkage would provide access to the medical and financial outcome information required by ISTEA for the Report to Congress.

But linkage would provide even more. Linkage enhances the value of each state data file being linked by expanding the comprehensiveness of each data set while incidentally improving data quality over time. At the same time, the delay and expense of new data collection is avoided. Linkage promotes standardized data which, in turn, facilitate identifying state and national priorities. Characteristics of the crash, vehicle, and occupant behavior for the motor vehicle crash are permanently linked to the specific medical and financial consequences for each person involved in the crash. Detailed medical information is generated about the patient’s symptoms, level of severity, treatment, and disposition. Instead of a one purpose data base, linked data can be used by multiple users for different purposes at any time. For example, severity can be defined at the local level in functional, physiologic, or anatomic terms to monitor high crash rates, populations at risk, or unique crash characteristics; at the state level to monitor and improve mortality and morbidity rates, health care practices, and the cost of care; and, at the national level to set priorities for federal legislation, regulation, resource allocations, and the implementation of countermeasures.

Thus NHTSA decided that the most efficient strategy for generating the population-based patient specific outcome data necessary to meet the ISTEA requirements would be to collaborate with states to link the crash and injury state data.

CONCEPTS OF LINKAGE

Prior to the CODES project, linkage of traffic records files was initially performed manually and then, as computer capabilities expanded, with an ad hoc linkage methodology. The manual method involved the actual paper records. All information included in the record was available to decide the validity of a record pair. This method was time consuming and labor intensive for small files, but neither efficient nor feasible for linking a large volume of records. The ad hoc computer method was more efficient for a large volume of records, but was restricted to using only the information which was computerized. It also required that the linkage information (age, sex, date, identification number, etc.) match exactly in both files. In order to compensate for the inevitable errors and missing data, multiple passes were necessary to adjust the linkage data. For example, age was adjusted plus or minus one year and the linkage repeated with the adjusted value. Additional passes also were needed so that groups of records most likely to match could be submitted for linkage first and those least likely to match submitted last.

Probabilistic Linkage

Probabilistic linkage techniques became available for highway safety data linkage in the form of newly developed software (AUTOMATCH)[3] that increased the volume and likelihood for accurate matches in a phenomenally short amount of time compared to the other linkage methodologies. This type of computerized data linkage focused on the probability of a match and thus did not require exact matches to link the files, a crucial asset for the crash to injury linkage in which it is uncertain when a crash report actually has a corresponding injury record and when an injury record has a corresponding crash record. Probabilistic linkage was effective because of the following characteristics.

First, probabilistic linkage simplifies the linkage problem by first sorting the files into blocks of 10-20 records and then limiting the linkage to the records within each block. All of the records within the block match on the same set of blocking variables, usually indirect identifiers with complete and accurate data on each record. Records which are not included within the blocks do not participate in the linkage process. Thus different blocking variables are used for each pass. Usually only two passes are required to ensure that records not included among the blocks in the first pass will be included within the blocks of the second pass. Other indirect identifiers, usually those not chosen to block the file, are used to link the records. Both direct (unique person identifiers) and combinations of indirect (date of birth, gender, town code, time, etc.) identifiers are important for blocking and linking. Together, the content of the data must be sufficiently powerful to discriminate among events and the people involved in a specific event.

Second, weights are assigned to each attribute value of the linkage variables according to its frequency of occurrence. Rare occurrences have a higher value than more frequent occurrences. One weight is assigned based on the likelihood of matching among valid matched pairs and is called the agreement weight. The other weight is assigned based on the likelihood of matching among unmatched pairs, called the disagreement weight, and is expressed as the probability of chance agreement. When two attribute values match, the value is expressed as a logarithm to the base two of the ratio of the agreement (match) weight and the disagreement (chance agreement) weight. When two attribute values do not match, the value is calculated as the logarithm to the base two of the ratio of one minus the agreement (match) weight and one minus the disagreement (chance agreement) weight. Assignment of the agreement and disagreement weights includes a lower penalty for mismatches caused by missing data.

Third, the linkage process assigns a value to the linkage of two attributes. Exact matches receive the full weight. When they do not match exactly, adjustments to the weights are made according to pre-determined match parameters which allow weights to be prorated within an acceptable range or percentage, or to be adjusted when a character varies or when a match occurs within an array of choices, etc. Thus, the process considers the value of all available information.

Fourth, the attribute weights are totaled and a composite weight is assigned to each record pair. The composite weight will be positive for a match and negative for a non-match. The unsure matches include the low positive weights, duplicates, and record pairs which do not match on critical attributes.

Fifth, unsure, unusual, and duplicate matches are manually reviewed and reclassified as a match or non-match. False positives and false negatives are minimized by adjusting the cut-off weights, the range of weights defining the unsure matches. On average, each state was able to limit the number of matched pairs requiring manual review to about 10 percent of the record pairs generated by the computer during each pass of the crash and injury linkage.

DESCRIPTION OF THE CODES STATES

NHTSA sought grant applicants with existing statewide crash and injury data systems capable of generating medical and financial outcome information after linkage. Any state agency, non-profit organization, or educational institution was eligible to develop and coordinate a coalition of data owners and users to perform the linkage.

Because of the necessity to generate specific data to conduct the require analyses, NHTSA decided not to fund any states which would need to create new databases. To promote cooperation between owners and users of the required databases, the grants would be made to a single applicant in a state who would be responsible for obtaining cooperation of the owners and users of the data. Selection of the states also was independent of their belt and helmet use rates and current legislation.

In a May 5, 1992, Federal Register notice, NHTSA issued a grant solicitation notice requesting applications from states. Applicants were required to demonstrate the existence of and the capability to access computerized state crash, EMS, emergency department, hospital, outpatient, rehabilitative, long term care, and insurance claims data. They were also required to work cooperatively with NHTSA to implement the probabilistic linkage algorithm, and to guarantee transfer of their linked data base to NHTSA for use in preparing the Report to Congress. Agencies in 20 states responded to the solicitation.

Hawaii, Maine, Missouri, New York, Pennsylvania, Utah, and Wisconsin were awarded grants effective October 1, 1992, to generate Crash Outcome Data Evaluation Systems (CODES)

(See Exhibit 1). CODES was implemented successfully by these states through different organizational entities. Missouri, New York, and Pennsylvania implemented CODES through offices within the Department of Health: The Offices of Emergency Medical Services in New York and Pennsylvania and the Division of Health Resources in Missouri. Maine directed CODES through the Department of Public Safety and Wisconsin through the Department of Transportation. The Maine Office of EMS (located in the Department of Public Safety) subcontracted with the Maine Health Information Center to implement CODES in Maine. Wisconsin sub-contracted with the Center for Health Services Research and Analysis (CHSRA) at the University of Wisconsin, Madison. Hawaii and Utah coordinated CODES through the state university system. The Department of Urban Planning at the University of Hawaii at Manoa provided the leadership for the Hawaii CODES, while the medical school at the University of Utah led the Utah CODES project.

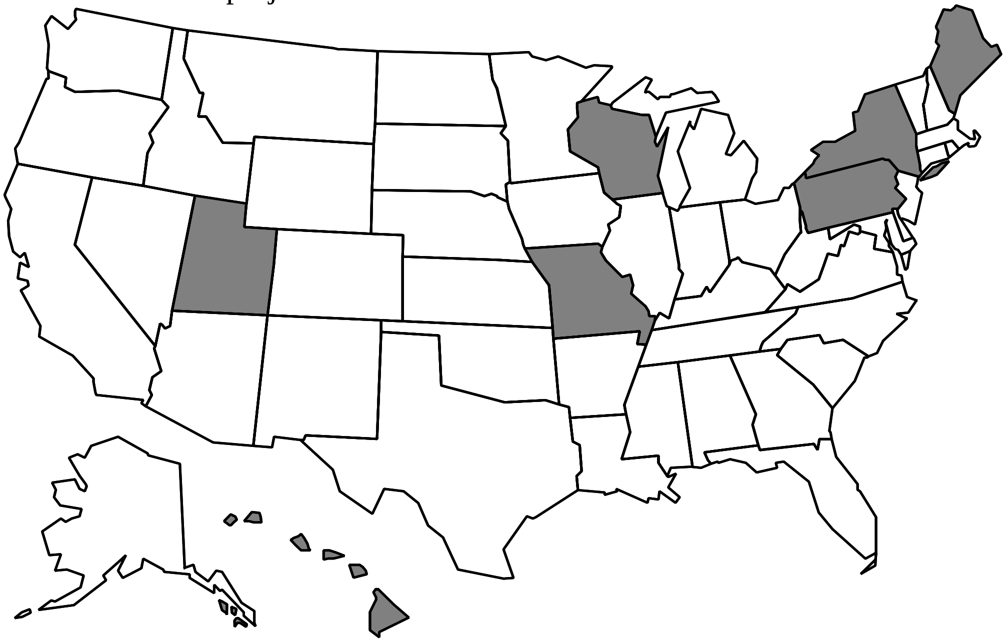


Exhibit 1. States Selected for the CODES Project: Hawaii, Maine, Missouri, New York, Pennsylvania, Utah, and Wisconsin.

Exhibit 2 indicates the unique characteristics of the seven states. During the study period, safety belt legislation for adults was in force in all of the CODES states but Maine. Two of the states had primary belt legislation that provided for motorists to be ticketed for not wearing a belt. Four states had secondary belt legislation that permitted ticketing for non-belt use only when the motorist was stopped for another reason. Belt use rates reported by police or occupants to police were higher for those states with primary legislation and higher than rates recorded by side of the road observers regardless of whether the state had primary or secondary legislation. During the study period, helmet legislation, at various times adopted by all seven states, was in force in three. The states also varied relative to no-fault insurance. Two of the seven states, New York and Hawaii, enforced no-fault insurance requirements for motor vehicle crashes.

Exhibit 2. Characteristics of the CODES States Reflecting the Year of Data Collection.

State Profile	HI	ME	MO*	NY	PA	UT	WI
Population (1000's)	1108	1228	5117	18058	11961	1770	4955
Belt Legislation for Adults	Primary for front seat occupants	None	Secondary for front seat occupants; except pickups	Primary front seat occupants	Secondary for front seat occupants	Secondary front seat occupants	Secondary
CODES Reported Belt Use Rate	97%	55%	79%	88%	86%	74%	86%
State's Observed Belt Use Rate	81%	35%	55%	69%	71%	47%	55%
Universal Adult Helmet Legislation	No	No	Yes	Yes	Yes	No	No
CODES Reported Helmet Use Rate	30%	49%	94%	98%	80%	26%	33%
State's Observed Helmet Use Rate	47%	22-30%	NA	>99%	>99%	NA	44% (1993)
No Fault Insurance	Yes	No	No	Yes	No	No	No

* Data were linked only for drivers.

CODES Advisory Committees

Each CODES state convened an Advisory Committee consisting of the owners and users of state data. The purpose of this committee was to facilitate collaboration between highway safety, medical, and insurance communities. For most of the states, this was the first time that these diverse groups collaborated on highway safety issues. Usually, state crash and injury data were used independently by the various groups for their own purposes. For example, physicians studied the relationship between the types of injuries and crash characteristics. Highway departments studied the occurrence of injury without concern about the type of injury, its survivability or cost of care. The type of members included on the State Advisory Committees varied by state as indicated in Exhibit 3. The owners of the various state data files were included on most CODES committees. Also included were researchers, medical providers, injury control experts, engineers, etc., to reflect the breadth of interest in linked data.

Exhibit 3. Types of Representation Included in the CODES Advisory Committees.

	HI	ME	MO	NY	PA	UT	WI
HIGHWAY SAFETY							
Crash Data File	✔	✔	✔	✔	✔	✔	✔
Traffic Safety Program	✔	✔	✔	✔	✔	✔	✔
Department of Transportation	✔			✔	✔	✔	✔
Department of Motor Vehicles				✔	✔		✔
Traffic Safety Committee				✔			
Law Enforcement	✔		✔	✔	✔	✔	✔
Engineers	✔				✔	✔	✔
HEALTH							
EMS Data File	✔	✔	✔	✔	✔	✔	✔
Hospital/Rehabilitation Data File	✔	✔	✔		✔	✔	✔
Nursing Homes/Long Term Care Data File		✔		✔			
Department of Human Services	✔	✔	✔	✔	✔	✔	✔
Public Health Professionals	✔	✔	✔	✔	✔	✔	✔
Physicians / Medical Society	✔	✔	✔	✔	✔	✔	✔
Medical School/University Researcher	✔	✔	✔	✔	✔	✔	✔
Rehabilitation	✔		✔		✔	✔	
Nursing Society	✔						
Medical Records			✔		✔	✔	✔
Injury Registry	✔	✔	✔		✔	✔	
INSURANCE AND OTHER							
Medicaid / Medicare	✔		✔		✔	✔	✔
Health Insurance	✔	✔			✔	✔	
Vehicle Insurance	✔				✔	✔	
Vital Statistics		✔	✔		✔	✔	✔
Mothers Against Drunk Driving			✔	✔	✔	✔	
Legislator		✔				✔	

Together the members of the committee resolved problems related to data access, data quality, data processing, patient confidentiality, and appropriate interpretation of the linked data. In the process they promoted standardization of definitions across data files, encouraged timely data processing, and expanded data content to facilitate linkage. By monitoring the linkage results and applications of the linked data to ensure appropriateness, they engaged in a multi-disciplinary approach to decision making. To date, all of the Advisory Committees have developed data release policies to encourage use of the linked data. They also considered various alternatives for promoting on-going linkage of state data to support injury control.

DESCRIPTION OF CRASH AND INJURY STATE DATA FOR LINKAGE

Outcome information is important to identify specific populations at risk, and the causes, nature, and severity of their injuries over time. CODES generated outcome information from existing crash and injury population-based state data. Most state data sets are designed to meet the specific needs of the agency collecting the data. These needs may be non-medical and focus on the circumstances of the injury event as recorded by the police at the scene. Or the needs may be medical and focus on a particular phase of patient care recorded by medically trained personnel such as emergency medical services personnel at the scene and en route, nurses and physicians at the emergency department and in the hospital, medical personnel responsible for rehabilitation and long term care, and by non-medical personnel responsible for billing and payment. No state data file by itself is sufficiently comprehensive to support injury control efforts.

Characteristics of Statewide Data

For state data to be useful to local, state, and national decision makers, the data must be accessible, of reasonably high quality, automated, and linkable. Different owners control state data. Although the owners are usually public entities, they may also include private entities such as hospitals. Access to each data file is governed by specific data release policies that are legislated, mandated through regulation, or controlled by organizational policies. Exhibit 4 summarizes the characteristics of the sources of injury and claims state data useful for linkage. These characteristics describe who collects the data, if the collection is mandated and routinely computerized, if access is restricted by patient confidentiality or other policies, if the data are population based, whether they are routinely edited, what the record unit is (vehicle, crash, or person), and if cause of injury information is recorded.

Exhibit 4. Characteristics of the Injury, and Claims Data Sources Used by the CODES States.

Data Source	Data Collector	Statewide	Population Based	Edited	Record Unit	Indicates Crash
CRASH	Department of Transportation/ Public Safety / Motor Vehicles	✔	✔		Crash	✔
Vehicle Registration	Department of Motor Vehicles	✔	✔		Vehicle	
Driver Licensing	Department of Motor Vehicles	✔	✔		Driver	
Census	Department of Health	✔	✔		Person	
Roadway/Infrastructure	Department of Transportation	✔	✔		Road Marker	✔
MEDICAL DATA SOURCES						
EMS	Depts of Health or Public Safety	Except Wisconsin	✔		Event	✔
Emergency outpatient	Hospital/Claims				Event	
Hospital discharge	Dept. of Health	✔	✔	✔	Event	NY Only
Registries: Trauma, Head & Spinal Cord, Poison	Hospital or Dept. of Health			✔	Person	✔
Death Certificates	Dept of Vital Statistics	✔	✔	✔	Person	✔
INSURANCE CLAIMS DATA						
Medicaid, Medicare	Dept of Health	✔		✔	Claim	
Private Health Insurance	Health Insurance Co				Claim	
Worker's Compensation	Dept. of Labor	✔		✔	Claim	
Private Vehicle Insurance	Vehicle Insurance Co				Claim	✔
National Auto Insurance Files	Association of Insurance Companies				Claim	✔

Advantages of Linkage

The cornerstone of an effective highway safety program is accurate, comprehensive data covering the three phases of a crash: crash related events occurring before the crash, during the crash itself, and after the crash. By aggregating and linking occupant-specific data, linkage provides access to this type of longitudinal information and generates a record of the sequence of the events from the time of the occurrence of the crash through the medical care system to final disposition. Exhibit 5 displays the crash and injury data sources considered for use in the CODES project. The data files may be linked from the scene through the medical care system to final disposition. Or they may be linked backwards from the medical disposition back to the scene. A description of each data set follows.

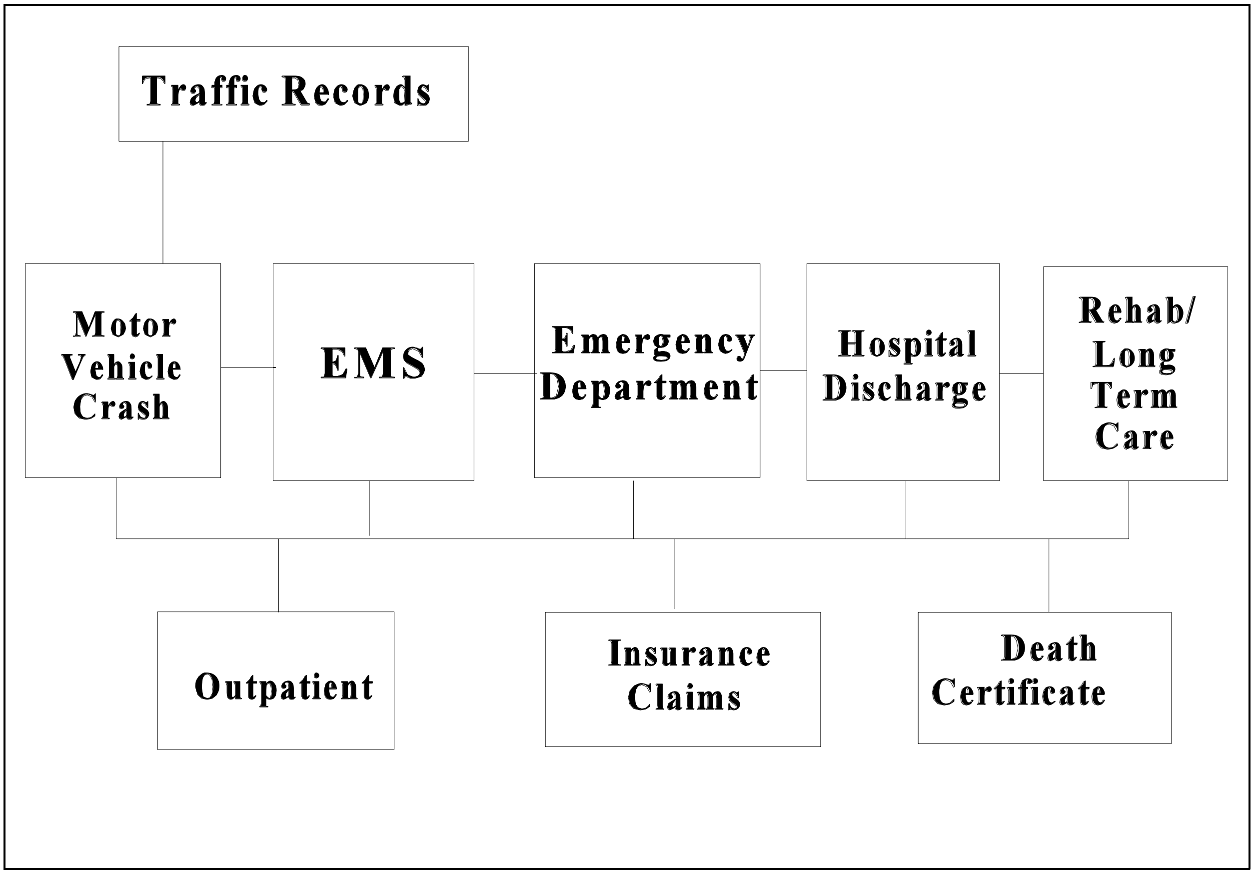


Exhibit 5. Crash and Injury Data Sources.

Non-Medical Data Resources

Non-medical state data may be crash specific or provide descriptive information about a component of the environment surrounding the event. Crash specific information is generated by the crash report. Environmental data are generated from vehicle registration, driver licensing, and census data which provide non-crash specific reference information about the driver, vehicle, and geographic location.

POLICE CRASH REPORT

The police crash report is a crash specific record that describes the characteristics of the crash, vehicle, and occupant behavior at the time of the crash. This information includes the type of crash, contributing factors, type of roadway, driver identifiers and actions, injured occupants, use of safety devices such as belts and helmets, etc. Police crash data are the major source of information indicating the time of onset for the crash-related injury. Exhibit 6 indicates that five of the seven CODES states collected complete data for both injured and uninjured occupants who were involved in the crash. Wisconsin reported safety belt and helmet use information for the uninjured passengers but not their identifiers such as age and sex. Missouri excluded the uninjured passengers altogether. Uninjured passengers are an important source of information describing the success stories (such as those occupants who are not injured or who suffer less serious injuries because they were wearing safety belts). Lack of information about all involved occupants, injured and uninjured, may result in an under-representation in the linked data of musculoskeletal injuries such as whiplash, for example, or occult abdominal injuries such as lacerated spleen.

Police document injury severity using a functional measure of severity consisting of five levels: killed (K), severe or incapacitating injury (A), non incapacitating injury (B), possible injury (C), and not injured (0). Because evaluation of severity is based on level of functioning, injuries which are minor in terms of survivability may be included among the severe injuries and vice versa. Often, just the transport of a crash victim for treatment is enough for the police officer to code “incapacitating injury.” In contrast, some types of head injuries are not evident at the scene but may become life threatening within hours of the crash. Police do not have the time or training to collect detailed medical information at the scene or to obtain other medical data generated either en route or at the hospital. The police severity score, KABC0, is useful for predicting linkage to an injury record, but is associated with survivability only for those who are killed at the scene .

Designation of the severity levels varied among the CODES states. For example, about one-third of the occupants involved in crashes in New York were coded as suffering possible injuries compared to about 10 percent in the other CODES states. Linkage made it possible to standardize the severity levels among the CODES states by redefining them according to the location of treatment (died, inpatient, transported and/or ED, slightly injured).

All states have reporting thresholds so that not all motor vehicle crashes are reported or are reportable to the police. Persons in crashes involving no injury or a single vehicle with little damage may feel no obligation to notify authorities, particularly if the consequence might be higher insurance rates. In some instances, the crash may be reported but not computerized. The minimum reporting threshold excludes some or all of those crashes causing only minor property damage and no injuries. Exhibit 6 indicates that the property damage thresholds ranged from $500 to $1000 for the CODES states.

The police crash data file includes a large volume of records which are usually stored on a mainframe computer. To facilitate access, police data are split into occupant, vehicle, or crash specific data files. Some states also store, in separate files, the vehicle identification numbers and the points of impact for vehicles involved in crashes, and the types of fixed objects struck during crashes. All of these data files may be linked using an identification number unique to the crash. When police crash data were stored in multiple data files, the CODES states merged the files into an occupant-specific data file. When the data were stored in one crash-specific data file, the data file was expanded into an occupant-specific data file.

Exhibit 6. Crash Reports: Owners, Scope, and Reporting Thresholds.

State	Owner	Scope	Reporting Threshold
Hawaii	DOT	69,072 persons statewide	Damage of >$1,000 or injury on public road.
Maine	Dept. of Public Safety	87,596 persons statewide	Damage of >$500 or injury on public road.
Missouri	State Highway Patrol	299,679 drivers and injured passengers	Damage of >$500 or injury on public road.
New York	Dept. of Motor Vehicles	581,983 persons statewide	Damage of >$1,000 or injury on public road
Pennsylvania*	DOT	329,535 persons statewide	Any injury or towed vehicle on public road
Utah*	DOT	98,373 persons statewide	Damage of >$750 or injury on public road
Wisconsin	DOT	384,298 persons statewide	Damage of >$500 or injury on any public road

* Excludes pedestrians and bicyclists.

Some states, recognizing the advantage of linkage, collected the unique numbers for records to be linked. For example, both New York and Hawaii required police to record the

EMS run report number on the crash report. However, budget considerations led to the decision not to computerize this information so it was not available for linkage.

VEHICLE REGISTRATION DATA

Vehicle registration data describe detailed characteristics of the vehicle being registered. This information includes vehicle identifiers including identification number (VIN). The VIN can be decoded to obtain information about the type of restraint system, vehicle weight and other vehicle characteristics useful for evaluating the consequences of particular types of crashes. When the VIN is also collected on the crash report, the crash and vehicle registration files can be linked directly. Linked crash, vehicle registration, and injury data generate information that relate specific types and characteristics of the vehicle to urban and rural crash patterns and their specific medical and financial consequences.

DRIVER LICENSING DATA

Driver licensing data are driver-specific and include the driver license number, birth date, social security number (SSN) and sometimes the driver's history of citations. When driver information from the crash data are combined with medical cost and citation information, this information is useful to assess the societal costs caused by repeat offenders. Linkage of the crash and driver licensing data files provides access to the SSN to facilitate linkage to insurance claims data, such as Medicaid.

CENSUS

Census data are not crash specific but provide information about the geographic location where the crash occurred. These data generate population estimates for geographic areas, usually towns and counties. These data can be linked to square mile estimates and then used to standardize crash locations in terms of population density (population per square mile) to indicate areas such as metro, urban, suburban, rural or wilderness. This information is useful for intra or inter-state comparisons.

ROADWAY/INFRASTRUCTURE

Roadway/infrastructure data are not crash specific. Instead they describe bridges, pavements, roadside inventories, etc. that describe the type of road where the crash occurred. These data, when linked to the crash and medical cost data, are useful to determine the cost-effectiveness of options for maintaining and upgrading streets and highways.

Medical Data Resources

Medical data are collected by medically trained providers treating the patient at the scene, en route, at the emergency department, in the hospital, and after discharge for rehabilitative and long term care and by non-medical personnel responsible for billing and insurance claims. The medical outcome files useful for highway safety are described below.

EMERGENCY MEDICAL SERVICES

The Emergency Medical Services (EMS) data include information about all victims who are treated and transported to a hospital by an ambulance. A separate report is completed to record the status, treatment, and disposition of the victim by each EMS service which responds (first responder, basic life support, advanced life support, air transport). Thus the EMS data file may include many records for the same patient covering a single emergency event. New York, Pennsylvania, and Missouri stored their EMS run report data on a mainframe computer whereas Hawaii, Maine, Utah, and Wisconsin used a mini-computer.

Exhibit 7. Emergency Medical Services State Data.

State	Owner	Scope	Reporting Threshold
Hawaii	EMS Dept. of Health	9,389 motor vehicle crashes statewide	Mandated for each patient responded to by EMS statewide
Maine	EMS Dept. of Public Safety	125,000 reports statewide	Mandated for each patient responded to by EMS.
Missouri	EMS Dept. of Health	492,553 reports statewide (excludes deaths at the scene)	Mandated for each patient transported by EMS. Does not include first responders.
New York	EMS Dept. of Health	1,641,123 reports statewide	Mandated for each patient responded to by a licensed EMS service. Does not include first responders.
Pennsylvania	EMS Dept. of Health	857,624 reports statewide	Mandated for each patient responded to by a licensed ambulance service
Utah	EMS Dept. of Health	80,967 reports statewide	Mandated for each patient responded to by EMS.
Wisconsin	Milwaukee County	2,987 records county wide	Mandated for paramedic runs in Milwaukee County.

Exhibit 7 indicates that the EMS data are owned by the Office of EMS. In the CODES states, the Office of EMS is located in the Department of Health except for the State of Maine where EMS is located in the Department of Public Safety. Wisconsin is the only CODES state without a state EMS data system. (However, the Wisconsin crash report compensates for this omission by collecting information that the occupant was transported. This information, along with date of birth and zip code of residence for all injured passengers, enables the Wisconsin crash data to be linked to the hospital discharge and claims data in the absence of EMS data.)

EMS reports are the first medical records completed for people injured in motor vehicle crashes requiring transport to the emergency department. Severity is described in physiological terms based on the patient's vital signs which are associated with survivability.

The availability of cause-of-injury information on the EMS record varied in the CODES states. Missouri recorded "trafficway" to indicate the EMS pick-up location. The other states used a box to indicate motor vehicle crash. Although this information is useful for patient care and facilitates linkage between the crash and EMS data, the quality was often perceived as unreliable for case selection for linkage. EMS data are the only source of routinely collected information which directly link the events at the scene with the hospital. None of the EMS records include information about crash victims not transported by EMS. Use of occupant protection devices and alcohol/substances recorded in the EMS data were used to corroborate similar information on the crash report.

EMERGENCY DEPARTMENT

At the emergency department, a report is completed for each patient treated. Information is first recorded in the emergency department log and then subsequently in notes completed by the triage nurse, the attending physician and nurse, in addition to the medical and mental health specialists who provide treatment. Billing data, including patient identifiers, are collected and usually computerized more frequently than the patient care data. The emergency department is the source of information about crash victims who are not transported by EMS but who obtain outpatient medical treatment at a hospital. It also provides information about the additional treatment and disposition for those crash victims who were transported by EMS. Like the EMS report, severity is recorded in physiological terms based on the patient's vital signs.

In spite of the importance of emergency department information for highway safety and injury control in general, only Missouri has mandated its collection and computerization statewide. Utah and Hawaii obtained statewide emergency department information from hospital case mix data and health claims data respectively. New York obtained population based emergency department data for New York City only from the New York City Health and Hospitals Corporation. This Corporation maintains an ambulatory care database including billing and summary discharge data for all patients treated at emergency departments in municipal hospitals and by EMS services within New York City. Maine and Wisconsin obtained limited ED data from their claims data. Pennsylvania merged uniform emergency department billing data from a stratified sample of hospitals to determine the feasibility of creating a statewide data file for linkage purposes.

INPATIENT HOSPITAL AND REHABILITATIVE RECORDS

Once admitted as an inpatient for acute care, a medical record is completed during the length of stay and abstracted into a discharge record for every patient. Patients who receive rehabilitation services in the same acute care hospital are also included in the inpatient data system as a separate admit and discharge. When rehabilitation speciality hospitals are required to submit discharge data to the state, these records become part of the hospital discharge data file. Hospital data have been standardized for reporting to the Health Care Financing Administration for payment under Medicare/Medicaid. The data include patient, hospital and provider identifiers, procedures and diagnoses, disposition, charges, etc. Hospital data provide a source of routinely collected financial information describing total charges and, in some states, hospital-based physician charges. Charges for other professional services are not included but are estimated to represent an amount equal to 25 percent of inpatient charges[4]. The charges reported reflect the price charged and do not represent the actual cost of providing care to that specific patient or the revenue received by the hospital.

All states had routinely computerized statewide inpatient data files except Hawaii and Utah. Hawaii's hospital discharge data were generated from an Injury-in-Hawaii project sponsored by the Department of Health and funded by the Centers for Disease Control. For this project all hospital discharge data were collected for all patients discharged from acute care hospitals in Hawaii statewide for a three year period. This file was unique because it also included indicators of the patient's level of functioning at the time of discharge. The Utah CODES team merged hospital-specific case-mix data statewide using a data set which excluded sensitive information. After performing the linkage, they returned the linked data to the data owner to replace the sensitive information only for those records which linked.

Because inpatient data are collected by licensed/certified trained medical records technicians and serve as the basis for payment, data quality is usually higher than other injury data. Quality may vary for specific data elements, such as the E-codes or EMS run report numbers, not routinely used for billing purposes. For example, New York is the only CODES state which records the EMS run report number on the hospital discharge abstract. However, because these data are not related to hospital use and thus are not monitored, only 17 percent of the records had a valid EMS number.

The discharge diagnosis codes recorded in the inpatient data can be used to generate an injury severity score (ISS)[5] to standardize severity according to the types of injuries. The ISS is an anatomic measure based on body region injured as defined by a narrative description of the injury or by the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) hospital discharge diagnosis codes.

Hospital records do not computerize information about the use of occupant protection devices, and alcohol related information may be restricted from public access.

Exhibit 8 indicates the owner, volume of records, and the reporting thresholds for inpatient data in each of the CODES states.

Exhibit 8. Inpatient Hospital Discharge State Data.

State	Owner	Scope	Reporting Threshold
Hawaii	Dept. of Health	1,475 motor vehicle crash injury discharges statewide	Injury in Hawaii including all motor vehicle crash injury discharges statewide.
Maine	Health Care Finance Commission	160,000 discharges statewide	Mandated for all discharges from Maine hospitals statewide.
Missouri	Dept. of Health	799,039 discharges statewide	Mandated for all discharges with a length of stay of at least 24 hours from Missouri hospitals statewide.
New York	Dept. of Health	2,576,619 discharges statewide	Mandated for all discharges from New York hospitals statewide.
Pennsylvania	Health Care Cost Containment Council	1,943,244 discharges statewide	Mandated for all discharges from Pennsylvania hospitals statewide.
Utah	Hospitals	165.541 discharges generated from hospital specific case mix files statewide	Includes all discharges for acute and rehabilitative care. These data include 75 percent of the rehab data statewide.
Wisconsin	Commissioner of Insurance	663,857 discharges statewide	Mandated for all inpatient discharges from Wisconsin hospitals statewide.

Access to hospital discharge data is usually restricted by legislated requirements. Data requests must be in writing. A fee may be required. And a data release must be signed indicating that the data will not be used except as stated. There may be other requirements specific to access for linkage. For example, to obtain access to the identifiers needed for linkage, Wisconsin CODES staff became volunteer hospital data staff for a two week period and performed the linkage using the computer storing the hospital data. A sanitized version of the linked crash hospital data was then transferred to the CODES site for further analysis. Missouri was allowed restrictive access to only the hospital data which included the identifiers needed for linkage. After the linkage, they returned the linked hospital data to the data owner in order to add the charge information for those hospital records which linked.

LONG-TERM HEALTH CARE (NURSING HOMES) INFORMATION

More-seriously-injured crash victims may require long-term medical care in a nursing home. Long term care medical data are collected to meet the needs of the facility and for payment by Medicaid and Medicare. These data document the functional status of the patient receiving long-term care. They are rarely computerized statewide and must be accessed directly from the long-term care facility. Both Maine and New York had access to computerized statewide long-term care data because of participation in a pilot study. However, only Maine was successful linking to the actual data file. Severity information is generated from data describing the patient’s level of impairment and vital signs. Computerization of this information varies by facility.

DEATH CERTIFICATE

The death certificate data describe the medical causes, time, location, and mechanisms of injury for all injury deaths, including those caused by motor vehicle crashes. They do not include standardized diagnosis codes describing the medical condition such as are recorded on the inpatient hospital data file; but they do use standardized codes to document the causes of death. The death certificate also records the time and location for the onset of an injury which can be used to corroborate information on the crash report. Unfortunately this latter information sometimes is not computerized. These files record all deaths, regardless of the residence of the victim, occurring within the state and all deaths of residents who die out of state. Death certificate data are computerized statewide according to standards that are uniform nationally.

OTHER INJURY DATA SYSTEMS

Medical status, treatment, and disposition information for injured victims of crashes may be obtained from other injury data generated by hospitals, health maintenance organizations, and government agencies. These data systems include trauma registries, primary care data systems, Fatal Accident Reporting System (FARS), etc. Trauma registry data are usually generated by designated trauma centers and, thus, are considered a subset of the EMS and hospital data for those patients with the most serious injuries. Some states, particularly those without statewide hospital discharge data systems, may include all patients statewide with injuries requiring hospitalization in their trauma registries. Centralized primary care data systems include data collected when outpatient care is provided, such as by health maintenance organizations. FARS data are generated by NHTSA from police and EMS data and include all victims of crashes who die within 30 days of the crash or who suffer non-fatal injuries in fatal crashes.

INSURANCE CLAIMS

Limited medical and health care financial information are generated as part of the claims process for health and vehicle insurance. Medical treatment and payment data describing injured crash victims over 65 years of age or disabled may be obtained from Medicare, for victims who are financially needy from Medicaid, for victims of occupational injuries from Worker's Compensation, and for victims whose care is paid by specific insurance groups such as Blue Cross/Blue Shield, Allstate, Aetna, State Farm, etc. The advantage of claims data is that they may include both outpatient (emergency department) and inpatient medical and financial information, and they are carefully edited to facilitate payment. The disadvantage is that the data reflect information necessary to process an insurance claim and usually do not provide the detailed medical information, including injury severity, required to evaluate patient outcome. In addition, claims data files are usually very large since they include multiple claims records per event and multiple events per person. Records must be identified that relate to the specific event being studied.

Use of insurance claims data for linkage to crash data is complicated by the fact that more than one insurance company may be involved and not all pay at the same rate. In most cases, the no-fault insurance carrier or the automobile insurance company is liable for the health care charges. However, some victims file the claim with their health insurer to avoid having to pay higher automobile insurance rates. When the victim is also eligible for Medicare, the claim to Medicare will be filed last since Medicare pays at a lower rate. On the other hand for Medicaid eligible recipients, the claim may be filed first since Medicaid is often willing to recoup expenses from the payer who is liable for the costs. It is not surprising that the lag between billing and processing causes a delay in the availability of data for linkage and that the various co-payment arrangements complicate the process of documenting the actual payers for analytical purposes. However, linked claims data are useful to audit and cross-check cases across different databases, and thus are significant to insurance companies and health providers interested in controlling costs.

National insurance data facilitate linkage. The American Insurance Services Group (AISG) describes its national Insurance Index System as a leading national clearing house for bodily injury claims. It is administered by the AISG and is considered the leading industry-sponsored provider of loss data. This extensive system of claims records was initiated in the 1920's by the Association of Casualty Insurance Companies as a research tool to defend supporting insurance carriers against fraudulent bodily injury claims. The system is currently supported by 1,450 property/casualty insurance companies, 1,500 self-insurers, and 120 claims administrators that represent over 93 percent of the industry in premium volume. The Index System serves all of North America and the American possessions. These national data can be split into statewide files to support the linkage of state data.

FILE PREPARATION

The purpose of data linkage is to identify records for the same person that are located in different data files, most of which were not designed to be linked together. Unique personal identifiers frequently are not uniformly computerized or available for linkage. Instead, individuals must be identified using a combination of indirect identifiers.

All files must be prepared prior to linkage regardless of the linkage method. This step may take months, particularly if the state data are not routinely edited or monitored to support local decision making.

The data resources varied among of the CODES states. Exhibit 9 summarizes the file preparation performed by each CODES state. File preparation usually began with the creation of an occupant-specific file for linkage. Then the data files were edited. Except for Wisconsin, which benefitted from state data which were extensively edited routinely, all of the states spent time, sometimes months, preparing their data. In most states, the hospital data required the least amount of editing. Preparation included converting the coding conventions for town/county codes, facility/provider, address, gender, and date in one file to match the codes in the other file. New variables were created to expand the use of existing information.

Exhibit 9. File Preparation Performed Relative to Existing Data Resources by Each CODES State

ADJUST RECORDS FOR LINKAGE	**HI**	**ME**	**MO**	**NY**	**PA**	**UT**	**WI**
Consolidate multiple records per person	✔	✔	✔	✔	✔	✔	✔
Create occupant-specific crash file	✔	✔	✔	✔	✔	✔	✔
PERFORM EDITS/LOGIC CHECKS							
Recode newborns, unknown age	✔	✔	✔	✔	✔		✔
Correct out of sequence times	✔	✔		✔	✔		
Correct Date of birth and Age variations			✔	✔	✔		✔
Add minutes to hour				✔	✔		
STANDARDIZE NON-UNIFORM CODING SYSTEMS							
Town/County Codes	✔	✔	✔	✔	✔	✔	✔
Hospital/EMS Provider Codes			✔	✔	✔	✔	✔
Address	✔			✔			
Seating Position	✔						✔
Gender	✔			✔		✔	✔
Date	✔			✔		✔	✔
CREATE NEW VARIABLES							
Names converted to phonetic spelling (Soundex, etc.)			✔	✔		✔	
Times converted to time blocks	✔	✔	✔	✔	✔		
Location codes converted to hospital service area	✔	✔	✔	✔	✔	✔	✔
EMS Region / EMS Service Area	✔			✔	✔	✔	
Area and type of injury recoded	✔	✔	✔	✔	✔	✔	
Decode VIN; Recode vehicle types	✔			✔	✔	✔	✔
Probable Admit Date		✔	✔		✔		
Occurrence of Injury yes/no	✔	✔	✔	✔	✔	✔	✔
Recode protective device	✔		✔		✔	✔	✔
Occurrence of Injury; Occurrence of hospitalization	✔	✔	✔	✔	✔	✔	✔

Linkage Variables With The Power To Discriminate

The information in each file being linked was evaluated to ensure its adequacy to discriminate among the events and the persons involved in each event. The CODES states used different variables to block and link their files. Exhibit 10 indicates that most states used location, date, times, provider service area, and hospital destination to discriminate among the events. However, Hawaii, Missouri, New York, and Utah did have access to name or initials for some of the linkages. The power of an indirect identifier to discriminate also differed among the states. For example, Hawaii, with four separate counties, each of which represents an island or group of islands, was able to use county for blocking. The other states relied on town/city codes. Which variables were used for blocking and which for linkage depended on both the reliability and availability of the data within the state, the linkage phase, and the files being linked.

Exhibit 10. Variables Used to Discriminate among Events for CODES Linkage.

Variables	HI	ME	MO	NY	PA	UT	WI
Location Code of Crash (town, city, county, state)	✔	✔	✔	✔	✔	✔	✔
Hospital Service Area	✔	✔	✔	✔	✔	✔	✔
Date of Event (crash, EMS, Hospital, Claim)	✔	✔	✔	✔	✔	✔	✔
Day of Event; Year of Event			✔	✔	✔		
Month of Event	✔		✔	✔	✔		
Actual Time of Event (crash, EMS, Hospital, Claim)	✔	✔	✔	✔	✔	✔	
Time Code		✔		✔	✔		
Type of Event	✔		✔		✔		
Vehicle Type	✔				✔		
MVA field	✔	✔	✔	✔	✔		
VIN				✔			
Address	✔			✔			
EMS Region	✔			✔	✔	✔	
Alcohol, Belt, Helmet			✔		✔		
Destination hospital		✔	✔	✔	✔	✔	

Exhibit 11 indicates that most states used age, date of birth, gender, and description of the injury to discriminate among persons involved in the same event. Again, the variables used by each state to discriminate among persons also varied with the linkage phase and the files being linked.

Exhibit 11. Variables to Discriminate among Persons for CODES Linkage.

	HI	ME	MO	NY	PA	UT	WI
Age	✔	✔	✔	✔	✔	✔	
Date of Birth	✔	✔		✔	✔	✔	✔
Year of Birth			✔	✔	✔		✔
Month of Birth	✔		✔	✔	✔		
Day of Birth			✔	✔	✔		
Gender	✔	✔	✔	✔	✔	✔	✔
Injury: Yes/No	✔		✔	✔	✔		✔
Types of Injury (Head, neck, etc.)	✔	✔	✔	✔	✔		✔
Injury Severity	✔		✔		✔		
Name	✔			✔		✔	
Initials	✔		✔	✔			
Soundex Name			✔			✔	
Residence Code (town, city, county, state)	✔	✔	✔	✔	✔		
Residence (zip code)	✔		✔	✔		✔	
First 3 digits of zip code				✔	✔		✔
Last 2 digits of zip code					✔		✔
Transport: Yes/No		✔		✔	✔		✔
Probable Admit Date		✔	✔		✔		
Address of Residence				✔			
Hospital ID	✔	✔	✔	✔	✔	✔	✔
Admit Hour		✔		✔	✔		
Admit Date	✔	✔	✔	✔	✔	✔	✔
Occurrence of Death	✔	✔	✔		✔		
Date of Death		✔	✔		✔		
Run Report Number	✔			✔	✔		

	HI	ME	MO	NY	PA	UT	WI
Social Security Number					✔		
Year of Admission			✔	✔	✔		
Month of Admission			✔	✔	✔		
Day of Admission			✔	✔	✔		
Year of Discharge			✔		✔		
Month of Discharge			✔		✔		
Day of discharge		✔	✔		✔		
Disposition		✔	✔		✔		
Pay Source			✔		✔		
Position in Vehicle	✔						
Diagnosis Codes	✔	✔			✔		

Ancillary Linkages Performed by Each State

When the indirect identifiers were weak, the CODES states were forced to perform ancillary linkages (using either probabilistic or ad hoc methods) to other files in order to obtain additional information to strengthen the identifiers. Before these linkages could be performed, the ancillary files also had to be “prepared” for linkage. Sources of ancillary data included computerized EMS data for a large urban area, state injury registries, national insurance index files, and state vehicle registration, and driver licensing files. Ancillary linkages were most commonly performed because of deficiencies in the power of the existing variables to discriminate among individuals. Name and date of birth were the most common data added to the original files for linkage.

Exhibit 12 indicates that New York took advantage of its New York City data and state insurance data to perform multiple ancillary linkages.

Exhibit 12. Ancillary Linkages by CODES State.

CRASH LINKED TO:	HI	ME	MO	NY	PA	UT	WI
Driver’s Licensing	✔			✔			✔
Vehicle Registration				✔	✔		
VIN		✔			✔	✔	✔
Traffic Citation	✔						
Head/Spinal Cord Registry			✔		✔		
Municipality Gazetteer				✔			
Alcohol Conviction File						✔	
EMS LINKED TO:							
EMS Inter/facility transfers		✔	✔		✔		
Private EMS service					✔		
City Specific EMS	✔				✔		
Hospitals/emergency department			✔		✔		
HOSPITAL LINKED TO:							
Head/Spinal Cord Registry			✔				
INSURANCE CLAIMS LINKED TO:							
Central Index				✔			
No-Fault Insurers				✔			
Driver’s License	✔						
Membership Roster	✔	✔					✔

THE LINKAGE PROCESS

The Sequence of Linkage

Once the state data were prepared for linkage, the states linked first to EMS, hospital and other injury data and then to the insurance files. Exhibit 13 indicates that all of the CODES states linked the crash data to the hospital discharge data and all of the states, except Wisconsin, linked to state EMS data. Only Missouri, New York, and Utah had access to population based data directly from emergency department records.

Exhibit 13. Core Data Files Linked by Each CODES State.

Crash Report Linked To:	HI	ME	MO	NY	PA	UT	WI
State EMS	✔	✔	✔	✔	✔	✔	
ED/Hosp Outpatient			✔	✔		✔	
Hospital/ Rehabilitation	✔	✔	✔	✔	✔	✔	✔

Exhibit 14 indicates that four of the seven CODES states relied on health claims data to obtain access to ED and other outpatient information. (As indicated previously, Missouri used statewide emergency department data and Utah used hospital outpatient files. Pennsylvania tested the feasibility of creating statewide emergency department data from billing information.)

Exhibit 14. Linkage to Claims Data by Each CODES State.

Crash Linked To:	HI	ME	MO	NY	PA	UT	WI
Medicaid/Medicare	✔						✔
Workers Compensation				✔			
Central Index Auto Insurance Files				✔			
HMO	✔						
Private Health Insurance	✔	✔					

Ancillary linkage, presented in Exhibit 15, generated valuable information for state specific analyses. These analyses are presented in a later section which discusses the applications of linked data.

Exhibit 15. Linkage to Other Files for State Specific Analyses for CODES.

Crash Linked To:	HI	ME	MO	NY	PA	UT	WI
Trauma Registry	✔		✔				
Long term care		✔					
Death Certificates		✔	✔		✔		
Driver's Licensing	✔			✔			✔
Vehicle Registration (for VIN)		✔					
Highway Sufficiency Data				✔			
Traffic Citation	✔						
Alcohol Conviction File						✔	
Census	✔	✔					

The Linkage Results

Exhibit 16 indicates that in each CODES site about 10 percent of all occupants involved in a crash were linked to an EMS record and slightly less than two percent linked to a hospital inpatient record.

Exhibit 16. Linkage Rates by CODES State.

State	Total Involved In Crash	Links to EMS		Links to Hospital Inpatient	
		Number	Percent	Number	Percent
Hawaii	69072	6631	9.6%	1105	1.6%
Maine	87596	9105	10.4%	1117	1.3%
Missouri *	299679	28170	9.4%	7792	2.6%
New York	502774	59327	11.8%	8547	1.7%
Pennsylvania	329535	29658	9.0%	6261	1.9%
Utah	98373	10723	10.9%	1082	1.1%
Wisconsin	384298	0	NA	4996	1.3%
Total	1771327	143619	10.4%*	30922	1.8%

* Includes only drivers and injured passengers.

Note the similarity of the linkage rates for EMS and inpatients among the CODES states, an indication of the low rate of hospitalization and EMS transport for crash injuries. The linkage rates generated by the CODES states using probabilistic linkage are higher for both EMS and inpatient records than those generated earlier by Maine and Missouri using ad hoc linkage techniques for the Sensitivity Index project.[6] The Sensitivity Index project linkage rates are displayed below (Exhibit 17).

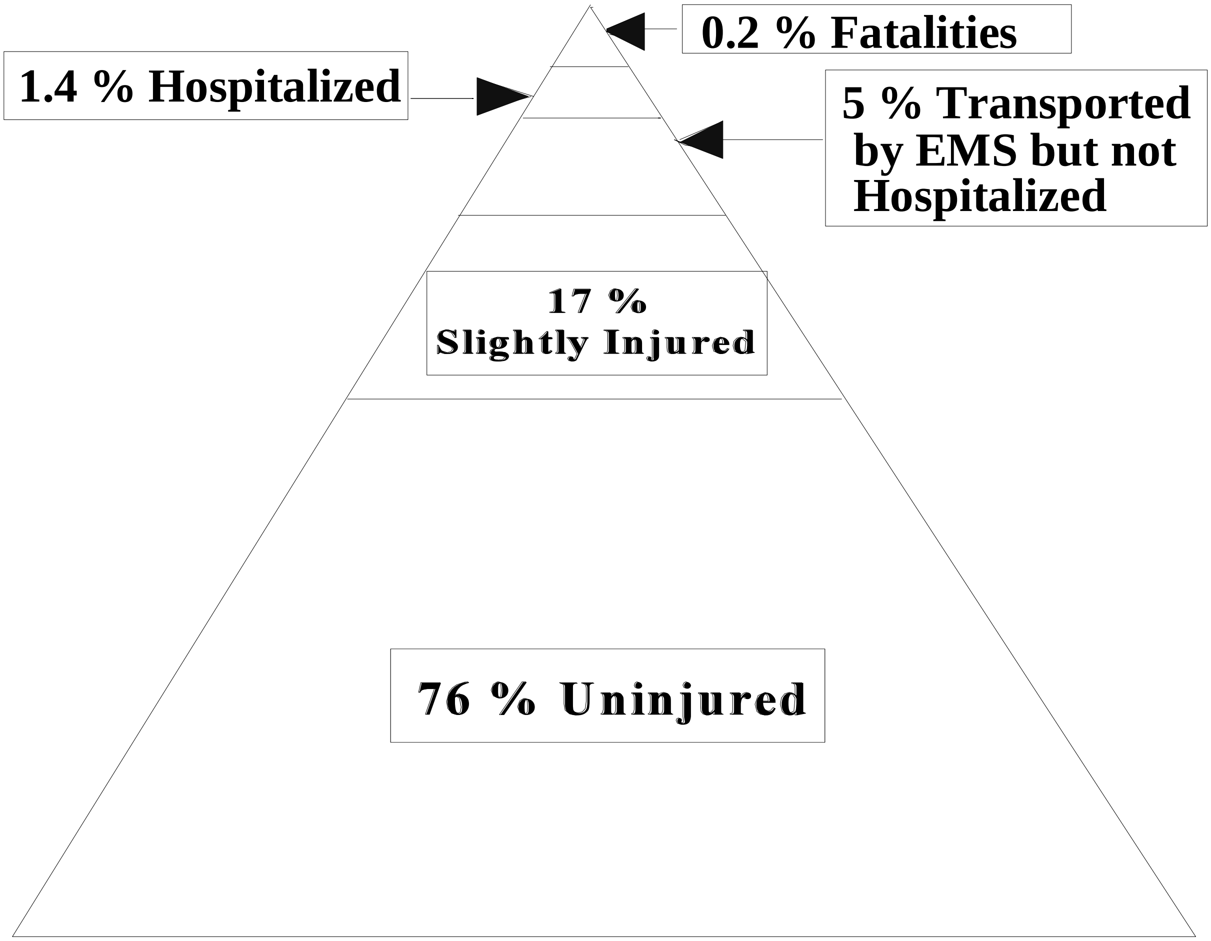


Exhibit 17. Distribution of Persons Involved in Motor Vehicle Crashes by Injury Outcome. Based on Linkage Rates Generated by Maine and Missouri for the Sensitivity Index Project.

Exhibit 18 presents the linkage rates by police designated severity level for the belt analyses which included only drivers. As expected, since the more serious injuries (fatal and incapacitating) were more likely to be treated, transported, or admitted to a hospital, they also were more likely to be documented in an injury record that could be linked to a crash report. Linkage rates for the fatal injuries varied according to whether EMS was responsible for transporting the deaths at the scene to the hospital.

Exhibit 18. Percentage of Crash Records That Linked to at Least One Injury or Claim Record Categorized by Police Designated Severity (KABC0) by CODES State for Drivers of Cars and Light Trucks/Vans.

	HI*	ME	MO	NY*	PA**	UT	WI***
Fatal	85%	64%	99%	68%	42%	70%	14%
Incapacitating	80%	85%	87%	76%	43%	79%	36%
Non-Incapacitating	68%	50%	0.43	63%	38%	62%	9%
Possible	63%	39%	23%	66%	18%	39%	4%
No Injury Indicated or Unknown	52%	2%	<1%	11%	0.4%	5%	0.3%
Percent of records **with designated injury** which linked	66%	47%	40%	66%	23%	52%	10%
Percent of records **for all drivers regardless of injury which linked**	55%	10%	7%	36%	10%	13%	2%

* Hawaii and New York included all linkages to claims data that indicated payment for service.

** Pennsylvania's lower rate of linkage is related to the way injuries are classified by the police.

*** Wisconsin had limited access to EMS, emergency department data, and claims data for linkage.

About 76-87 percent of the drivers with incapacitating injuries linked to at least one injury or claims record, except for Wisconsin, which had limited access to outpatient data, and Pennsylvania . Wisconsin's rates were considerably lower because of the absence of outpatient (EMS, ED, vehicle claims) data. Pennsylvania uses a slightly different scheme than the KABCO scoring system used in the other states. Their system records killed, major injury, moderate injury, minor injury, no injury, and missing. It appears that some of the incapacitated might be ending up in the non-incapacitated and possible injury categories. In all of the states, linkage rates decreased as severity, and the likelihood for treatment, decreased. Linkage rates for occupants with possible injuries varied widely depending on the access to health or vehicle insurance claims data. Because of their extensive data resources, about two-thirds of the possible injuries linked in Hawaii and New York compared to a third or less in the other states. Many more records indicating no injuries matched in New York and Utah, again because of their access to extensive computerized outpatient data for minor injuries. Included in this group of "not injured" were people who appeared uninjured at the scene but who hours or days after the crash sought treatment for delayed symptoms, such as whiplash.

Exhibit 19 indicates that the overall linkage rate for all motorcycle riders was much higher than the car/light truck/van model, a reflection of the high injury rate for cyclists involved in police reported crashes. As expected, the linkage rates were lower for the lower severities. Except for Pennsylvania and Wisconsin, more than 45 percent linked to at least one injury record. Since Pennsylvania does not use "possible" as an injury severity level, only those records which linked to some type of outpatient record were defined as "possible." Thus, by definition, Pennsylvania's linkage rate for the possible injuries had to be 100%.

Exhibit 19. Percentage of Crash Records That Linked to at Least One Injury or Claim Record Categorized by Police Designated Severity (Kabc0) by CODES State for Motorcycles.

	HI*	ME	MO Drivers	NY*	PA**	UT	WI***
Fatal	100%	93%	98%	52%	33%	91%	29%
Incapacitating	92%	89%	87%	64%	43%	84%	50%
Non-Incapacitating	76%	55%	43%	43%	29%	67%	12%
Possible	70%	48%	28%	50%	100%	56%	7%
No Injury Indicated	59%	9%	0%	13%	2%	23%	3%
Percent of records **with designated injury** which linked	63%	63%	57%	52%	33%	74%	25%
Percent of records **for all occupants regardless of injury which linked**	76%	53%	46%	49%	31%	67%	21%

* Hawaii and New York included all linkages to claims data.

** Pennsylvania did not attempt to link to emergency department or claims data.

*** Wisconsin had limited access to EMS, emergency department data, and claims data for linkage.

SIGNIFICANCE OF THE LINKAGE RATES

Linkage to an injury record verifies existence of the injury documented on a crash report or may call attention to the existence of an injury that was not documented. Exhibits 18 and 19 indicate that Hawaii and New York were able to link more than half of the total occupants included in both mandated models to at least one injury or claim record. Both defined linkage to include any claim record that indicated medical treatment or payment, thus increasing the probability of linkage to records for physical exams to rule out the need for further treatment. Identifying these minor events as injuries suggests that previous estimates of about 24 percent injured may understate the actual occurrence of injury, particularly the minor injuries not requiring transport by EMS or treatment at a hospital. Further experience with the linkage is needed to understand the minor injuries and determine their impact on health care costs.

Validation of the Linkage Results

Since we do not know which records should link, the crash to injury linkage occurs under conditions of uncertainty which make it difficult to validate the linkage results. Crash records indicating the more serious injuries (fatality, incapacitating injury) and the EMS or hospital discharge records indicating motor vehicle crash as the cause of injury are expected to have a link among the EMS or hospital records. However, the matching record may not be available because of reporting thresholds (i.e., exclusion of private roadways, out-of state residents), failure to enforce reporting requirements, or data collection and processing problems. On the other hand, records not expected to match may have a matching record. For example, crash records designating no injury may have a match among the injury records. Injury records which fail to designate cause of injury may have a match among the crash records. Linkage depends on the data files available for linkage. Occupants injured in motor vehicle crashes may be treated in a physician’s office or location other than an emergency department or hospital. So, although the occurrence of the injury is documented on the crash report, if the data files being linked do not include all treatment locations (physician office, EMS, emergency department, hospital, other outpatient, etc.), then some of the records that should link will not link.

When conditions of uncertainty exist, linkage equals “injury.” Non-linkage equals “not injured” except when assumptions are made that a fatal or incapacitating injury which does not link should be considered an injury. Thus, by definition, the “linked” records, or injured occupants, are a very different population from the “unlinked” records, or uninjured occupants. So, it is important to determine if the “linked” records are representative of the injured population and the “unlinked” records are representative of the uninjured population.

In order to validate the linkage results, the CODES states manually linked a random sample of crash reports and/or reviewed all records indicating a crash injury. They also reviewed the case-mix of linked and unlinked records for potential systematic biases that might affect use of the linked data analytically for the Report to Congress.

FALSE POSITIVES: (Internal Validity)

A false positive match represents a pair of records which matched but the two records do not represent the same person. The states assigned a high priority to ensuring a low rate of false positive cases and conservatively set the weight defining a match to a higher positive score to minimize the opportunity for false positives to occur. At the same time, they were careful not to set the score so high that too many pairs would require manual review.

The false positive rate ranged from 3.0 - 8.8 percent for the seven states and was viewed as not significant since the linked data included thousands of records estimated to represent at least half of all occupants involved in motor vehicle crashes in the seven CODES states (See Exhibit 16).

Besides differences in strategy, the states also varied in the availability of direct identifiers such as name (to ensure certainty when declaring a valid match). False positives were measured by identifying a random sample of crash and/or injury records and reviewing those that linked to verify that a motor vehicle crash was the cause of injury. Maine, Pennsylvania, and Wisconsin read the actual paper crash, EMS, and hospital records to validate the linkage. Missouri compared agreement on key linkage variables such as injury county, last initial, date of event, trafficway/trauma indicators, date of birth, or sex. Wisconsin determined that the false positive rate for the Medicaid linkage varied from that for hospitalizations generally since Medicaid cases were more likely to be found in urban areas.

FALSE NEGATIVES: (External Validity)

A false negative, on the other hand, represents a record (crash or injury) that did not match but should have. For the most part, these are injury records with a motor vehicle crash designated as the cause which did not link to a crash report. However, it is also possible to have a crash record with a designated severe injury (i.e. fatal, incapacitating) for which no match was found.

The rates for false negatives varied from 4-30 percent depending on the linkage pass and the files being linked. The higher rates occurred when the power of the linkage variables to discriminate among the crashes and the occupants involved was problematical. False negatives were measured by first identifying the records which should match. These included crash reports indicating ambulance transport, EMS records indicating motor vehicle crash as the cause of injury or hospital records listing an E code indicating a motor vehicle crash. These records were then compared to the linked records to identify those that did not link. False negatives were also identified by randomly selecting a group of crash reports and manually reviewing the paper records to identify those which did not link.

Crash and injury records failed to match when one or the other was never submitted, the linking criteria were too restrictive, key data linkage variables were in error or missing, the case selection criteria, such as the E-code, were in error or missing, the crash-related hospitalization occurred after several hours or days had passed, the crash or the treatment occurred out-of-state, etc. Lack of date of birth on the crash report for passengers was a major obstacle to linkage for all of the states except Wisconsin which included this information for all injured passengers. As the result of the linkage process, Maine targeted the importance of including this data element on the crash report. Among the false negatives identified by Wisconsin, 12 percent occurred because the admission was not the initial admission for the crash and 10 percent occurred because key linkage variables were missing. Another 7.5 percent occurred because the linking criteria were too strict. About 7 percent were missing a crash report because the crash occurred out of state or the patient had been transferred from another institution. Twelve percent of the false negatives were admitted as inpatients initially for other reasons than the crash. It was not possible to determine the false negative rates when the key data linkage variables or E-code were in error, when out of state injuries were treated in Wisconsin Hospitals and when the crash record was not received at DOT.

Missouri estimated linkage rates of 65 percent of the hospital discharge, 75 percent of the EMS records, and 88 percent of the head and spinal cord injury registry records when motor vehicle crash as the cause of injury was designated on the record. Comparison of Missouri's linked and unlinked records suggested that actual linkage rates were even higher, as unlinked records contained records not likely to be motor vehicle related injuries (such as gunshot, laceration, punctures, and stabs). The linked records showed higher rates of fractures and soft tissue injuries, which are typical of motor vehicle crashes. Seventy-nine percent of the fractures were linked, as were 78 percent of soft tissue injuries. The absence of a record in the crash file prevented linkage to an injury record; the absence of a cause of injury code risked a denominator inflated with non-motor vehicle crashes.

The comparison of linked and unlinked records do not suggest that significant numbers of important types of records are not being linked, though perhaps some less severely injured patients may be missed. Because ambulance linkage was used as an important intermediate link for the hospital discharge file, some individuals not injured severely enough to require an ambulance may have been missed, but they would also be less likely to require hospitalization. Any effect of this would be to erroneously raise slightly the estimate of average charges for hospitalized patients.

False negatives were considered less serious than a false positive so the states adjusted the cut-off weight defining a non-match to give priority to minimizing the total matched pairs requiring manual review.

It must be noted that although the rates for the false negatives and false positives were not significant for the belt and helmet analyses, they may be significant for other analyses using different outcome measures and smaller population units. For example, analyses of rural/urban patterns may be sensitive to missing data from specific geographic areas. Analyses of EMS effectiveness may be sensitive to missing data from specific EMS ambulance services or age groups. Another concern focuses on the definition of injury. When minor injuries are defined as injuries only if their existence is verified by linkage, then by definition the unlinked cases become non-injuries relative to the data sources used in the linkage. States using data sources covering the physician's office through to tertiary care will have more linkages and thus more "injuries." Estimates of the percentage injured, transported, admitted as inpatients, and the total charges will vary accordingly.

Obstacles to Linkage

The major obstacles to linkage resulted from data which had insufficient power to discriminate among the events and persons involved in the events and which failed to document the cause of injury. Data quality and lack of computerization were the two most important causes of non-discriminating identifiers.

All of the CODES states successfully negotiated the various problems associated with the linkage process. While police crash reports are most often considered public records for the purposes of access, patient medical records are considered confidential and thus access to these data systems was restricted by legislative or administrative policies. Access required collaboration with the owners of the data and compliance with all restrictions including written data requests, data releases, and in some cases a fee for access to the data. State data were frequently stored on different storage media, and the CODES teams learned to delegate to an expert the job of creating occupant-specific files and downloading large mainframe data files to a microcomputer.

The states worked with data files, advertised as computerized, which upon closer examination revealed that some of the important identifiers were not computerized uniformly statewide. Or if the identifiers were computerized, some of the attribute values would be missing or inaccurate. Missouri became adept at discovering transpositions among the initials. Most states culled newborns from the unknown ages. All of the states found the sevens which should have been nines, threes instead of fives, the 91 year old who was really 19, etc. Different combinations of the indirect identifiers were tried when the data content initially produced insufficient information to discriminate among events and the multiple occupants involved in the same event. Reporting thresholds and submission rates by police agency or medical provider were reviewed to determine when records were not available for linkage. Cause-of-injury information was not always available making it difficult to know which records to choose for linkage.

Most of the states found the inter-agency political barriers manageable. However, Pennsylvania's legislature managed to delay its approval of the expenditure of CODES project funds for nine months. Wisconsin was permitted to link the hospital data only at the site of the owner of the hospital data.

Probabilistic linkage requires computerized data. Failure to computerize EMS, emergency department, rehabilitative, and long term care data complicated the process of tracing the patient through the sequence of medical care. Wisconsin and Missouri failed to computerize sufficient information to include the uninjured passengers in the linkage. Hawaii collected EMS run numbers, driver's license number, and license plate numbers but did not computerize this information.

Implementing AUTOMATCH required expertise in data file management and the data files being linked, particularly information about how the EMS system responds. No one person had all these skills. The most common equipment problems were caused by unfamiliarity with the equipment or the network to which it was attached. States which received the linkage software first were delayed by bugs in the early versions of the software.

MANDATED RESEARCH MODEL FOR SAFETY BELTS AND HELMETS

To meet the requirement of the ISTEA to estimate the benefits of safety belts and helmets with respect to mortality, morbidity and injury severity, each of the CODES states was required to implement a uniform research model to ensure comparable results across diverse states for the Report to Congress.

The Study Population

The study population for the mandated model was defined to include all drivers involved in police reported crashes statewide for a twelve month period beginning on or after January 1, 1990. All of the CODES sites used the state data which was most current at the time of the study: Hawaii and Missouri used 1990 data; New York used 1992 data; and the other states used 1991 data.

Two variations of the models were calculated for the safety belts, one for drivers (all states) and one for all occupants 5 and older. The second model excluded Missouri and Wisconsin because their crash reports had insufficient information to link the records for uninjured passengers. Age and sex information was not recorded for uninjured passengers in Wisconsin; no information was collected about the uninjured passengers in Missouri. In the other states, passengers under 5 years old were excluded to insure the results did not include child safety seat data. The safety belt analyses were limited to passenger cars, light trucks, and vans. The helmet analyses, which used all riders, were limited to motorcycle crashes. Both the belt and helmet analyses were limited to crashes reported by the police.

The linking of the various databases in the grantee states produced a large number of crashes which contributed 879,670 drivers for the belt analysis and 10,353 motorcyclists for the helmet analyses (See Exhibit 20). The groups chosen as the study populations for the mandated models represent all riders of motorcycles involved in police reported crashes and about 53 percent of all occupants involved in passenger car/light truck crashes

Exhibit 20. Number of Drivers and Motorcycle Riders Contributing to the CODES Analysis of Effectiveness of Safety Belts and Motorcycle Helmets, by Severity/Treatment Levels.

Severity/Treatment Levels	Passenger Vehicle Drivers		Motorcycle Riders	
	Percent	Number	Percent	Number
Not Injured	80.0%	703,319	27.9%	2,892
Slightly Injured	9.2%	81,353	30.2%	3,128
Transported	8.9%	78,054	23.0%	2,378
Inpatient	1.7%	14,599	15.5%	1,604
Died	0.3%	2,345	3.4%	351
Total	100.0%	879,670	100.0%	10,353

OUTCOME MEASURES

To meet the requirement of the ISTEA to estimate the benefits of safety belts and helmets with respect to mortality, morbidity and injury severity, different categories of injury severity (outcome measures) for crash-involved occupants were established. These measures took into account information available only from the linked data. Exhibit 21 summarizes the definitions for the severity levels specified in the analytic models. Each crash-involved motor vehicle occupant or motorcycle rider was coded into one of these mutually exclusive categories.

Exhibit 21. Severity/Treatment Definitions Used in the CODES Analysis of Effectiveness of Safety Belts and Motorcycle Helmets.

Severity/ Treatment	Definition
Not Injured	Reported by the police as either a possible injury or not injured, and did not link to a medical outcome record and did not die.
Slightly Injured	Reported by the police as injured (except possible injury) but did not link to a medical outcome record; or reported as possible injury and linked to an insurance claim record for outpatient care other than EMS/ED and did not die.
Transported/ Treatment at ED	Linked to an EMS and/or Emergency Department record but was not linked to a hospital inpatient record and did not die.
Inpatient	Linked to medical outcome record indicating inpatient treatment (acute, rehabilitative and/or long-term care) and did not die.
Died	Police-reported killed or linked to a medical outcome record indicating death within 30 days after the crash as a result of the crash

The actual outcome measures derived from this scale were:

(1) -- Died;
(2) -- Died or inpatient;
(3) -- Died, inpatient, or transported;
(4) -- Any injury (Died, inpatient, transported, or slightly injured).

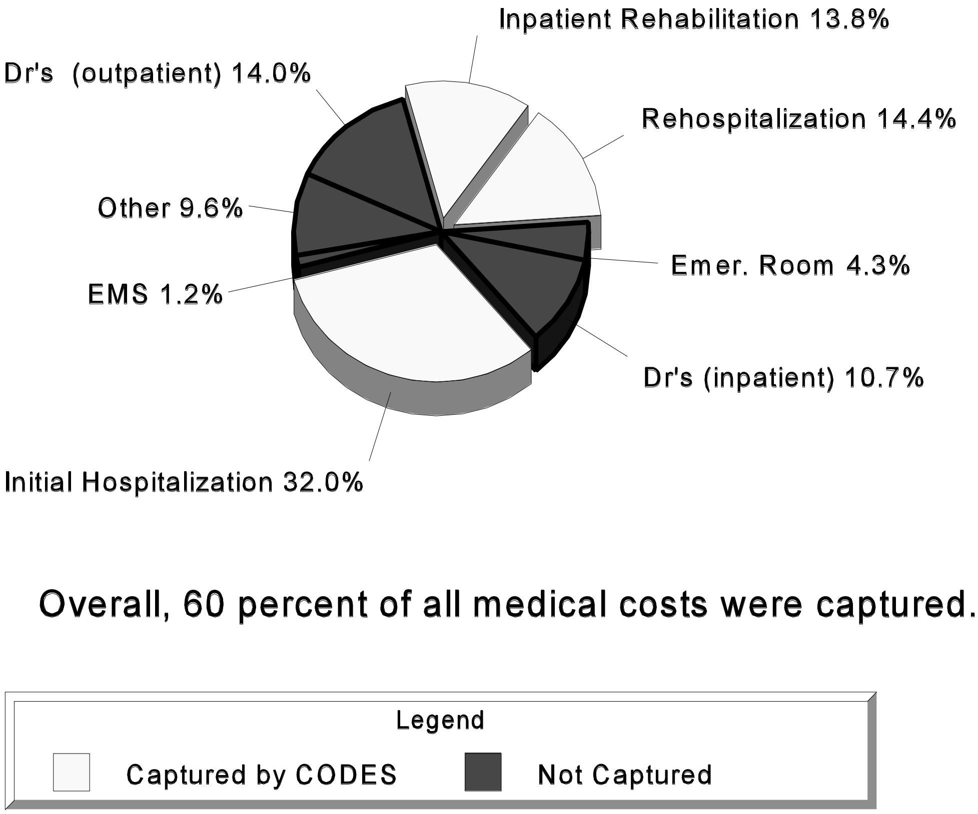
Using this scale, several of the ISTEA requirements were satisfied. First, the requirement to evaluate the benefits of safety belts or motorcycle helmets with respect to mortality was examined by evaluating effectiveness with respect to preventing a fatality. (Effectiveness represents the percentage reduction in injuries or deaths if everyone wore safety belts or helmets.) The concept of effectiveness is discussed later in the statistical methods section. For **mortality** (outcome measure 1), the group of crash victims who died was compared with all other crash-involved occupants.

Second, reducing **any injury** (outcome measure 4) was examined by estimating effectiveness in preventing any injury. Here, the group of crash victims experiencing any injury, i.e., died, inpatient, transported, or slightly injured, was compared with those not injured.

Finally, the benefits of safety belts in reducing **injury severity,** (outcome measures 1-4), were examined by comparing each of the injury groups with those at the lower severity levels.

COSTS AS AN OUTCOME MEASURE

Costs were defined in terms of total charges and estimated actual costs for inpatient acute, rehabilitative, and long term care as recorded on the inpatient hospital discharge, rehabilitation, and long term care data files. Because outpatient and other types of non-inpatient charges could not be uniformly collected by the CODES states, they were eliminated as outcome measures from the mandated research model. For example, charges from private physicians were not included. Exhibit 22 indicates that the charges reported by CODES represent about 60 percent of the total.



Overall, 60 percent of all medical costs were captured.

Exhibit 22. Breakdown of Medical Costs of Motor Vehicle Injury, from **Cost of Injury in the United States**[4]. (All the states in the CODES project were able to capture costs in the lightly shaded categories. Not all states could capture costs in the darker categories, so those costs were not included in the analyses.)

Discussion of Charge Versus Costs

The actual cost of providing care to a specific patient is not routinely calculated or computerized by most hospitals. Thus this information is not part of each unit record included in the inpatient discharge data file. However, total charges are recorded for each inpatient discharged from a facility. The charge represents the retail price for inpatient services before discounts. They do not represent what was actually paid for the services. As in any other business, the price consists of cost plus a markup factor established by each health care provider to ensure the overall viability of the facility by covering bad debts, cost shifting among the payers, profit/surplus revenue, etc. Total charges do not reflect the discounts and so when totaled do not reflect the total revenue received by the facility. All health care facilities negotiate at regular intervals discounted rates with the payers covering patients treated at their facilities. Because the rates vary by payer and by facility, the same procedure in the same facility and among different facilities may be "priced" differently for different payers. Charge data for inpatients are collected by licensed medical records experts and recorded per uniform billing guidelines established by the payers. The data are subject to routine edits. As a result, these data, in the absence of actual costs, have become a credible measure routinely used by states to statistically monitor use patterns and to estimate actual costs.

In this analysis, costs for inpatient care are estimated using a charge to cost ratio obtained from the Medicare cost reports for each inpatient facility. Although the cost reports are generated to support management of the Medicare program, the data used to calculate the ratio include all patients treated at the facility. Each facility reports the ratio of gross patient revenue plus other operating revenue divided by total operating expenses for all patients, outpatient and inpatients, treated at the hospital. The ratios shown in Exhibit 23 represent the median ratio for the state for the year reported. The ratio is valid at the state level but is not generalizable to payer source or other smaller units of analysis.

Exhibit 23. Charge-to-cost Ratio[7] for Year of Data Collection for Each CODES State.

	HI 1990	ME 1991	MO 1990	NY 1992	PA 1991	UT 1991	WI 1991
Ratio of Charge to Cost	1.15	1.43	1.47	1.36	1.71	1.3	1.29

For the CODES mandated analyses, total inpatient costs were estimated by dividing the ratio into the total inpatient charges for each CODES state, and then totaling the results for the seven states. Average actual costs was then calculated by dividing the total patients receiving inpatient care into the total actual costs.

Long term care charges for the first twelve months represent only a fraction of the total overall charges and were available only for Maine and New York. However, only Maine included the charges in the mandated model. The Maine charges were included in the total to calculate the actual costs.

INDEPENDENT VARIABLES: (Covariates)

Many risk factors other than the use of safety belts influence the likelihood and severity of injury. Selection among the many factors important to the safety belt and helmet analyses depended on the availability of uniform data among the CODES states. Up to ten risk factors were selected. Each is described below.

TYPES OF RISK FACTORS UNIFORM AMONG THE CODES STATES	
Type of crash	Belt analyses only: defined as rollover, or single vehicle (fixed object), single vehicle (other), multiple vehicle (head-on), or multiple vehicle (other). (The last classification acted as the reference group for all the other crash types and so is not identified in the analyses.)
Rural	Roadway functional classification information recorded on the crash report.
Age	Defined as a continuous variable. Passengers less than five years of age were excluded to separate belt-use from safety-seat use.
Gender	Male or female.
Posted speed limit	Chosen as a surrogate for crash severity. Defined as recorded on the crash report or obtained from roadway inventory files.
Roadway conditions	Collapsed to dry versus any other condition (wet, snowy, slushy, or icy).
Time of day	8:00 p.m. to 3:59 a.m. to be used as a surrogate for alcohol use.
Intersection related	As reported on the crash report.
Type of vehicle	For belt analysis: Only passenger cars, light trucks, and vans were analyzed, with all passenger cars in one category and all vans and light trucks in another. Served as a surrogate for vehicle size, because of the problem obtaining and decoding VIN data, which would have given a more accurate estimate of vehicle size. The breakdowns also serve to isolate vehicles with non-standard crush space from the standard, and driver behavior related to non-passenger car from passenger car driver behavior. For helmet analysis: Only motorcycles (no mopeds) were analyzed.
Belt/helmet use	Defined as the value reported by the police on their crash report. Belt use and helmet use were analyzed separately.

The factors actually used in each of the safety belt and helmet models are shown below.

Exhibit 24. Contributing Factors Used in the CODES Safety Belt and Motorcycle Helmet Analyses.

Factor	**Analysis**	
	Safety Belt	**Motorcycle Helmet**
Type of Crash	✔	Not Used
Rural/Urban	✔	✔
Age	✔	✔
Male/Female	✔	✔
Posted Speed Limit	✔	✔
Wet/Dry	✔	✔
Night/Day	✔	✔
Intersection Related	✔	✔
Vehicle Type	✔	Not Used
Seating Position	✔	Not Used

STATISTICAL METHODS

To evaluate the benefits of safety belt and motorcycle helmet use in reducing mortality, morbidity, and injury severity, NHTSA used a measure of effectiveness. Effectiveness is defined as the percentage reduction in injuries or deaths for people wearing safety belts or helmets compared to people not wearing safety belts or helmets. For example, if the effectiveness of some device in reducing injuries is 35 percent, then 35 percent of those people who were injured while not using the device would not have been injured had they used it.

To statistically control for possible biases caused by the contributing factors, logistic regression was used. It has the ability to deal with a dichotomous (yes/no) or ordinal (a small number of categories that can be ranked from high to low) outcome measure while simultaneously adjusting for other factors (dichotomous, ordinal and continuous) to ensure that estimates of seat belt effectiveness or helmet effectiveness were independent of other factors (covariates).

Similarly, linear regression was used to control for many of the same variables when the outcome measure was continuous, such as patient charges.

Logistic regression was used to estimate the effect of being belted on the odds of sustaining various levels of injury. It has become popular within the last 30 years as a method of analyzing categorical, multivariate data. One type of categorical measure is usually a dichotomous variable, such as died or alive, injured or uninjured. Multivariate refers to analyzing many variables simultaneously.

To estimate the effect of safety belt and motorcycle helmet use on inpatient charges, each grantee computed average inpatient charges for passenger vehicle drivers and for motorcycle riders. Averages were computed based on the victims' belt or helmet use and for various payers. (NHTSA staff statistically combined the average inpatient charges from the states to produce the overall estimates). In another analysis of charges, linear regression was used to investigate the effect of safety belt use while controlling for many of the same covariates used in the logistic regression.

Equations follow for two of the general safety belt models using logistic regression: "any injury versus no injury" (outcome measure 4) and "died versus alive" (outcome measure 1):

$$\begin{aligned}\text{logit Prob[Injury=1]} &= \text{Intercept} + \text{Param}_{(\text{BeltUse})}*\text{BeltUse} + \text{Param}_{(\text{Roll})}*\text{Roll} + \text{Param}_{(\text{SVFO})}*\text{SVFO})\\ &\quad + \text{Param}_{(\text{SVO})}*\text{SVO} + \text{Param}_{(\text{MVH})}*\text{MVH} + \text{Param}_{(\text{Rural})}*\text{Rural} + \text{Param}_{(\text{Age})}*\text{Age} +\\ &\quad \text{Param}_{(\text{Male})}*\text{Male} + \text{Param}_{(\text{SpLim})}*\text{SpLim} + \text{Param}_{(\text{Driver})}*\text{Driver} + \text{Param}_{(\text{FrntPas})}*\text{FrntPas} +\\ &\quad \text{Param}_{(\text{Wet})}*\text{Wet} + \text{Param}_{(\text{Time})}*\text{Time} + \text{Param}_{(\text{Inter})}*\text{Inter} + \text{Param}_{(\text{PC})}*\text{PC};\end{aligned}$$

and

$$\begin{aligned}\text{logit Prob[Died=1]} &= \text{Intercept} + \text{Param}_{(\text{BeltUse})}*\text{BeltUse} + \text{Param}_{(\text{Roll})}*\text{Roll} + \text{Param}_{(\text{SVFO})}*\text{SVFO} +\\ &\quad \text{Param}_{(\text{SVO})}*\text{SVO} + \text{Param}_{(\text{MVH})}*\text{MVH} + \text{Param}_{(\text{Rural})}*\text{Rural} + \text{Param}_{(\text{Age})}*\text{Age} +\\ &\quad \text{Param}_{(\text{Male})}*\text{Male} + \text{Param}_{(\text{SpLim})}*\text{SpLim} + \text{Param}_{(\text{Driver})}*\text{Driver} + \text{Param}_{(\text{FrntPas})}*\text{FrntPas} +\\ &\quad \text{Param}_{(\text{Wet})}*\text{Wet} + \text{Param}_{(\text{Time})}*\text{Time} + \text{Param}_{(\text{Inter})}*\text{Inter} + \text{Param}_{(\text{PC})}*\text{PC};\end{aligned}$$

where logit (x) = ln (x/(1-x));
ln = natural logarithm, or $\log_e$;
$\text{Param}_{(x)}$ = The parameter from the logistic regression for variable x;
Injury= 1 if the person sustained any injury, 0 if uninjured;
Died = 1 if the person died, 0 if survived;
Intercept = the odds of the outcome if the person had a 0 for every variable on the right side of the model;
BeltUse = 1 if the person was wearing a safety belt as reported on the crash report;
Roll* = 1 if the vehicle rolled over during the crash, 0 otherwise;

SVFO* = 1 if no roll-over occurred and it was a single-vehicle crash and the vehicle struck a fixed object (anything from a bush to a bridge abutment, but most often a tree, pole, or sign), 0 otherwise;

SVO* = 1 if no roll-over occurred and it was a single-vehicle crash and the vehicle struck a non-fixed object (anything from an animal or pedestrian to a parked car or locomotive), 0 otherwise;

MVH* = 1 if no roll-over occurred and it was a multiple-vehicle crash and the two vehicles collided head-on, 0 otherwise;

Rural = 1 if crash occurred in a rural area, 0 if in an urban area;

Age = the age of occupant in years;

Male = 1 if occupant was a male, 0 if a female;

SpLim = the posted speed limit at the crash location;

Driver* = 1 if occupant was a <u>driver</u>, 0 otherwise;

FrntPas* = 1 if occupant was a front seat <u>passenger</u>, 0 otherwise;

Wet = 1 if roadway was slippery for any reason, 0 if dry;

Time = 1 if crash occurred between 8:00 pm and 3:59 am (Heavy drinking hours), 0 if it occurred between 4:00 am and 7:59 pm;

Inter = 1 if crash occurred at an intersection, 0 otherwise;

PC = 1 if vehicle was a passenger car, 0 if it was a light truck or van (Heavy trucks and buses not included in any analyses, motorcycles included only in the helmet analyses).

*The four crash-type variables (Roll, SVFO, SVO, and MVH) use non-head-on multiple-vehicle crashes as a reference group, e.g. the 0 group. For all states, this was also the largest crash type. Likewise, the two seating variables (Driver and FrntPas) use back-seat passengers as a reference group. Unlike the crash-type reference group, <u>this</u> reference group was usually the smallest of the seating position groups.

Exhibit 25 shows the differences between odds ratios and relative risk (from which effectiveness is derived). The data are fictitious, and only look at belt use and two outcome measures ("died versus survived" and "any injury versus no injury"). For simplicity's sake the other independent variables (contributing factors/covariates) are ignored.

Note that in the "Any Injury" column, the Odds Ratio is smaller than Relative Risk. This is true whenever relative risk is less than one, even though the difference in the "Mortality" column is so small it is less than rounding error. If (A) is very small relative to (B), and (C) is very small relative to (D), the Odds Ratio will be very close to the Relative Risk.

Effectiveness can be interpreted as an effect on the unsafe condition: For the mortality figures, "About 90 percent of the unbelted drivers would have survived had they been wearing a safety belt. In this situation, ninety-two lives could have been saved." (88.5% * 104 = 92). For the any-injury figures, “About half of the unbelted drivers would not have been injured had they been wearing a safety belt. In this situation, almost 2,100 injuries could have been prevented.” (52.8% * 3,973 = 2098).

Exhibit 25. Fictitious Data to Illustrate the Difference Between Odds and Odds Ratios on One Hand and Probability, Risk Ratios, and Effectiveness on the Other.

		Outcome Measure			
		Mortality		**Any Injury**	
Belted drivers	**(A)**	Dead	64	9,988	Injured
	(B)	Alive	62,424	52,500	Uninjured
Unbelted drivers	**(C)**	Dead	104	3,973	Injured
	(D)	Alive	11,620	7,751	Uninjured
Totals			**74,212**	**74,212**	
(E) *Odds* of _______ given **Belted**. (**A**/**B**)		Dying	0.001	0.190	Being injured
(F) *Probability* of _______ given **Belted** (**A**/(**A**+**B**)).		Dying	0.001	0.160	Being injured
(G) *Odds* of _______ given **Unbelted** (**C**/**D**).		Dying	0.009	0.513	Being injured
(H) *Probability* of _______ given **Unbelted** (**C**/(**C**+**D**)).		Dying	0.009	0.339	Being injured
(I) *Odds Ratio* of the effect of being belted on the odds of _______. (**E**/**G**)		Dying	0.115	0.371	Being injured
(J) *Relative Risk* of the effect of being belted on the probability of _______. (**F**/**H**)		Dying	0.115	0.472	Being injured
(K) ***Effectiveness*** of safety belts on **not** being _______ ((1-**J**)*100).		**Killed**	**88.45**	**52.83**	**Injured**

RESULTS--BENEFITS OF SAFETY BELTS

Odds Ratios

NHTSA has completed many analyses of the effectiveness of safety belts. Based on these studies NHTSA believes that the effectiveness of safety belts is in the range of 40-50 percent for preventing death and in the range of 45-55 percent for preventing injury. These estimates are not entirely consistent with those produced from the CODES analyses, and NHTSA believes that the CODES results may be inflated by over-reporting of belt use on the police crash reports. The latter means estimates of “percentage belted” from police reports are always much higher than estimates from independent observers of safety belt use, an indication that people put themselves in a favorable light, even in Maine, where adults did not have to wear safety belts. Such a directional misclassification has the effect of artificially magnifying the effectiveness of safety belts.

The benefits of safety belts are presented below, by injury level and state, as odds ratios (Exhibits 26-34), and then as effectiveness rates (Exhibits 34 and 37). The odds ratios have been statistically adjusted for all the control variables listed in Exhibit 24, and thus should be independent of those variables. However, they have not been adjusted for the “over-reporting factor.”

Another interpretation issue arises from the computation of the weighted averages[8]. The odds ratios themselves were not averaged, rather their natural logarithms, weighted by their standard errors, were averaged. The parameters and their standard errors were taken from the states’ logistic regressions. For each state, the reciprocal of the square of the standard error of the belt parameter became the weight. These were summed to become the <u>denominator</u> of the weighted average. Each state’s belt parameter was multiplied by the weight, and these products were summed to become the <u>numerator</u> of the weighted average. Because the standard errors are strongly influenced by the number of cases, larger states disproportionately influenced the weighted averages. For example, in the fatality analysis, New York and Pennsylvania contributed 57 percent of the numerator and 58 percent of the denominator for the weighted average.

However, this method of weighting the averages has the advantage of yielding a test of homogeneity (how well the states agreed with each other) and a test of association (whether the association between injury level and safety belt use was significant over all the states). All the tests of homogeneity failed, which meant there were significant differences among some of the states, not withstanding the large overlaps in their standard errors. These differences became smaller as the outcome measure concentrated on more serious injuries, but there were still significant differences at the “died/survived” level. This conveys the misleading conclusion that safety belts are more effective in Wisconsin than in Maine. Future investigations will attempt to find the factors accounting for these differences. In the mean time, it should be stressed that all safety-belt odds ratios from all states agree that safety belts are highly effective at all analysis levels. It is also felt that the weighted averages are the best estimates of the overall effects. However, one possible interpretation of the differences among the states is that the standard errors of the weighted averages are far too small, and should be ignored.

DIED

The best odds ratio (for **drivers** only) was 0.076 (Hawaii). This means the driver's odds of dying, given a police-reported crash occurred and the safety belt was **not** worn, were 13.2 times the odds of dying if the safety belt **was** worn. The odds ratio for <u>not</u> wearing a safety belt is the reciprocal of the odds ratio for <u>wearing</u> a safety belt: 1/0.076 = 13.2. See Exhibit 26. The least favorable odds ratio in the same situation was 0.257 (Maine). This translates to 3.9 times higher odds if the belt is not worn. Note that even the “least favorable” odds ratio is a highly significant safety effect. Note also that the confidence intervals for even the most extreme state, Maine, overlap with Utah. A combined estimate for **drivers** from all the states is an odds ratio of 0.107. This translates to the odds of dying being 9.4 times higher if a safety belt was not worn (see the rightmost I-beam in Exhibit 26). It must be stressed, **for Exhibits 26-33,** that the weighted average is not as precise as suggested by its confidence intervals. This is due to differing error bars among the states. For example, compare the length of the confidence interval in Maine to that in New York. This is to be expected, since the variance is strongly influenced by the sample size, and the largest state has roughly eight times as many drivers as the smallest state. Nevertheless, the states are remarkably consistent.

Exhibit 26. Belt Odds Ratios for Deaths by CODES State, with a Weighted Average in the Right I-beam for Drivers Only. (Vertical bars are 95% confidence intervals for each odds ratios. The calculated confidence interval of the weighted average is too small. See text for details.)

Police in Missouri and Wisconsin do not record the age and sex of <u>un</u>injured <u>passengers</u>, so they could not analyze safety belt effectiveness for all occupants. This may be unimportant, however, because in the twenty possible comparisons (five states times four levels of analysis) between **drivers only** and **all occupants**, there were no significant differences. Nevertheless, the all-occupant data will also be presented for completeness.

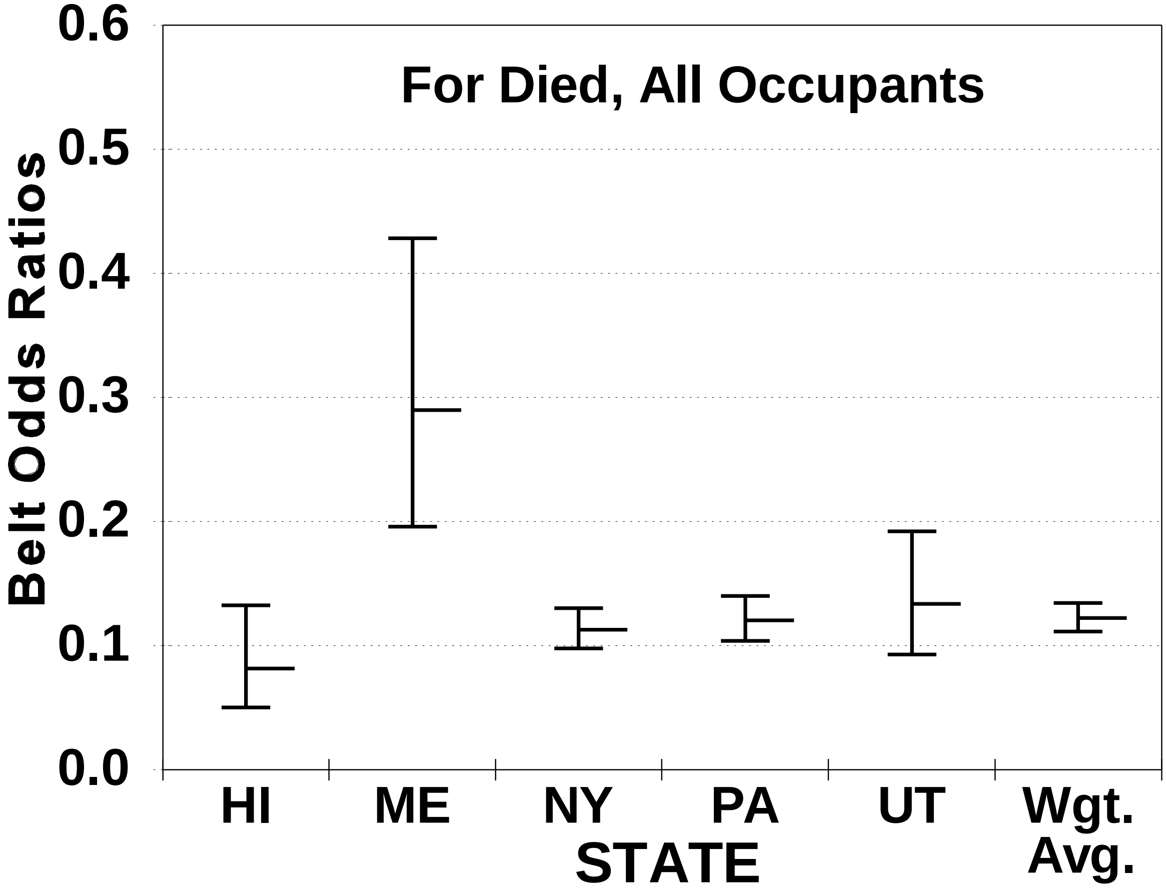


Exhibit 27. Belt Odds Ratios for Deaths by CODES State with a Weighted Average in the Right I-beam for All Occupants Older than 5 Years. (Vertical bars are 95% confidence intervals for each odds ratio. The calculated confidence interval of the weighted average is too small. See text for details.)

Of the five states for which all occupants were analyzed, the best odds ratio was .082 (Hawaii). This translates to the odds of a death being 12.0 times higher if the safety belt was not worn. See Exhibit 27. The least favorable odds ratio for all occupants was 0.290 (Maine). This translates to 3.4 times higher. A combined estimate for **all occupants** from all five states is an odds ratio of 0.122. This translates to the odds of dying being 8.2 times higher if a safety belt was not worn (see the right-most I-beam in Exhibit 27).

DIED AND/OR INPATIENT

For **drivers**, the best odds ratio in this category, which compared those who died or were inpatients to those who suffered a lesser injury or no injury, was 0.154 (Wisconsin). This translates to the odds (of being admitted as an inpatient or dying) being 6.5 times higher if the driver did not wear a belt. The least favorable odds ratio in the same category was 0.350 (Maine). This translates to 2.9 times higher. See Exhibit 28. A combined estimate for drivers from all the states is an odds ratio of 0.232. This translates to the odds (of being admitted as an inpatient or dying) being 4.3 times higher if a safety belt was not worn.

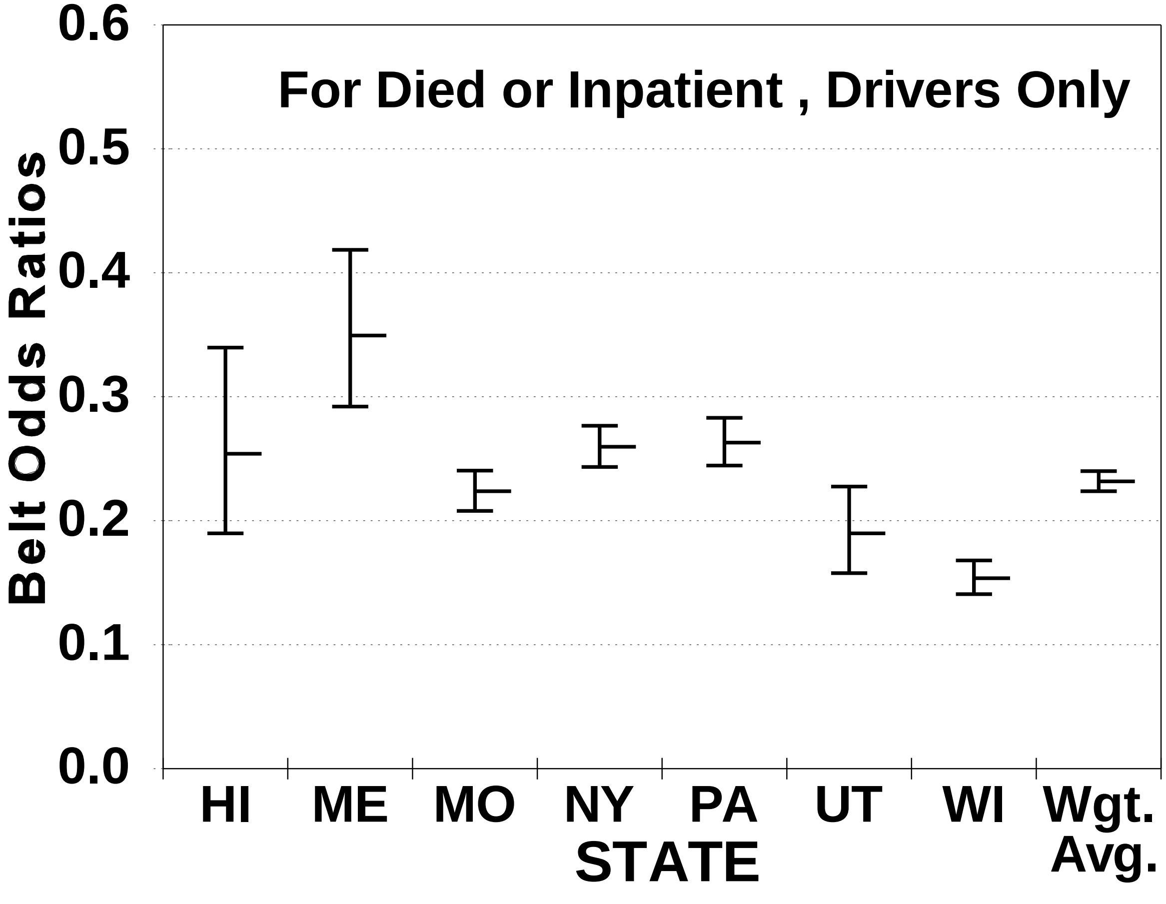


Exhibit 28. Belt Odds Ratios for Admitted as an Inpatient and/or Died by CODES State with a Weighted Average in the Right I-beam for Drivers Only. (Vertical bars are 95% confidence intervals for each odds ratio. The calculated confidence interval of the weighted average is too small. See text for details.)

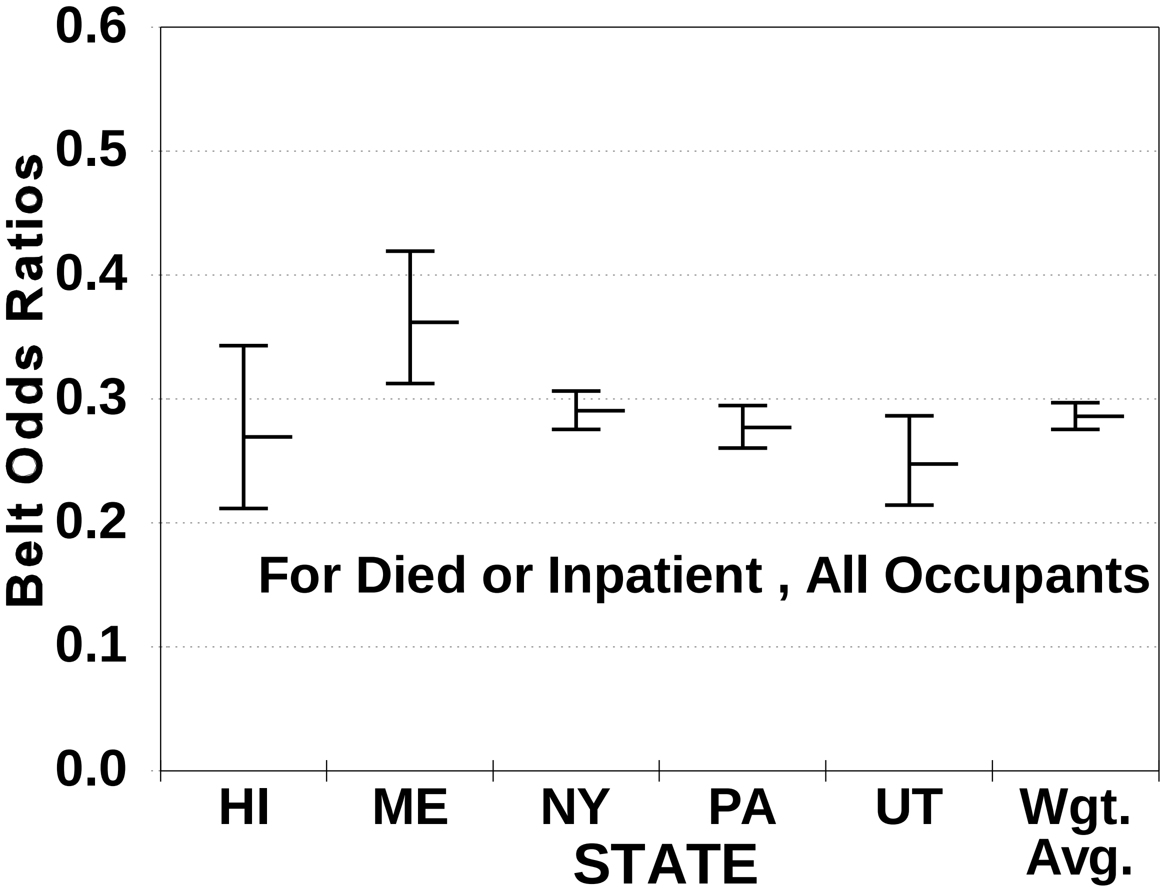


Exhibit 29. Belt Odds Ratios for Admitted as an Inpatient and/or Died by CODES State with a Weighted Average on the Right I-beam for All Occupants Older than 5 Years. (Vertical bars are 95% confidence intervals for each odds ratio. The calculated confidence interval of the weighted average is too small. See text for details.)

For **all occupants**, the best odds ratio was 0.248 (Utah). This translates to the odds (of being admitted as an inpatient or dying) being 4.0 times higher if the driver did not wear a belt. The least favorable odds ratio in the same category was 0.362 (Maine). This translates to 2.8 times higher. A combined estimate for **all occupants** from all five states is an odds ratio of 0.286. This translates to the odds of being admitted as an inpatient or dying being 3.5 times higher if a safety belt was not worn. See Exhibit 29.

DIED, INPATIENT, OR TRANSPORTED

For **drivers**, the best odds ratio in this category, which compared those who died, were admitted as an inpatient, or were transported to a hospital by an EMS, to those who suffered a lesser injury or no injury, was 0.240 (Wisconsin). This translates to the odds (of being transported or worse) being 4.2 times higher if the driver did not wear a belt. The least favorable odds ratio in the same category was 0.500 (New York). This translates to 2.0 times higher. A combined estimate for **drivers** from all the states is an odds ratio of 0.392. This translates to the odds (of being transported or worse) being 2.6 times higher if a safety belt was not worn. See Exhibit 30.

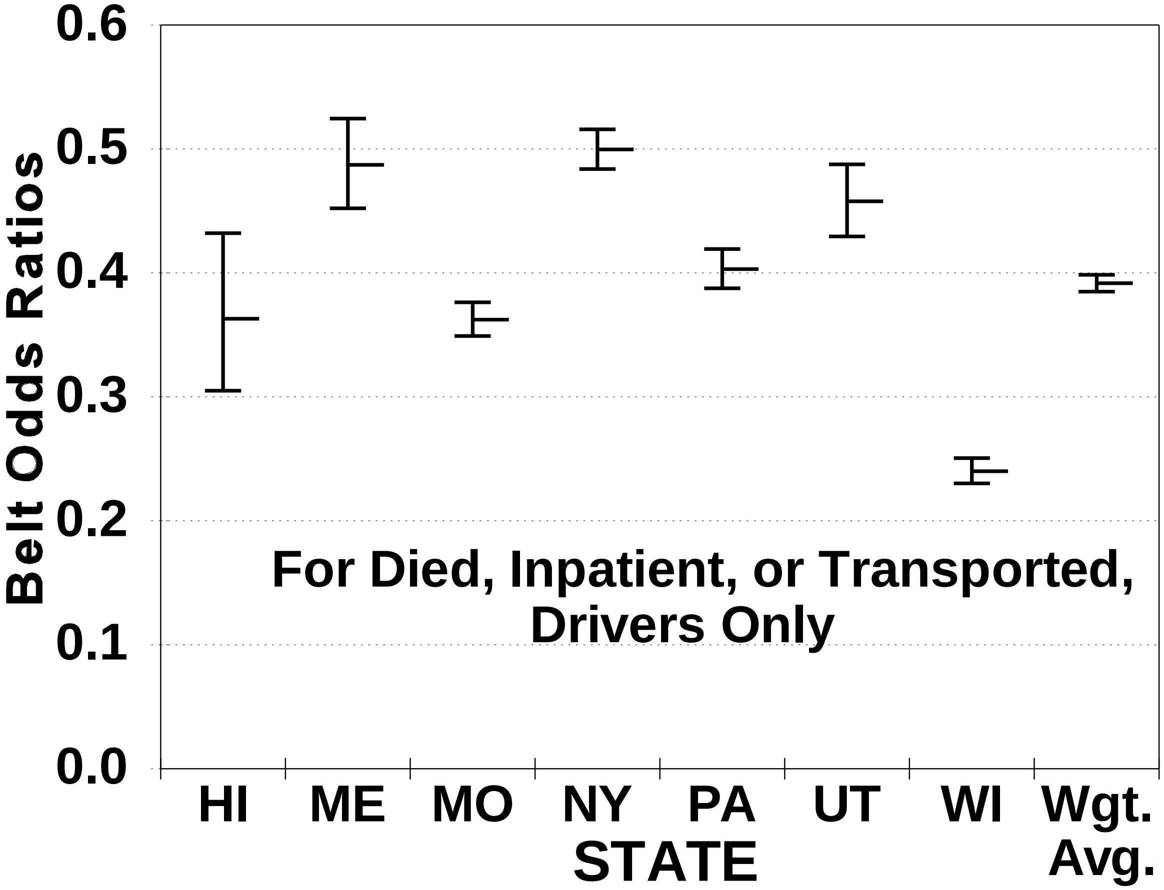


Exhibit 30. Belt Odds Ratios for Patients Transported by an EMS or Worse, by CODES State, with a Weighted Average in the Right I-bar for Drivers Only. (Vertical bars are 95% confidence intervals for each odds ratio. The calculated confidence interval of the weighted average is too small. See text for details.)

For **all occupants**, the best odds ratio was 0.403 (Hawaii). This translates to the odds (of being transported or worse) being 2.5 times higher if the occupant was not wearing a safety belt. The least favorable odds ratio was 0.529 (New York). This translates to the odds being 1.9 times higher. A combined estimate for **all occupants** from all five states is an odds ratio of 0.479. This translates to the odds of dying being 2.1 times higher if a safety belt was not worn. See Exhibit 31.

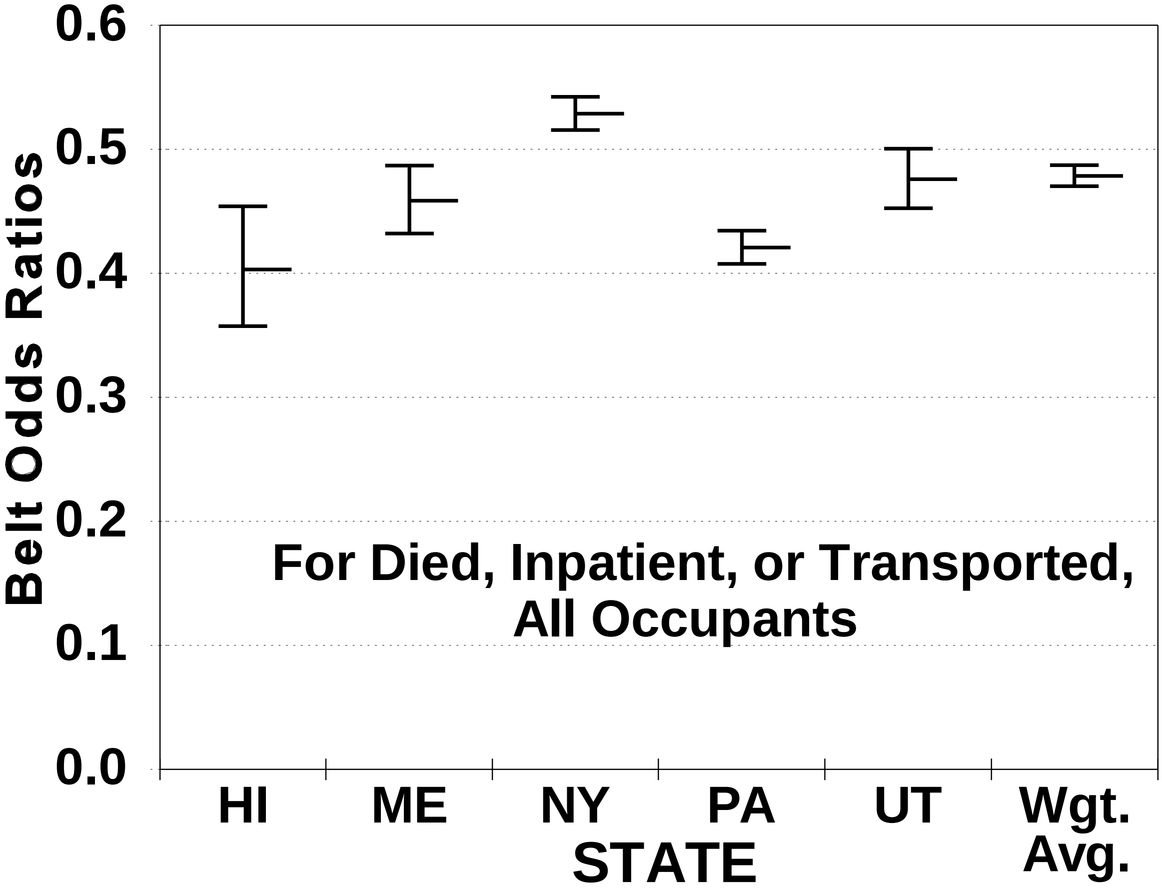


Exhibit 31. Belt Odds Ratios for Patients, Transported by an EMS or Worse, by CODES State, with a Weighted Average in the Right I-bar for All Occupants Older than 5 Years. (Vertical bars are 95% confidence intervals for each odds ratio. The calculated confidence interval of the weighted average is too small. See text for details.)

ANY INJURY

For **drivers**, the best odds ratio in this category, which compared those who suffered any injury, including death, to those who suffered no injury, was 0.242 (Wisconsin). This translates to the odds (of any injury or worse) being 4.1 times higher if the driver did not wear a belt. The least favorable odds ratio in the same category was 0.539 (Maine). This translates to 1.9 times higher. A combined estimate for **drivers** from all the states is an odds ratio of 0.377. This translates to the odds of injury being 2.6 times higher if a safety belt was not worn. See Exhibit 32.

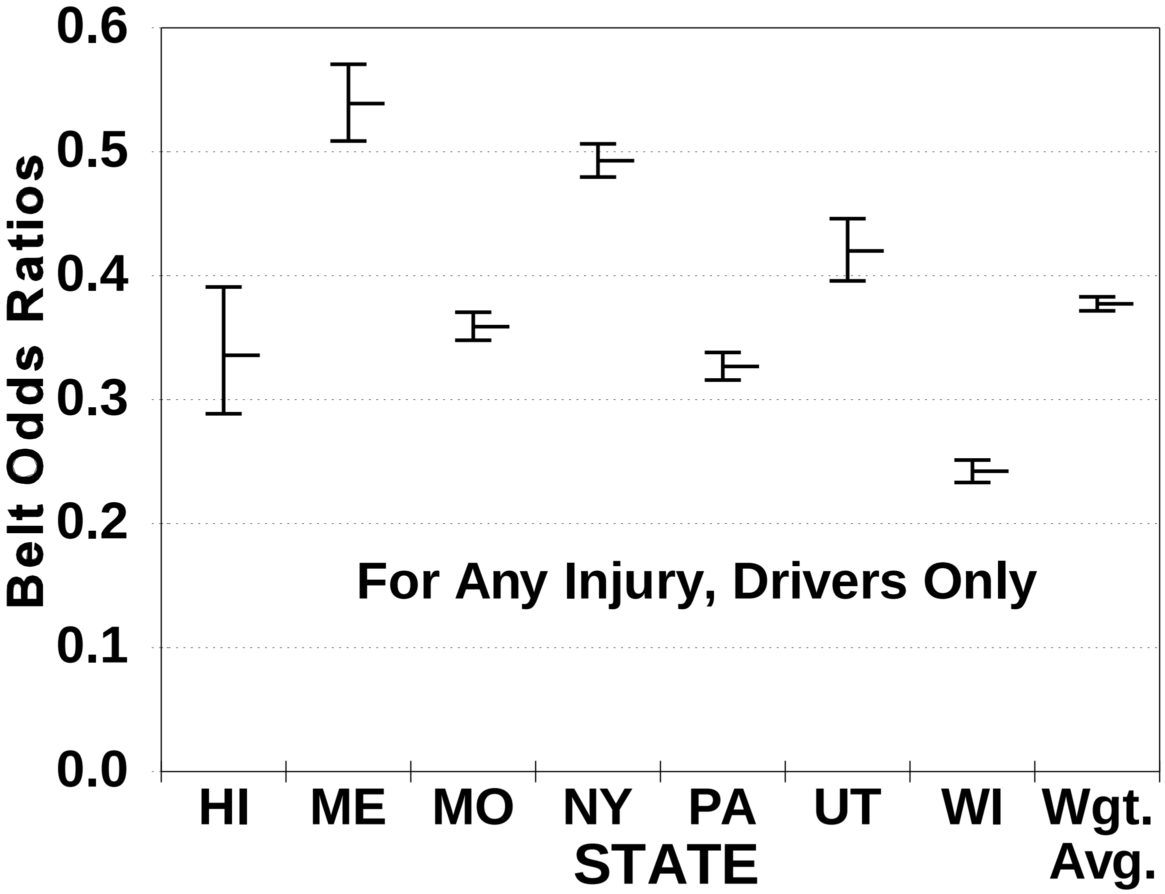


Exhibit 32. Belt Odds Ratios for Suffering Any Injury, Including Dying, by CODES State, with a Weighted Average in the Right I-beam. Drivers Only. (Vertical bars are 95% confidence intervals for each odds ratio. The calculated confidence interval of the weighted average is too small. See text for details.)

For **all occupants**, the best odds ratio was 0.339 (Pennsylvania). This translates to the odds (of any injury or worse) being 2.9 times higher if the driver did not wear a belt. The least favorable was 0.506 (Maine) which translates to 2.0 times higher. A combined estimate for **all occupants** from all five states is an odds ratio of 0.437. This translates to the odds of injury being 2.3 times higher if a safety belt was not worn. See Exhibit 33.

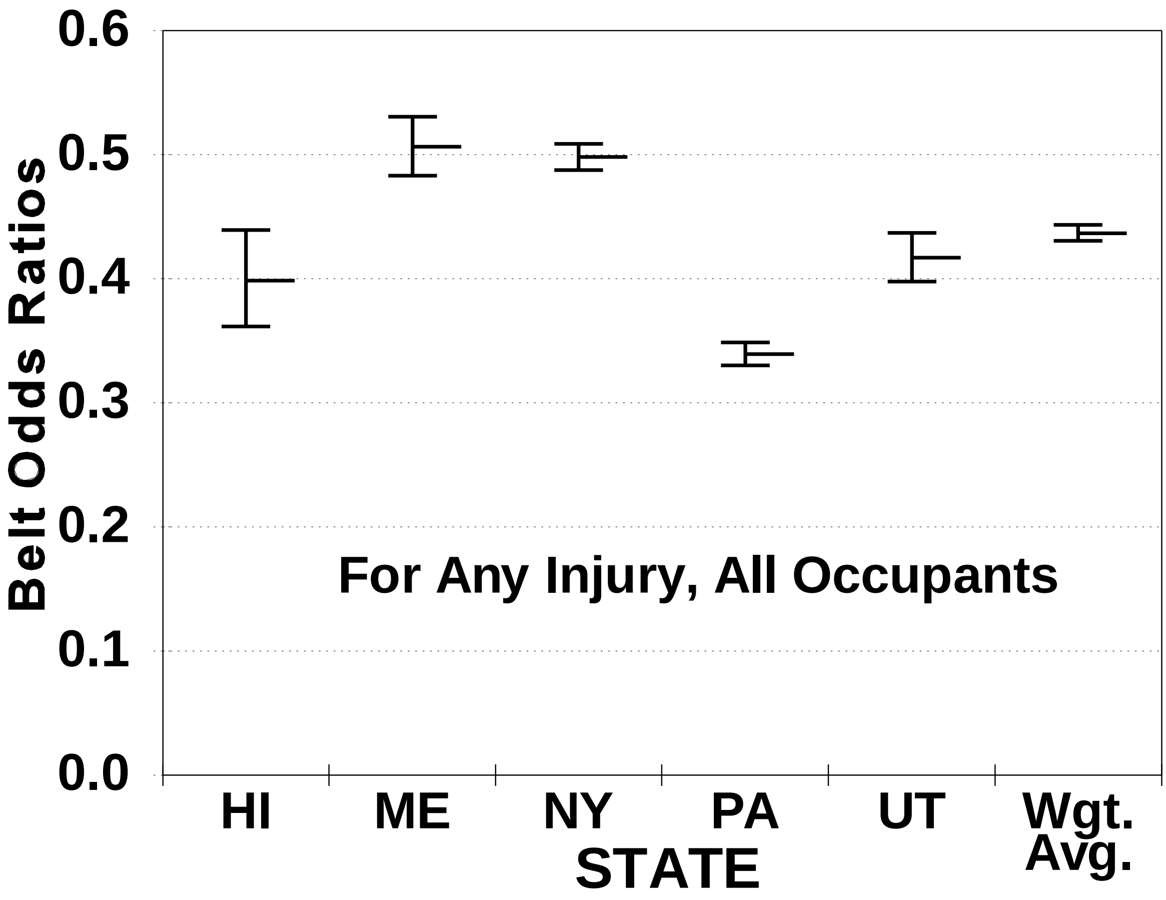


Exhibit 33. Belt Odds Ratios for Suffering Any Injury, Including Dying, by CODES State, with a Weighted Average in the Right I-beam for All Occupants Older than 5 Years. (Vertical bars are 95% confidence intervals for each odds ratio. The calculated confidence interval of the weighted average is too small. See text for details.)

Effectiveness

Effectiveness ratings cannot be directly computed from odds ratios, although if the probabilities of a positive response (e.g., dying) are very small, the computed odds ratio is almost identical to relative risk, and 1 - relative risk = effectiveness. However, that is the exception. Generally, relative risk is closer to one than its corresponding odds ratio if there is a significant safety effect. (An odds ratio or relative risk of one indicates neutrality.) Thus, for safety belts, effectiveness ratings are lower than what might be expected from the odds ratios.

Nevertheless, effectiveness ratings are very useful because they have become standard in NHTSA reports. Moreover, they lead to the following interpretation: "This means that *X* percent of the unbelted drivers would have survived had they been wearing their safety belt," a concept understood by the lay-person. Therefore, the following algorithm, expanded in Appendix A, was used to compute approximations of them:

> PROC LOGISTIC[9] wrote the predicted probability for each case (along with many other variables) to an output file. Then a DATA step computed the logit of the estimated probability, and if the occupant was belted, subtracted the parameter (beta-weight) for belt use. This gave the logit of each occupant's "unbelted" probability. Also, if the occupant was not belted, it added the parameter (beta-weight) for belt use, resulting in the logit of the occupant's "belted" probability. Then it computed the exponents of both logits, giving the predicted probabilities in both situations. Then PROC MEANS[9] computed the means of these probabilities. These means represent the population probabilities of a positive response (e.g., dying), adjusted for the covariates (other independent variables) in the model. An estimate of the risk ratio was obtained by dividing the mean probability if everyone was belted by the mean probability if everyone was not belted. This was done for every state and analysis level, for drivers only. Fleiss'[8] procedure (for averaging the odds ratios) gave a weighted average of the risk ratios among the states. However, the standard errors from the odds ratios had to be used, because there were no appropriate standard errors from the relative risk computations.

The resulting approximations are listed in Exhibit 34. They show safety belts are effective both in preventing any injury (effectiveness of 52 percent) and in reducing the likelihood of a death (effectiveness of 89 percent), given involvement in a crash. In reducing the severity of injuries, safety belts also are effective. Observe that effectiveness increases as the severity of the outcome increases. This shows that safety belts have a protective effect-causing a downward shift in the severity of injury sustained by vehicle occupants when injured in a crash.

Exhibit 34. Comparison of Odds Ratios and Effectiveness of Safety Belts in Preventing Death and Various Levels of Injury. Drivers only.

Level of Analysis	Odds Ratio	Effectiveness
Died	0.11	89%
Died or Inpatient	0.23	75%
Died, Inpatient, or Transported	0.39	54%
Any Injury	0.38	52%

These rates are consistent with those published by NHTSA in its report, the *Second Report to Congress on the Effectiveness of Occupant Protection Systems and Their Use*. Using data from NHTSA's National Accident Sampling System Crashworthiness Data System (NASS CDS), the report estimated that manual lap-shoulder belts are 66 percent effective in reducing the likelihood of moderate or greater injury. A "moderate or greater injury" included a range of injury severity. Some were transported and treated in a hospital emergency department (but not necessarily admitted for inpatient care) and some resulted in death. Thus, this classification is roughly equivalent to the CODES category of "Transported, Admitted as an Inpatient,, or Died," for which the effectiveness estimate was 54 percent.

Possible over-reporting of safety belt use could affect the CDS analysis as it may the CODES analysis. The occupant-restraint-use data in the NASS CDS analysis were determined by the NASS CDS investigator, when possible, through examination of the physical evidence in the vehicles and interviews with the involved occupants. For many crash victims, especially the uninjured, the investigator has only the information on the crash report. Unfortunately, the crash reports probably have more over-reporting of safety-belt use than the CDS data.

Belt use rates are higher for drivers in police reported crashes used in the CODES analysis than for drivers observed in the general motoring public. Exhibit 35 shows the police-reported belt usage (broken down by police estimate of injury) averaged from data for all of the CODES states, for the different levels of severity. For comparison, the estimated national use rate for 1991 based on observational data from NHTSA's 19 Cities Survey was 51 percent. Other than over-reporting, there has been no explanation for the thirty percent differential at the two lowest levels.

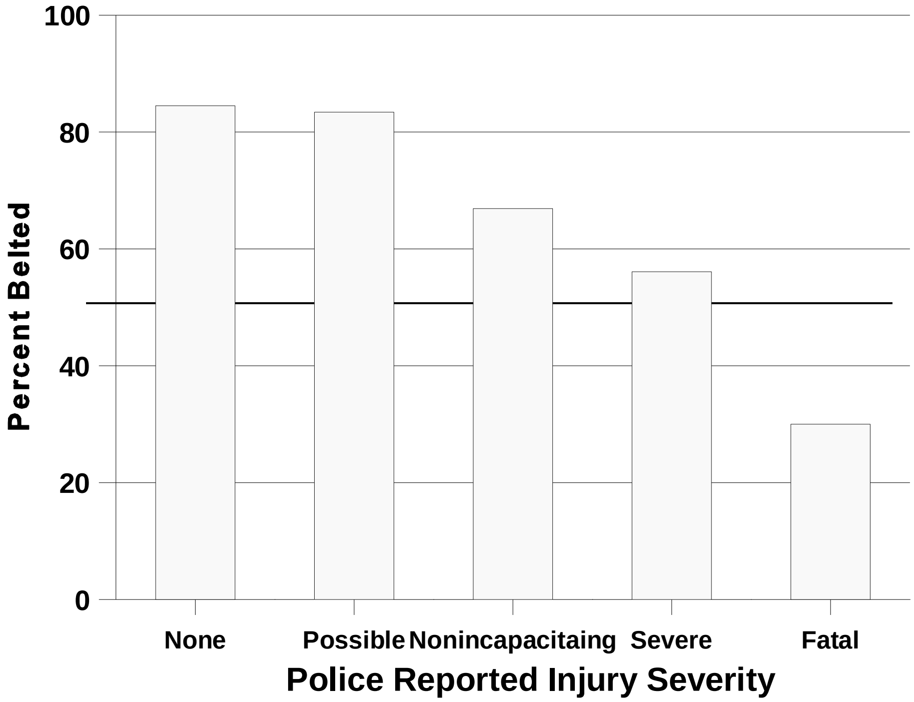


Exhibit 35. Police-Reported Belt Use, by Injury Severity for Crash-Involved Drivers in the CODES States. The horizontal line at 51 percent is the average from NHTSA's "19 Cities Survey."

The CODES states separately investigated procedures to adjust for this over-reporting. No consensus was reached on how this could best be done, nor how many "uninjured, reported belted drivers" should be changed to "uninjured, assumed unbelted drivers." With this caveat in mind, an estimate of an adjusted effectiveness for preventing fatalities would be between 50 percent and 60 percent. However, this potential over-reporting does not negate the conclusions of the NASS CDS study or of the CODES study that belts are effective in reducing deaths and injuries.

Exhibit 36 is a representation of the relative frequency of belted and unbelted drivers in the CODES project by injury level. It is included as a comparison to and an elaboration of Exhibit 17. Note that the numbers used to create the triangles differed slightly from the raw frequency counts. They were adjusted to produce odds ratios and effectiveness ratings as close as possible to those in Exhibit 34. However, the totals over belted and unbelted are accurate at every injury level. For example, 84.8 percent of 723,466 belted drivers, added to 68.6 percent of 150,473 unbelted drivers, equals the true number of uninjured drivers.

The triangles show how much larger the proportion of uninjured belted drivers is than uninjured unbelted drivers, and how much smaller the proportions are at all injury levels. For drivers transported by EMS (but not admitted as an inpatient or died), the proportions are approximately twice as large for unbelted drivers as for belted drivers. For drivers admitted as inpatients, the proportions are approximately four times as large, and for those who died, the proportions are ten times as large. However, the problem of over reporting of safety-belt use is also illustrated. In most minor crashes, drivers are out of the vehicle before the reporting officer arrives. Therefore, close to all of the uninjured, unbelted drivers have both the opportunity and motive to tell the reporting officer that they were belted when they were not. This is also true (to a lesser extent) for slightly injured and transported drivers. The size of the bottom of the "Belted" triangle is inflated by such people, and if they could be correctly reclassified, the relative proportions in the two triangles would not be as disparate. This over reporting is also evident in Exhibit 2 (page 7), where the fourth row shows each state's police-reported belt use, and the fifth row shows belt use as reported by roadside observers.

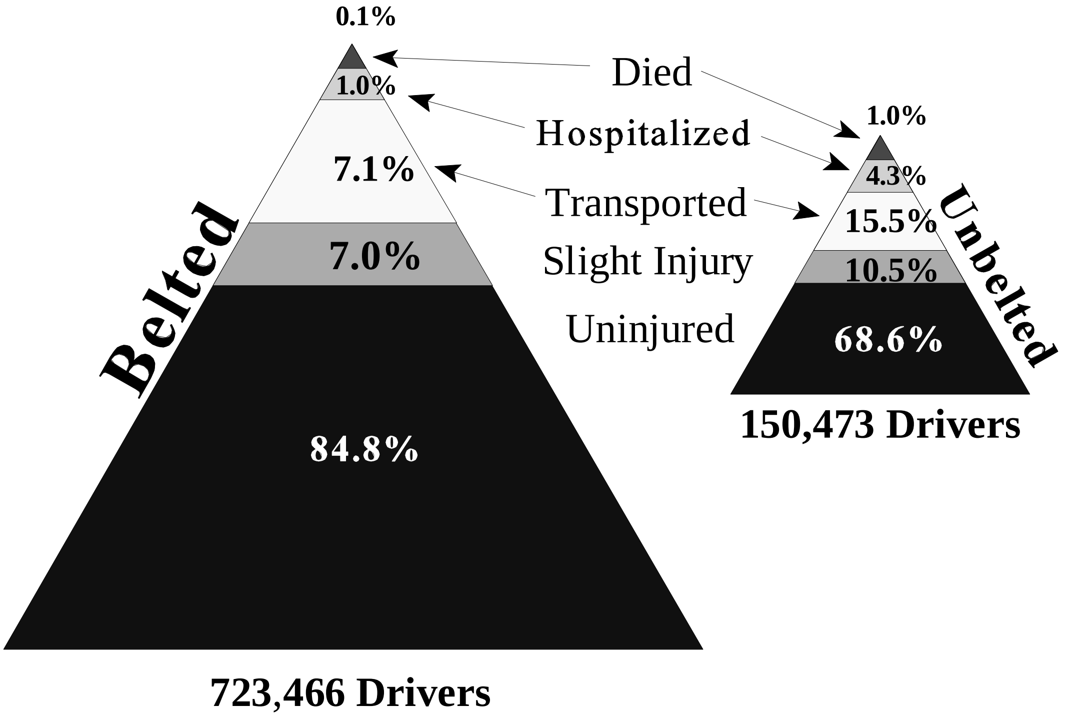


Exhibit 36. Injury Severity by Belt Use in the CODES Project. Areas inside the triangles represent the number of cases in each category.

For completeness, Exhibit 37 shows the effectiveness rates for each state. These are derived from the "relative risks" that were used to compute the weighted average effectiveness rates in Exhibit 34.

Exhibit 37. Effectiveness Rates by State and Outcome Measure. These rates were approximated from the logistic regressions for each state.

	STATE						
Outcome Measure	**HI**	**ME**	**MO**	**NY**	**PA**	**UT**	**WI**
Died	92%	74%	89%	89%	89%	84%	90%
Died or Inpatient	73%	63%	75%	71%	72%	80%	83%
Died, Inpatient, or Transported	57%	46%	58%	42%	54%	46%	70%
Any Injury	53%	39%	55%	35%	59%	48%	68%

Reduction in inpatient charges

Because there are more belted inpatients than unbelted inpatients, total charges were converted to average (per inpatient) charges when discussing belt-use effects. These charge data are discussed below, first broken down by payer source and converted to estimated costs, then broken down by state.

As mentioned earlier, analysis of the benefits of safety belts with respect to costs incurred by those injured has been restricted to the charge information available from the hospital discharge and other (rehabilitative) inpatient databases. (For purposes of this report the terms "inpatient" or "hospitalized" refer to someone who was admitted for treatment to a hospital or to a rehabilitative care facility.) Averages of these charges, over all the states, are presented in Exhibit 38 (Average charges are presented since total charges hide the difference between the belted and unbelted. Over all the states, far more vehicle occupants used safety belts than those who did not).

In addition, drivers wearing a safety belt were less likely to be admitted for inpatient treatment. (See Exhibit 34 which indicates that safety belts are 75% effective in preventing hospitalization or death.) Consequently, Exhibit 38 also shows the charges adjusted for the likelihood of being admitted, that is, the average charges for all crash-involved belted and crash-involved unbelted occupants, whether admitted to a hospital or not.

Exhibit 38. Average Inpatient Charges, by Safety Belt Use, First Using Only Inpatient Drivers as the Divisor, and Then Using All Crash-involved Drivers as the Divisor. CODES States, Passenger-vehicle Drivers Only.

Group	Safety Belt Use		Increase for Not Using Safety Belts
	Used	Not Used	
Inpatient Victims	$9,004	$13,937	55%
All Crash-involved Drivers	$110	$562	408%

The average inpatient charge is almost $5,000 higher for non-users of safety belts, compared to belt users, and including only hospitalized crash victims in the calculations. This is a 55 percent increase if the safety belt was not used. When total charges are distributed among **all** crash-involved drivers, the average charge, although smaller, shows an even larger percentage increase in charges for unbelted persons. Spread out over all drivers, hospital charges were 408 percent higher for drivers not using a safety belt. It should be noted that this latter figure would be inflated by over-reporting of safety-belts. However, over-reporting is less likely to inflate the 55 percent figure.

COMPARISON OF CHARGE TO COST

This analysis of the benefits of safety belts was based on the charge information available from the hospital discharge and other (rehabilitative and long-term care) inpatient databases. As discussed previously on page 39, actual costs are lower. In the CODES states contributing to the study, total charges (for drivers only) were $164.4 million which resulted in an estimated total actual cost of $114.5 million. If all drivers involved in police-reported crashes had been wearing a safety belt, the savings would have been approximately $68 million in reduced charges and $47 million in reduced inpatient costs, which are 41 percent reductions. This result is shown graphically in Exhibit 39. Note that these cost estimates reflect the seven CODES states and are not intended to be representative of the country as a whole.

These data include hospital inpatient charges, either from acute care facilities or rehabilitation centers. They do not include charges from the following: Emergency medical services, emergency departments, doctors, outpatient procedures or rehabilitation, drugs taken outside the hospital, chiropractors, or any other allied health professional, including (but not limited to) home health care and home rehabilitation. Inspection of Table 12 in *Cost of Injury*[4] leads to the conclusion the costs captured by the CODES project represent 60 percent of total direct medical costs (see page 39). This implies the $114.5 million costs in Exhibit 39 represent total medical costs (for only drivers, and for only the seven CODES states) of $191 million. In addition to the direct medical charges paid by the people who are injured in motor vehicle crashes, there are external costs which the public pays when someone fails to buckle up or wear a helmet.[10]

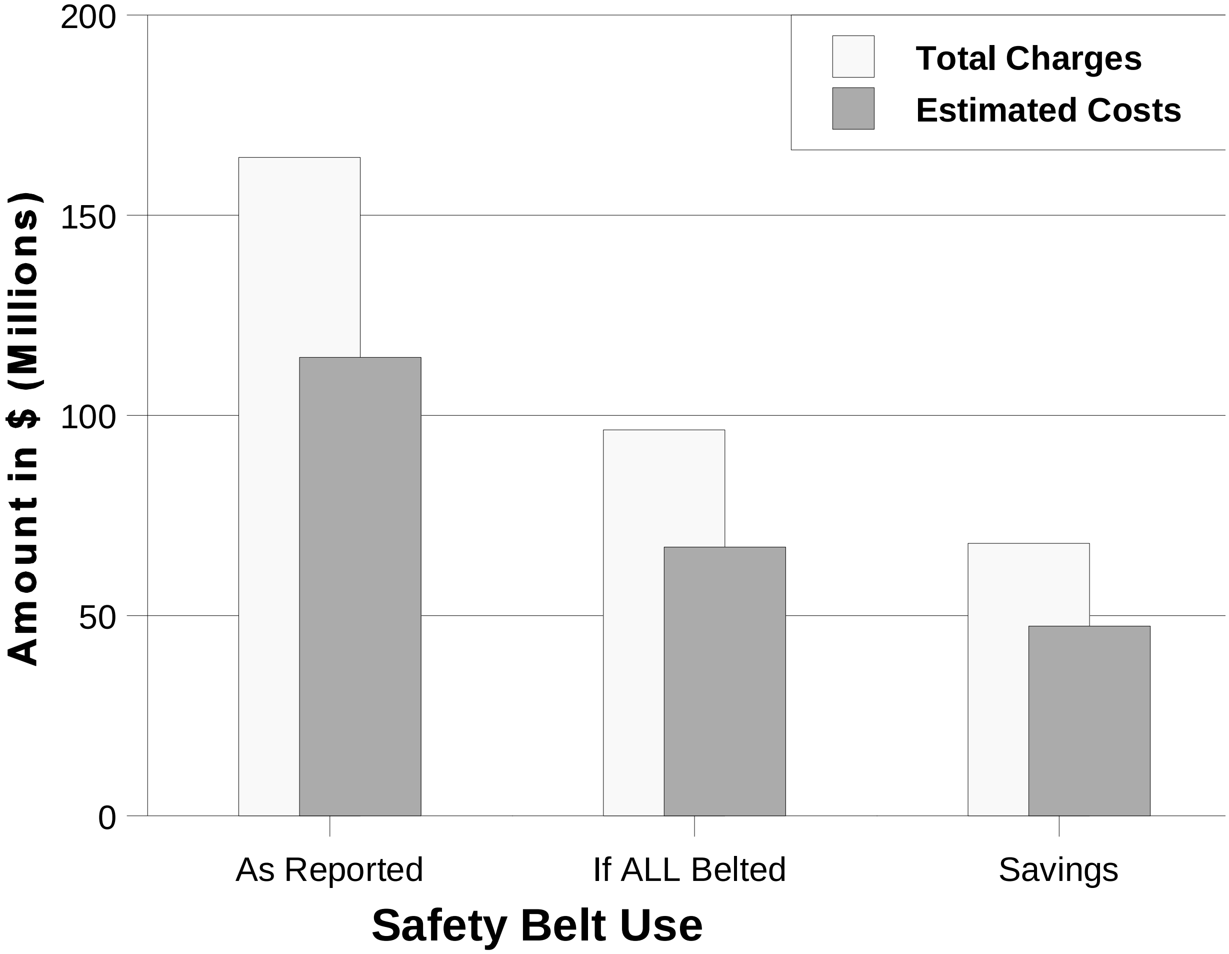


Exhibit 39. Total Inpatient Charges and Estimated Costs, by Safety Belt Use. (The left columns show total inpatient charges and costs in the CODES states, as reported with the present mix of belted and unbelted drivers. The middle columns show the **predicted** charges and costs **if** all drivers wore a seat belt, and the right columns show the difference.)

PAYER SOURCES

Hospitals and rehabilitative and long-term care facilities seek payment for charges from several sources. Private health insurance companies, including Worker's Compensation, are usually the primary source. The taxpayer is another source of payment through government programs such as Medicare and Medicaid. Victims without medical insurance are included in the other category. These "self-payers" often are unable to pay their bills and the cost of providing this care is passed on through higher charges for those who do pay.

Exhibit 40 shows the average hospital charges, broken down by payer source and by belt use. These data are concatenated from tabular data provided by the states, and have not been tested for statistical significance, excepting the "All Sources" bars on the right (See section on CHARGE EFFECTS BY STATES that follows). With the exception of Workers' Compensation, unbelted inpatients incurred higher charges in every category on the average. The "Other" category includes Self Payment, Self Insured, No Charge, and private payers not otherwise specified. The states are fairly certain that few, if any, cases in this category would eventually be paid through public funds.

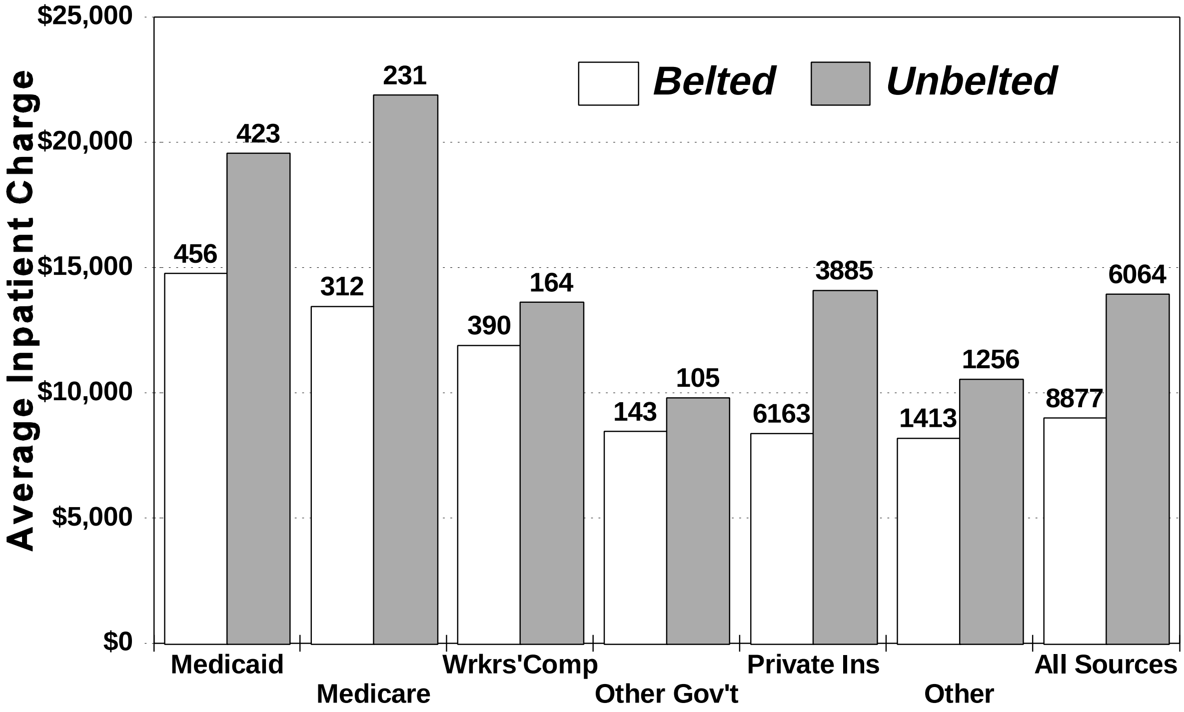


Exhibit 40. Breakdown of Average Hospital Charges in CODES States by Type of Payer and Belt Use. Drivers Only. Numbers above bars indicate patients in each category.

Exhibit 41 collapses Medicaid, Medicare, and Other Government categories into one called "Public," and then tabulates the averages by safety-belt use, and displays total charges (for drivers only). At the time of discharge, private insurance, including Worker's Compensation, was the payer for 69 percent of all inpatient charges. Public sources, usually Medicare and Medicaid and other government sources, accounted for 16 percent. The balance (15 percent) was in the other group. Regardless of pay source, the average charge for an inpatient who was not using a safety belt was higher than the charge for a belted inpatient. The average charge for unbelted drivers in the private insurance payer group was 64 percent higher than for those drivers using safety belts. For those not wearing safety belts in the public payer group the average charge was 42 percent higher than for the belted public payer group. For the other group, the difference was 29 percent.

Note that the most severely injured people who become medically needy can apply for Medicaid as a result of their injuries. Therefore, the reader is cautioned not to draw any unwarranted inferences about higher charges to public payers, a subject that was not studied in this project.

Exhibit 41. Average Inpatient Charge and Total Inpatient Charges by Source of Payment and Safety Belt Use for Crash Involved Drivers in the CODES States.

Source of Payment	Safety Belt Use		Difference	Total
	Used	Not Used		
Public*	$13,322	$18,922	$5,600	$26,498,675
Private Insurance**	$8,581	$14,058	$5,477	$113,156,421
Other***	$8,180	$10,534	$2,354	$24,788,922
Total All Sources	$9,004	$13,937	$4,933	$164,444,018

*Includes all charges to Government Funded Sources including Medicaid, Medicare, etc.
**Private Insurance Companies including Worker's Compensation
***Usually Self Payment

CHARGE EFFECTS BY STATE

Each state computed a multiple regression analysis using charges as the dependent variable, and the same set of independent variables as in the logistic regression analysis (see Exhibit 24). In the four states with larger populations (New York, Missouri, Pennsylvania, and Wisconsin), there were significant decreases in the average hospital charge when the patient was belted. The smaller states had so few cases that the differences were not statistically significant. Overall, the average hospital charge of a belted driver was 35 percent less than that of an unbelted driver. See Exhibit 42. The Exhibit shows only the coefficient for safety-belt use, i.e., the effect on the driver's charge if he or she wore a safety belt. The vertical bars, as in previous Exhibits, show the 95 percent confidence interval about the coefficient. If a vertical bar crosses the $0 line, there was no statistically significant effect in that state. If there were sufficient cases, a state showed a significant cost savings when the belt was worn, ranging from about $2,500 in Pennsylvania to $4,000 in Wisconsin. States with less than 2,000 cases (Hawaii, Maine, and Utah) showed no significant decrease.

The effects from the multiple regression are smaller than the averages presented in previous paragraphs. Three factors account for the differences. First, the multiple regression analysis included nine other factors that can also influence charges. The overall variance is partitioned among all the variables. Second, the regression analysis includes passengers for five of the seven states (Hawaii, Maine, New York, Pennsylvania, and Utah); passengers are generally younger than drivers, and charges are generally less for younger people. A reduced average for both belted and unbelted occupants would be likely to show a reduced difference between the two groups. Third, the multiple regression omitted any cases that had a missing value on any of the variables. It only used complete cases. Cases in the previous tables required only charge and safety-belt information.

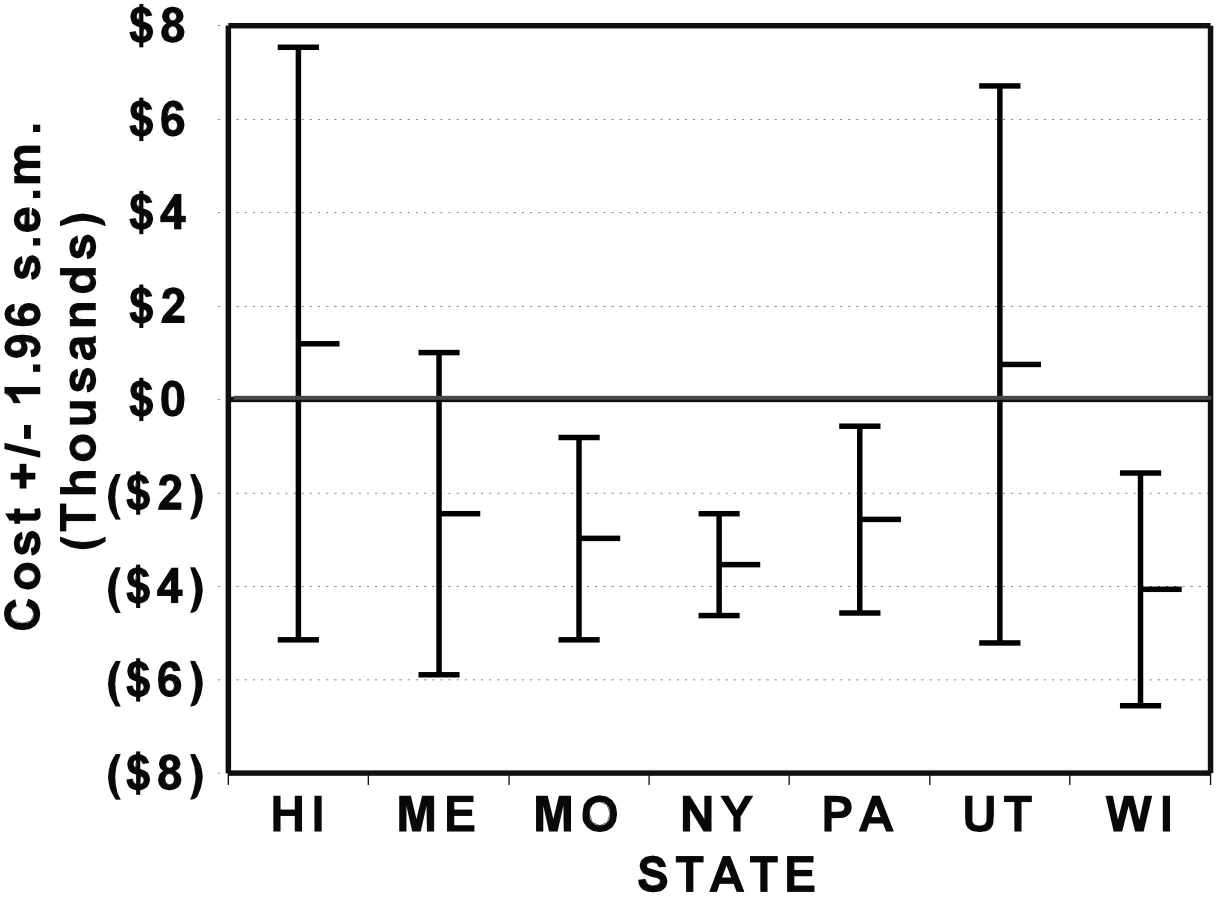


Exhibit 42. Breakdown of Belt Charge Savings for Hospital Inpatients (Passengers Included Except in Missouri and Wisconsin) by CODES State. (If entire bar is below the zero line, there is a significant charge savings in that state. Error bars are plus or minus 1.96 standard errors of the mean.)

RESULTS--BENEFITS OF HELMETS

Previous Studies

As with analyses of safety belt effectiveness, NHTSA has conducted and published many analyses on the effectiveness of motorcycle helmets in reducing fatalities and injuries. A 1989 NHTSA analysis[11] estimated that motorcycle helmets were 29 percent effective against a fatal injury. A 1986 NHTSA analysis[12] found that repeal of helmet use laws was associated with an estimated 10.4 to 33.3 percent increase in the per crash fatality rate between 1975 and 1984. A 1989 report[13] updated this estimate to an increase of 9.9 to 31.1 percent from 1975 to 1988. A 1994 report[14] estimated that, between 1984 and 1993, motorcycle helmets saved 6,410 lives.

Odds Ratios

Each of the grantee states computed a logistic regression analysis on motorcycle occupants involved in traffic crashes. This was analogous to the logistic regression for safety belts. Results showed the extent of the benefits of motorcycle helmets, with respect to the outcome of the crash. The outcome measures were identical to those used in the safety belt analysis. Several covariates (type of crash, vehicle type, and seating position) used in the safety belt analysis were not included because they were inappropriate for the helmet analysis.

Wearing helmets reduced the odds of injury or death very significantly in some states, but the results were not as consistent as they were for belt use. This is due to several factors: The first was the small sample sizes. Hawaii, Maine, and Utah had less than 600 cases each. Even the largest state, New York, had fewer than 4,600 cases (compared to almost 400,000 for their safety belt data).

The second factor is a different pattern in use and reporting of helmets. In states where there is a universal helmet law, such as Missouri, New York and Pennsylvania, observational studies estimate compliance is above 95 percent. Presumably, this is because it is easier for police to catch unhelmeted occupants on motorcycles than unbelted occupants of cars and trucks. This makes it difficult to find a reasonable sample of injured, unhelmeted motorcyclists, especially at the more severe injury levels.

The last factor relates to type of injury. Several states remarked that only head injuries should be included as injuries, since helmets only protect the head. NHTSA requested a “head-injury-only” analysis from each of the CODES states. Of the two states that responded, Wisconsin, which does not have a helmet law, and consequently has a sufficient sample of unhelmeted people with head injuries, found significant differences in favor of wearing helmets. New York, which has a helmet law, and therefore had a sample of unhelmeted head injuries of less than ten, found no differences due to this small sample.

DIED

Odds ratios (for dead versus alive and for helmet use) ranged from 0.033, in New York, to 1.686. The latter figure, from Utah, suggested a non-protective effect for helmets, but was not significant. Utah had only twenty-one deaths out of 586 usable cases. In addition, Utah police officers had no way to specify “helmet not used,” so Utah's analyses are based on “helmet used” versus “unknown,” which biases their analyses toward non-significance. The former odds ratio (0.033) means an unhelmeted motorcyclist has thirty times the odds of a death compared with a helmeted motorcyclist. This was a very extreme figure in the “good” direction, and it must be noted that New York had a very small number of unhelmeted fatalities. In addition, 38 percent of the motorcycle cases were “unknown” helmet use. If even a quarter of these “unknowns” were actually “helmet not used,” the odds ratio would be much less extreme. Because of these various factors, the helmet odds ratios are not portrayed graphically below.

DIED AND/OR INPATIENT

The range for this category was 0.136, in New York, (seven times the odds if no helmet worn) to 0.927, in Utah (not significant).

DIED, INPATIENT, OR TRANSPORTED

The range for this category was 0.250, in New York, (four times the odds if no helmet worn) to 0.994. The latter was not significant, but in this case it was from Pennsylvania.

ANY INJURY

The range for this category was 0.173, in Missouri, (six times the odds if no helmet worn) to 1.387. The latter was not significant, and also from Hawaii.

CONSOLIDATION

To increase the power of the analyses, and to investigate the effect of helmets on brain injury, NHTSA consolidated the data from six of the states: Hawaii, Maine, Missouri, New York, Pennsylvania, and Wisconsin. Utah's data were excluded because they could not identify “helmet not used.” Exhibit 43 shows the results of the mandated model analysis for this larger sample. This table differs from the safety belt data in that the effectiveness rates were calculated from raw data to maximize the sample size. In other words, when combining the states’ motorcycle data, the control variables (age, speed limit, rural/urban, etc.) were not included.

Exhibit 43. Comparison of <u>Odds Ratios</u> and <u>Effectiveness</u> of Motorcycle Helmets in Preventing Death and Various Levels of Injury*.

Level of Analysis	Odds Ratio	Effectiveness
Died	0.64	35%
Died or admitted as an inpatient	0.69	26%
Died, admitted as an inpatient, or Transported	0.58	26%
Any Injury	0.70	9%

*Utah's data were excluded because they could not identify "helmet not used." These cases were included in "unknown helmet use."

Exhibit 43 suggests that the effectiveness of motorcycle helmets goes down as less severe injuries are included in the "injured" category. This is not surprising, because motorcycle helmets are only designed to reduce the occurrence or severity of head injuries, not a wide range of injuries. Because motorcyclists are unprotected, when they crash they are very likely to sustain some type of injury, not just a head injury.

Prevention of Brain Injury

Helmets were not designed to protect the rider from most types of injuries which could affect a motorcycle rider. The main function of the helmet is to reduce injuries to the head and especially to the brain. Brain injury is more likely to result in expensive and long-lasting treatment, sometimes resulting in lifelong disability, whereas other head injuries, concussions and skull fractures (without damage to the brain itself), are more likely to result in full recovery. To examine whether motorcycle helmets would be more effective in reducing the injuries they were designed to prevent, NHTSA performed a separate analysis restricting the outcome measure to whether or not the motorcyclist received inpatient care for a brain injury. One state, Wisconsin, had subdivided its inpatients with head injuries into brain injury, concussion, and simple skull fracture groups. The inpatient files from Hawaii, Maine, Missouri, New York, and Pennsylvania were added to Wisconsin's data, using Wisconsin's definitions. Again, Utah was not used since the crash report did not include a code for not wearing a helmet.

Only helmet use was included as an independent variable, to maximize the number of cases that could be included in the analysis. The results showed that **helmets were 67 percent effective in preventing hospitalization due to a brain injury**. Unhelmeted motorcyclists were over three times as likely to suffer a brain injury as were those who were helmeted. Note that 67 percent is almost twice the helmet effectiveness rate for preventing death. In other words, if the 132 unhelmeted motorcyclists who <u>died</u> in these six states had been wearing a helmet, probably 46 of them would have survived. On the other hand, if the 135 unhelmeted motorcyclists who suffered a brain injury had been wearing a helmet, probably 90 of them would have escaped brain injury.

Cost of Crash Injuries to Motorcycle Riders

NHTSA used the same consolidated sample for a cost analysis, similar to the one for safety belts. Again, the analysis has been restricted to the charge information available from the inpatient databases. A summary of these results is presented in Exhibit 44.

Exhibit 44. Average Inpatient Charges for Inpatient Victims and All Crash Involved Motorcycle Riders, by Helmet Use. Data from Utah Were Excluded.

Average Charges	Motorcycle Helmet Use		Percent Difference
	Used	Not Used	
Inpatient Victims	$14,377	$15,578	8%
All Crash Involved Riders	$2,064	$2,808	36%

The average inpatient charge for motorcycle crash victims who did not use their helmet is $1,201 higher than for those who did, a difference of 8 percent. When adjusted for all crash-involved occupants, the difference is smaller, $744, but the relative difference increases to 36 percent. These differences are not as dramatic as those seen for safety belts. But this is likely to be an effect of both the smaller sample sizes involved and the likelihood that motorcycle riders will be injured in a crash, helmeted or not. Exhibit 45 shows this result graphically.

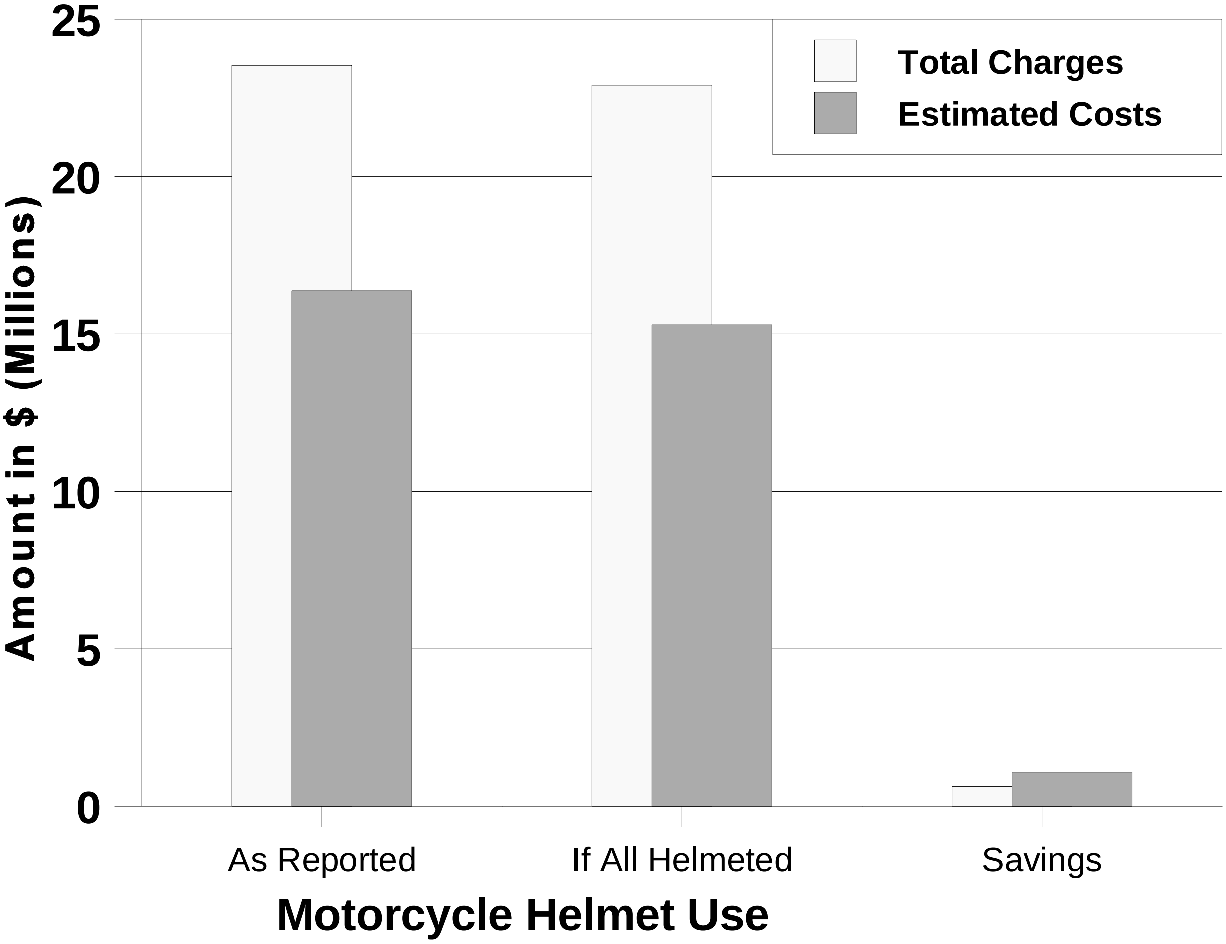


Exhibit 45. Estimated Total Inpatient Charges and Costs. (Left columns show them under present conditions. Center columns show them assuming all motorcyclists wore helmets, and the right columns show the savings that would result. Based on data from Hawaii, Maine, Missouri, New York, and Wisconsin.)

Exhibit 46 presents average hospital charges by type of payer and motorcycle helmet use. The results are similar to those shown for the safety belt analysis. At the time of discharge, the expected pay source for a majority of charges was a private insurance company. Billings to private insurance companies covered 63 percent of all charges, but the average charge for an unhelmeted motorcyclist was almost 15 percent higher than the charge for a helmeted rider in this group. On the other hand, the average charge for an unhelmeted motorcycle occupant in the "Other" payer group was slightly lower than for helmeted riders. Public sector sources covered about 23 percent of the inpatient charges for motorcycle crash victims in the six states in this analysis. The average inpatient charge for those injured motorcyclists who used a public payer source was more than 5 percent higher for motorcyclists who did not wear a helmet than for those who did.

Exhibit 46. Average and Total Inpatient Charges by Source of Payment and Motorcycle Helmet Use. Based on Data from Hawaii, Maine, Missouri, New York, Pennsylvania and Wisconsin.

Source of Payment	Motorcycle Helmet Use		Difference of Average Charges	Total Charges
	Used	Not Used		
Public*	$23,793	$24,925	$1,132	$5,364,759
Private Insurance**	$13,617	$15,687	$2,070	$14,764,706
Other***	$10,565	$8,913	($1,653)	$3,403,183

* Includes all payments made from Government Provided Sources including Medicaid, Medicare, etc.
** Private Insurance Companies
*** Usually Self Payment

Exhibit 47. Average Inpatient Charge by Motorcycle Helmet Use and Brain Injury Status for Inpatient Motorcyclists in Hawaii, Maine, Missouri, New York, Pennsylvania and Wisconsin.

Group/ Payer Source	Motorcycle Helmet Use			
	Used		Not Used	
	Brain Injured	Not Brain Injured	Brain Injured	Not Brain Injured
All inpatients, all sources	$26,985	$12,736	$26,805	$11,730
Public*	$33,764	$22,066	$46,347	$11,596
Private Insurance**	$29,610	$11,834	$24,461	$12,807
Other***	$16,664	$9,585	$10,238	$8,593

Average inpatient charges for brain-injured and non-brain-injured motorcyclists are shown in Exhibit 47. Regardless of helmet use, the average charge for inpatient care for a motorcyclist who sustained a brain injury is twice the average charge for motorcyclists receiving inpatient care for other injuries. For unhelmeted motorcyclists, the average charge for those with a brain injury is 2¼ times the average charge for those not sustaining a brain injury, a difference of over $15,000. Therefore, if all motorcyclists wore helmets, approximately $15,000 in inpatient charges would be saved during the first 12 months for every motorcycle rider who due to wearing the helmet did not sustain a brain injury, not to mention the savings from avoiding the continual costs for care over a lifetime.

Discussion of Motorcycle Helmet Analysis

Regarding the effectiveness of motorcycle helmets in reducing fatalities and injuries, the results are also consistent with previous analyses NHTSA has conducted. The 35 percent figure from Exhibit 11 is very close to a 1989 NHTSA analysis[11] which estimated that motorcycle helmets were 29 percent effective against fatal injury. The minimal effectiveness of helmets when lesser injuries are added to the analysis should not be surprising. Helmets prevent head injury, not all injuries.

This makes the analysis of brain injury all the more important, because it shows that helmets are effective in reducing the types of injury they were designed to reduce. They were 67 percent effective in the six selected states, which is more than twice the fatality effectiveness. Helmets also reduce the cost where it counts. In these six states, cases with brain injury were more than twice as costly as non-brain injury during the first twelve months.

With motorcycle helmets, the over-reporting problem does not exist, because it is easier to see “helmet use” than “belt use.” There is no substantial group of motorcyclists claiming they were wearing helmets when they were not. No adjustments need be contemplated as in the safety-belt analysis. However, there is a problem with missing data on motorcycle helmet use. New York, with a helmet-use law, showed “unknown helmet use” on 38 percent of its motorcyclist records. Wisconsin, without a helmet-use law, showed only 9 percent. In general, states with laws are more likely to have missing data. Police may be reluctant to give a ticket for not wearing a helmet to a motorcyclist who has just suffered a crash.

SUMMARY OF THE MANDATED MODEL

This study confirms and amplifies previous studies that found safety belts and motorcycle helmets were effective in reducing fatalities and injuries and in reducing inpatient costs. Even without including smaller (but more numerous) charges from EMS services, emergency rooms/departments, private doctor or chiropractor visits, home health services, and pharmaceutical expenses, **seven states show possible belt savings in the tens of millions of dollars**, and **six states show possible helmet savings in the millions of dollars for inpatient charges alone**.

The study also shows the efficiency with which disparate files can be merged using probabilistic matching, and how the linked files can generate comprehensive and precise answers to safety problems. The best illustration obtained from the data so far is the success of helmets in preventing brain injury, which could only have been computed with both crash and hospital data together.

OTHER STATE SPECIFIC ANALYSES USING THE LINKED STATE DATA

Each of the CODES states also performed state specific analyses to investigate issues related to the safety belt and helmet analyses, to issues related to the quality of the linked data, to factors related to crash and injury severity, and to geographic patterns of crash characteristics. The results from these studies are summarized below.

Data Quality

REPORTED SAFETY BELT USAGE

Missouri took advantage of the linked data to determine variations in reported belt use as recorded on the linked crash, EMS, and Head and Spinal Cord Injury/Trauma (HSCIT) files. Eighty percent of the linked records with no missing data agreed on belt use/non use. Agreement rates between the linked crash and EMS and the linked crash and HSCIT files were slightly higher. Agreement among linked pairs for the helmet variable was similar though the crash and EMS links showed 93 percent agreement. Average charges were studied to assess the affect of the disagreements in the three files. The results indicated that average charges for belt use were similar regardless of the file used. Results were less consistent for motorcyclists because of insufficient cases for analysis.

Maine compared reported belt use between police and EMS records and found overall agreement for belt use at 87 percent and for alcohol use at 97 percent. A comparison of police and hospital reporting of injury indicates a much lower level of reliability. While police reports are able to reasonably identify the general area of injury, the reports lack specificity in their reporting (i.e. head vs. face). If we use the hospital discharge abstract record as a benchmark, the police often identify a secondary injury as the “most severe.” Bleeding or complaint of pain are not very useful indicators for the analysis of motor vehicle crash injuries. The comparison of EMS and hospital reporting of head and spinal trauma suggested evidence that the EMS check boxes were underutilized. The results reported reinforced the view that valid reporting of the injury outcome of motor vehicle crashes can best be accomplished through the linkage of crash to hospital discharge and other medical records.

OVER-REPORTING OF BELT USAGE

Maine performed a within-vehicle analysis using conditional logistic regression to determine whether an alternative analytic technique would lead to similar conclusions as those reported in the Report to Congress. This analysis compared the outcome for individuals within the same vehicle, thus controlling for the severity of the crash without actually measuring severity directly. Because the nature and coding of the variables relevant to severity available at the various CODES states differed, part of the interstate differences in the estimate of efficacy of safety belts may reflect not actual differences in efficacy but instead variation in the extent to which confounding by severity can be removed in the unconditional analyses. A within-vehicle analysis may generate results that can be validly pooled across all states, whereas results based on unconditional logistic regression could be more likely to be biased by differences among states. With a conditional analysis, the estimates of efficacy were found to be somewhat reduced relative to the estimates from the unconditional analysis. However, the degree of this difference was not substantial, and strong evidence for efficacy was provided by the conditional (i.e., within-vehicle) analysis. Consequently, it seems likely that the unconditional analyses do not yield estimates of efficacy that overstate the true efficacy appreciably. Use of safety belts reduces the odds of injury by about 35 percent for drivers and nearly 50 percent for passengers. The upper confidence limits for these estimates indicate that the true efficacy in Maine is unlikely to be less than about a 12 percent reduction in injuries for drivers or less than about 30 percent for passengers.

Maine also performed an ordered logistic regression to better fit the ordinal nature of the dependent variables and thus increase the power to reject the notion that safety belts are not protective. The results indicate that for the safety belt model, the NHTSA model of four separate analyses produced a more precise measure of the benefits of safety belts. However, for motorcycles, the ordered logistic regression was as effective as the NHTSA model.

Utah studied the effect of the misclassification on the calculated odds ratio associated with safety belt use. Adjustment of the fraction of correct classification of safety belt use among reported belt users decreased the protective effect associated with safety belt use for the levels of injury studied. Although adjustment decreased the magnitude of the protective effect of belts, safety belts continued to be protective in preventing injuries and fatalities.

To determine the net effect of over-reported belt use on estimates of belt effectiveness, Wisconsin developed a new model for estimating the probability of belt use among crash occupants. A field observation study, conducted in the same period as the CODES study year, found a 55% belt use rate among Wisconsin passenger car occupants, compared with a reported 86% belt use rate among passenger car occupants in crashes. The Wisconsin team used logistic regression analyses on the data from the field observation study to determine whether occupant, vehicle and site characteristics were significant predictors of belt use. Logit parameters for occupant, vehicle and site characteristics were computed. Variables from the field observation study were mapped into variables in the crash data. Using the logit parameters and the variables in the crash data, a probability of belt use was computed for every passenger vehicle occupant whose crash record contained sufficient vehicle, site and occupant information. Finally, a new dichotomous variable was created to represent occupants' belt use, using the following algorithm:

1. The distribution of yes/no values for the new variable was to equal the distribution of belted/unbelted occupants in the field observation study (55%/45%).

2. Belt use was left as reported for unbelted occupants, and for occupants who died.

3. The value of the new variable was “no” for the N occupants with the lowest probabilities such that N plus the number of self-reported non-wearers totaled 45% of the occupants.

4. The value of the new variable was “yes” for all remaining occupants.

A medical record review conducted in conjunction with this study found that among occupants injured seriously enough to be admitted as inpatients, belt use is over-reported but not as extensively as among uninjured occupants. Analyses of safety belt effectiveness using the new belt use variable yielded lower estimates of the protective effect -- closer to the 50 percent effectiveness that has been demonstrated in other studies, including matched pair analyses. In analyses that estimate the risk of sustaining an injury outcome associated with safety belt non-use, over-reporting of belt use inflates the risk estimate by at least 212 percent (passengers: hospitalization or death, 6.25/2.94) and as much as 490 percent (drivers: death, 10.64/2.14).

ERRORS IN THE CHARGES

Missouri identified records with discrepant charges or length of stay and forwarded them to the hospitals for correction. Average charge and LOS were then recalculated with the errors corrected. Differences in average charges and LOS by belt use were not significantly different regardless of whether corrected or uncorrected values were used.

Ancillary Linkages to Improve the Results

Missouri linked the hospital discharge data to the Head and Spinal Cord/Trauma Injury Data (HSCIT) to compare hospital charges. Sixty percent of the records had no differences in charges and 76 percent had a difference of less than five percent. Although larger differences existed in some of the remaining records, they made relatively small difference in the average charges on those records where both were present. Although the HSCIT reports data for patients treated at a trauma center, some HSCIT records did not link to hospital discharge data. The majority of the unlinked HSCIT records were found to have low charges and a length of stay of one. These patients were not defined as inpatients by the hospital discharge data. HSCIT records which did link to the hospital discharge data were found to represent more severely injured patients (more emergency department discharges to the operating room and ICU units, more discharges to skilled nursing facilities and rehab units, more fatalities, fewer superficial injuries, etc). After contacting hospitals regarding some of the largest discrepancies, it was apparent that charges and length of stay from the hospital discharge file were most often correct. Thus, inpatient charges were always assigned from the hospital discharge file; they were assigned from the HSCIT file only if the charges were missing from the hospital discharge file. Belt users were found to have lower charges whether the corrections to the charges and length of stay were made or not. The implication is that conclusions about belt use by drivers of cars and trucks are relatively impervious to the range of error occurring in these data.

EMERGENCY DEPARTMENT DATA

Emergency department data are frequently not computerized statewide; however, this information is important for highway safety to evaluate injuries not requiring hospitalization. Pennsylvania attempted to create statewide emergency department data by merging electronic billing data at a stratified sample of all hospitals. While virtually all Pennsylvania hospitals use the UB-92 uniform billing format, most fail to permanently store ED patient billing data in computer-retrievable format. More than 2/3 of hospitals purged ED billing data from their computer system within six months and only 10 percent stored billing data on computer disk or tape after it was purged. For ED patients who were not admitted, three quarters of Pennsylvania hospitals included diagnostic and treatment information on these patients in their computerized information system. Important data on outpatient injuries may, therefore, be available from this source. Most computerized ED patient registration, billing and log systems are integrated systems, thus increasing the likelihood for standardization of patient data for later merging at the state level.

Other Factors Affecting the Relationship between Crash and Injury Severity

OUTLIERS

Missouri identified an outlier charge of $914,331 for a belted, truck driver. Beltedness for this driver was confirmed in all three files (crash, EMS, HSCIT) and the high charge was determined to be unusual for belted patients. It had the effect of distorting the average charge for belted patients by 7 percent. Two other victims were involved in the same crash. Both were unbelted and suffered fatal injuries but incurred no hospital charges. These three records reveal the difficulty in using hospital charges as an outcome variable to assess safety belt effectiveness. When the outlier was dropped from the analyses, the 95 percent confidence interval decreased around the average patient charge for belted patients when drivers of cars and trucks were included together. When trucks were analyzed separately, exclusion of the outlier decreased the average charges from $20,247 to $10,934! However, since the data, though an outlier, represented a valid linked record for a belted driver, including it in the analyses was perceived as being less objectionable.

TYPES OF RESTRAINTS AND CRASHES

Hawaiian belt usage (representing one of the highest rates in the United States) was studied in relationship to injuries among crash-involved front seat occupants of motor vehicles. Injury was defined using the KABC0 levels of no injury, possible/non-incapacitating, incapacitating/fatal. Crash type was defined as head-on, rollover, and other. Safety belt usage was defined as no restraint use, lap only, shoulder only, and combined lap-shoulder protection systems. Lap-shoulder systems afforded the greatest level of protection, followed by lap only, shoulder only. No restraints increased the likelihood of a fatal or incapacitating injury as did rollover or head-on crashes.

ALCOHOL AND DRUG USE

Hawaii developed a structural model to explain the relationships between certain driver characteristics and behaviors, crash types, and injury severity once a crash has occurred. The model clarified the role of driver characteristics and behaviors in the causal sequence leading to more severe injuries. The effects of various factors were studied to determine how much each factor increased or decreased the odds of more severe crash types and injuries. The results indicated that driver behaviors of alcohol or drug use and lack of safety belt use greatly increase the odds of more severe crashes and injuries. Driver errors were found to have a small effect, while personal characteristics of age and sex were generally insignificant. The study failed to find any strong association between age, sex, and driver behavior suggesting that the young males involved in crashes are not much more likely to be engaging in these negligent behaviors than anyone else involved in crashes. As a result, they are not much more likely to be involved in the more severe crashes and injuries as one might expect from a disproportionately high rate of negligent behavior.

COST OF CARE

The New York CODES mandated model failed to establish a direct relationship (R-square = 0.02) between crash parameters and cost of care. Separate consideration of the crash parameters was studied to determine the relationship between the type and severity of injury with variations in the cost of care. The injury severity for drivers' admitted as inpatients, measured by the maximum abbreviated injury scale (MAIS) score, was shown to be a fair (R-square = 0.25) predictor of case level cost as measured by hospital charges. However, there was wide variance in cost by body region ($3,623 for external injuries to $15,874 for abdominal injuries) within the same severity level. Since AIS severity level assignments reflect only a single injury and a crash victim may be treated for several injuries, the Injury Severity Score (ISS) was substituted to improve the cost model. ISS measures cumulative injury severity across multiple body regions. As expected, inclusion of the multiple injuries per victim caused approximately 14 percent of all cases to shift to higher severity levels with ISS versus the MAIS. In addition, many average hospital charge values changed significantly. The progressive increase of charges by severity level was much more consistent across all body regions with ISS severities. More consistent average charge values at the injury category level did not change the estimated total charges significantly, and did not improve the situation at the case level. High variances within injury categories mean that low confidence cases still contribute approximately one-third of the estimated total charges. Case level models using ISS severity showed only slight improvements over models using MAIS severity. These study results suggest that case level cost prediction using diagnosis codes and computer algorithms for translation to injury severity, body region, and average cost may be an effective approach. However, model predictions should be coupled with medical record data that identify transfers, extraordinary treatment cases, or other outliers.

Wisconsin used linked crash and Medicaid claims data to obtain information on health outcomes and service utilization for each Medicaid-injured crash occupant for one year following the crash. The Wisconsin Medicaid program paid $6.5 million to cover crash-related costs incurred during the year following the crash, for eligible beneficiaries who were in crashes any time during 1991. In fiscal year 1991, $6.5 million was paid by Wisconsin Medicaid to cover crash-related costs incurred during the year following the crash for eligible beneficiaries. Over $4 million was paid by Medicaid for inpatient hospital services, slightly less than $1 million was paid for physician services, and one-half million dollars was paid for outpatient services. Over $3.5 million was paid on behalf of beneficiaries involved in passenger car crashes, with payments for crash-involved pedestrians and motorcyclists totaling approximately $1 million for each group. Costs were incurred immediately for (1) individuals who were Medicaid-eligible prior to the crash, and (2) individuals who became eligible immediately following the crash as a result of severe injuries requiring expensive care. Many others became eligible after their casualty insurance reached its maximum limits. Although this study tracked Medicaid costs for only the first year following each occupant's crash date, some severely-injured occupants become eligible for Medicaid two or three years after the crash when the payments from their liability settlements finally run out. An algorithm was developed to identify the crash-related health care specifically for physician, hospital, long term care, and other services provided to Medicaid beneficiaries. The Medicaid population of drivers, more likely to be female and younger, suffered higher injury severity possibly because of a higher reported rate of alcohol use and a lower rate of safety belt use.

RELATIONSHIP OF CRASH INJURY AND AGE

New York used the linked data to investigate whether crash related injuries differed between older and younger drivers hospitalized as the result of a motor vehicle crash. All drivers were assigned to groups covering a span of 10 years (16-24, 25-34, etc.). Only 68 percent of the drivers hospitalized age 16-54 were belted compared to 81 percent of the drivers age 55 and older. Almost 90 percent of the crashes were defined as low speed. Older drivers hospitalized were more likely to sustain a wide spectrum of crash related injuries (internal injuries, fractures, and contusions or superficial injuries) than younger drivers. Length of stay was longer (10 days versus 6 for younger drivers) and hospital charges greater (26 percent higher for the age group 65-74). Although belted and driving more slowly, elderly drivers are likely to suffer more serious injuries than younger drivers. Thus programs targeted at the elderly should include crash prevention.

Geographic Patterns of Crash Characteristics

GENDER, AGE, TIME OF DAY, DAY OF WEEK, MONTH

Using geographic information systems technologies, data collected on all reported moped collisions in the City and County of Honolulu during 1990 were combined and used to evaluate the impact of gender, age, time of day, day of week, and month on the location of moped crashes. The results identified intersections, roadways, and districts experiencing high moped crash rates. By identifying the areas where moped collisions occur, it is possible to coordinate traffic enforcement, public education, and training programs designed to enhance moped safety. Temporal strategies include developing enforcement and education campaigns targeted at Monday mornings and Friday evenings when moped collisions are likely to occur. Institutional approaches are necessary because tourists and students make up a large proportion of persons involved. Finally individual approaches are necessary to encourage the use of helmets and other protective gear.

TRAFFIC AREAS

CODES data were used to perform a spatial analysis of Honolulu motor vehicle crashes in 1990. Most crashes were found to occur closer to employment centers than to population centers suggesting that the distribution of crashes followed the distribution of traffic. Motorcycle crashes appear to be significantly higher in the major recreational, entertainment, and tourist center of the island. Moped crashes are higher around the University of Hawaii and in areas near several community colleges. Exceptions were noted for fatalities, crashes involving serious injuries and crashes involving alcohol, suggesting an interaction between speed, poor driving conditions, residential activities and alcohol. Different types of vehicle crashes were shown to have different spatial patterns suggesting either different population pools or different activities. In general traffic crashes were related to the conditions producing traffic and, in particular, to “attractors” of traffic more than to “generators.” GIS makes it possible to estimate a likely level of crashes which is useful for monitoring the significance of existing patterns of crashes. It also demonstrates the interrelationships between travel patterns, activity level, and the organization of the area.

NEIGHBORHOODS

A spatial lag model was developed to examine the relationship between motor vehicle crashes, population and several categories of employment. Crash predictors were found to fluctuate according to different trip generating activities and changed considerably over the day. Land use was found to interact with trip generating activities. This crash analysis method focuses attention on characteristics of neighborhoods and areas, and not just on the road system.

TRAFFIC VOLUME, DAILY WORK PATTERNS, AFTERNOON AND WEEKEND ACTIVITIES, HOLIDAYS, WEATHER

Changes in daily motor vehicle crashes during 1990 were examined for the City and County of Honolulu. Daily crashes fluctuated according to an interaction between traffic volume, daily work patterns, afternoon and weekend activities, holidays and weather. Major holidays generate fewer daily crashes, primarily because of lower traffic volumes, but minor holidays generate more daily crashes. Rainfall, while reducing traffic volumes, also increased the risk of crashes. The interaction between Friday afternoons and rainfall is particularly dangerous.

ANALYTICAL ISSUES

Measures such as effectiveness rates for countermeasures are not affected unless the false negative rate is high enough to reduce the power of the sample to represent the group. However, the failure to link crash reports which should have linked may result in system measures, such as total EMS transports, hospitalizations, charges, and hospital days, to be understated. In addition, average charges may be understated if the unlinked records contain severe cases with high hospital charges and long lengths of stay. Thus, before performing any analyses, the accuracy and completeness of the linked data must be evaluated relative to the population and the outcome measures implemented.

One of the advantages of data linkage is that it highlights the under-submission of records when it exists. Variations in reporting thresholds and in submission rates by police agency, provider, or geographic service area were evaluated by each state to ensure that specific population groups, types of services, etc. were not under- or over-reported for either the injured or uninjured. Of particular interest was the potential for variations in the quality for each linkage variable to cause under- or over-representation of a particular group or unit of measure.

Systematic bias may occur during specific linkage phases because of variations in the power of the linkage variables to discriminate. For example, except for Wisconsin, date of birth was available on the crash report only for drivers. Adding date of birth to the EMS data increased the probability that driver records would match and their characteristics would prevail. As indicated before, the CODES states varied in their abilities to obtain date of birth through ancillary linkages.

SIGNIFICANCE OF CODES

CODES represents a successful experiment using state linked data that demonstrated not only a decrease in the number and severity of injuries but also a reduction in health care charges and estimated actual costs with the use of belts and helmets. In addition, the implementation of CODES promoted collaboration among the highway safety, medical, and insurance communities in the CODES states and improved the quality of state data for future use.

The linked data provide unique insights into the **financial outcome** of highway crashes. Police crash reports provide information about the crash environment and driver/occupants; EMS reports and hospital discharge data add medical information about injury type and severity; and hospital discharge and insurance claims data reveal the financial consequences. Taken together, these linked data generated greater value than when considered alone.

Hundreds of thousands of police-reported crashes were included in the statewide linked data. This large volume of **vehicle-related information** increased the available statistical power to discriminate among specific vehicle attributes while controlling for non-vehicle-related factors and generating cost benefit analyses of vehicle safety performance standards.

An important concern of the public health community relates to the **availability of medical services** and their impact on outcome. The availability of linked injury and crash information supports collaboration between the non-medical and medical communities. These data can be used to demonstrate the effectiveness of the emergency response by police, EMS, and the acute care system, and to predict the need for an aggressive medical response when specific crash, vehicle, and behavioral characteristics exist.

NHTSA often examines state data to evaluate the benefits of specific highway safety countermeasures. CODES linked data allow the agency to examine not only a more accurate description of injury consequences, but also the public health cost savings associated with highway safety initiatives. Since a high percentage of these costs are funded by citizens through increased taxes to cover the expenses of uninsured and underinsured crash victims, documentation of the costs is important to motivate public and legislative support for stricter laws and enforcement actions. CODES provides documentation, generated from a state's own linked data, that is more credible among local decision makers who may be tempted to repeal the safety mandates, such as helmet legislation. CODES information has the capability to demonstrate the increased costs associated with head injuries for unhelmeted riders, to identify the health care costs for specific vehicles, crashes, and behaviors (e.g. alcohol involvement, unsafe driving actions), to generate community-based information to support community based traffic safety programs, and to target specific populations at risk at the local, regional, or state levels. All of this information identifies and supports outcome-based injury control activities that have the most potential for reducing health care costs.

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2. Blincoe, Larry and Faigin, Barbara. *The Economic Cost of Motor Vehicle Crashes,1990.* DOT HS 807-876, Sept. 1992.

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Appendix A.

SAS® code for estimating effectiveness from PROC LOGISTIC output.

The SAS[1] program below was used to estimate the effectiveness estimates from the PROC LOGISTIC regression output. This method allows the covariates to be accounted for in addressing system effects. Effectiveness estimates cannot be directly computed from odds ratios, although if the probabilities of a positive response (e.g., dying) are very small, the computed odds ratio is almost identical to the relative risk, and (1 - relative risk) * 100 = effectiveness. However, that is the exception. Generally, relative risk is closer to one than its corresponding odds ratio if there is a significant safety effect.

Nevertheless, effectiveness estimates are very useful because they have become standard in NHTSA reports. Moreover, they lead to the following interpretation: “This means that *X* percent of the unbelted drivers would have survived had they been wearing their safety belt,” a concept understood by a wider audience than the use of odds ratios. Therefore, the following algorithm was used to compute approximations of them:

PROC LOGISTIC wrote the predicted probability for each case (along with many other variables) to an output file. Then a DATA step computed the logit of the estimated probability, and if the occupant was belted, subtracted the beta-weight for belt use. Occupants who were unbelted needed no adjustment. This gave an “unbelted” logit for every occupant, whether belted or not. Conversely, if the occupant was not belted, the data step added the beta-weight for belt use, resulting in the occupant's “belted” logit. Occupants who were belted needed no adjustment. This gave a “belted” logit for every occupant, whether belted or not. Then the DATA step computed the exponents of both logits, giving the predicted probabilities in both situations. Then PROC MEANS[1] computed the means of these probabilities. These means represent the population probabilities of a positive response (e.g., dying), adjusted for the covariates (other independent variables) in the model. In a spread sheet, an estimate of the risk ratio was obtained by dividing the mean probability if everyone was belted by the mean probability if everyone was not belted. This was done for every state and analysis level, for drivers only.

The following is the SAS® LOG from a run for Wisconsin. The original output had no **bold** or *Italics*. **Bold text** is usually original text that has been bolded for emphasis. All *Italics* text is added explanation. Credit Ellen Hertz and Terry Klein for the original formulas. Variable names with the letters **Hat** in them mean the variable is a statistical estimate.

◆

```
/*Jon Walker.  CODES.  PROC LOGISTIC for Wisconsin data.
* Runs ALL levels with OUTPUT statements added to capture
* predicted probabilities, prior to calculating
* the probabilities of 'injured/died, given Unbelted' and
* 'injured/died, given Belted' for each analysis level.
* The means of these will be used to estimate effectiveness.
```

```
* From file WiLog9.SAS;6
*/

OPTIONS LS=165 PS=64 NOCENTER NOOVP ;
```

NOOVP stops overprinting, which is only appropriate for impact or line printers. The linesize and pagesize are set up for landscape printing.

```
PROC FORMAT;
  VALUE Yes2No
          0 = "No"
          1 = " Yes " /*Makes odds ratios go in right direction*/
          ;
RUN ;

LIBNAME CRASH '##############';
```

File name deleted for security reasons.

```
/* DataSet within [############] is ######## */
/* Includes proper vehicles (and cycles) for mandated model. */

DATA NoCycle;
   SET CRASH.######## ;
          IF Case type = 1 /* Car/van/pickup Drivers only, Cycles deleted */ ;
```

Above is specific to Wisconsin.

M_OutC_A, M_OutC_B, M_OutC_C, and M_OutC_D are the four outcome variables in Wisconsin. See the following ATTRIB statements.

```
          KEEP M_OutC_A M_OutC_B M_OutC_C M_OutC_D
                    BeltUse Roll SVFO SVO MVH Rural Age
                    Male SpLim Wet Time Inter PC ;
```

(Only these variables were needed.)

```
ATTRIB M_OutC_A FORMAT=Yes2No. LABEL="Any Injury " ;
ATTRIB M_OutC_B FORMAT=Yes2No. LABEL="Trans+ " ;
ATTRIB M_OutC_C FORMAT=Yes2No. LABEL="Hosp+ " ;
ATTRIB M_OutC_D FORMAT=Yes2No. LABEL="Died " ;
/* Reformat Injury Levels: Put Odds Ratios in right direction. */
RUN ;


PROC LOGISTIC DATA=NoCycle SIMPLE ;
  MODEL M_OutC_A = BeltUse Roll SVFO SVO MVH  Rural Age
                Male SpLim Wet Time Inter PC ;
  OUTPUT OUT= WI_OutA P= PHatA ;
```

PHatA is a programmer-assigned name that serves as a reminder that it contains an estimate of the predicted probability of injury for each person. ***A*** *and* ***a*** *are only necessary because all four analyses are being run before the averages are calculated. It would probably be easier to run a PROC LOGISTIC, then a DATA step, and then* *a PROC MEANS together for each analysis level.*

```
TITLE1 ' CODES: WI: Hospital (Large) dataset.  PROC LOGISTIC for the odds of
any injury for Car/van/pickups drivers. ' ;
RUN ;
```

The following NOTE comes from the SAS® LOG. It probably occurs because the Yes2No format forces SAS to model the probability differently than the default model. However, this method forces the odds ratios into the direction that NHTSA mandated.

NOTE: PROC LOGISTIC is modeling the probability that M_OUTC_A=' Yes'. One way to change this to model the probability that M_OUTC_A='No' is to specify the DESCENDING option on the PROC statement. Refer to Technical Report P-229 or the SAS System Help Files for details.

```
PROC LOGISTIC DATA=NoCycle SIMPLE ;
  MODEL M_OutC_B = BeltUse Roll SVFO SVO MVH  Rural Age
                 Male SpLim Wet Time Inter PC ;
  OUTPUT OUT= WI_OutB P= PHatB ;
TITLE1 ' CODES: WI: Hospital (Large) dataset. PROC LOGISTIC for the odds of
EMS trans+ for Car/van/pickups drivers. ' ;
RUN ;

PROC LOGISTIC DATA=NoCycle SIMPLE ;
  MODEL M_OutC_C = BeltUse Roll SVFO SVO MVH  Rural Age
                 Male SpLim Wet Time Inter PC ;
  OUTPUT OUT= WI_OutC P= PHatC ;
TITLE1 ' CODES: WI: Hospital (Large) dataset. PROC LOGISTIC for the odds of
hosp/death for Car/van/pickups drivers. ' ;
RUN ;

PROC LOGISTIC DATA=NoCycle SIMPLE ;
  MODEL M_OutC_D = BeltUse Roll SVFO SVO MVH  Rural Age
                 Male SpLim Wet Time Inter PC ;
  OUTPUT OUT= WI_OutD P= PHatD ;
TITLE1 ' CODES: WI: Hospital (Large) dataset. PROC LOGISTIC for the odds of
dieing for Car/van/pickups drivers. ' ;
RUN ;

DATA ;
        SET WI_OUTA ;
LnPHatA= LOG( PHatA / ( 1 - PHatA )) ;    /*Compute Logit of est. prob.*/
```

Note: The logic in the next two lines only works if BeltUse=1 for belted and BeltUse = 0 for unbelted. It will not work if the values are reversed or if values of 1 and 2 are used.

```
LnQHatA= LnPHatA - BeltUse * -1.4185 ;   /*Subtract Beta(BeltUse) if Belted*/
```

```
LnRHatA= LnPHatA + (1-BeltUse) * -1.4185 ;        /*Add Beta(BeltUse) if NOT Belted*/
QHatA = Exp(LnQHatA)/(1 + Exp(LnQHatA)) ;         /*Estimate PHat if NO ONE Belted */
RHatA = Exp(LnRHatA)/(1 + Exp(LnRHatA)) ;         /*Estimate PHat if EVERYONE Belted */
TITLE1 ' CODES: WI: Hospital (Large) dataset. PROC MEANS for the odds of
any injury for Car/van/pickups drivers. ' ;
RUN ;
```

The value ***-1.4185*** *is the BeltUse Parameter from a previous PROC LOGISTIC run, identical to the one above. It may not be necessary to make two runs. There are two optional output data sets in PROC LOGISTIC:* ***OUT= DataSetName1*** *(pages 1077, 1084-1085, 1096[1]) contains a record for each person with all of the variables in the final model plus output variables that the programmer lists by keyword;* ***OUTEST= DataSetName2*** *(page 1077, 1078, 1095[1]) contains final parameter estimates (as a minimum) in one record (more if the covariance matrix is requested. DataSetName2 would contain the needed values, but merging the two data sets correctly would not be elementary. Example 2 in the SAS manual[1] lists both data sets (pages 1105-1106) but does not merge them.*

```
PROC MEANS ;
```

Add ***VAR QHatA RHatA ;*** *to get the means for only the essential variables.*

```
DATA ;
     SET WI_OUTB ;
LnPHatB= LOG( PHatB / ( 1 - PHatB )) ;    /*Compute Logit of est. prob.*/
LnQHatB= LnPHatB - BeltUse * -1.4269 ;    /*Subtract Beta(BeltUse) if Belted*/
LnRHatB= LnPHatB + (1-BeltUse) * -1.4269 ;        /*Add Beta(BeltUse) if NOT Belted*/
QHatB = Exp(LnQHatB)/(1 + Exp(LnQHatB)) ;         /*Estimate PHat if NO ONE Belted */
RHatB = Exp(LnRHatB)/(1 + Exp(LnRHatB)) ;         /*Estimate PHat if EVERYONE Belted */
TITLE1 ' CODES: WI: Hospital (Large) dataset. PROC MEANS for the odds of
EMS trans+ for Car/van/pickups drivers. ' ;
RUN ;

PROC MEANS ;
```

Add ***VAR QHatB RHatB ;*** *to get the means for only the essential variables.*

```
DATA ;
     SET WI_OUTC ;
LnPHatC= LOG( PHatC / ( 1 - PHatC )) ;    /*Compute Logit of est. prob.*/
LnQHatC= LnPHatC - BeltUse * -1.8725 ;    /*Subtract Beta(BeltUse) if Belted*/
LnRHatC= LnPHatC + (1-BeltUse) * -1.8725 ;        /*Add Beta(BeltUse) if NOT Belted*/
QHatC = Exp(LnQHatC)/(1 + Exp(LnQHatC)) ;         /*Estimate PHat if NO ONE Belted */
RHatC = Exp(LnRHatC)/(1 + Exp(LnRHatC)) ;         /*Estimate PHat if EVERYONE Belted */
TITLE1 ' CODES: WI: Hospital (Large) dataset. PROC MEANS for the odds of
hosp/death for Car/van/pickups drivers. ' ;
RUN ;
```

```
PROC MEANS ;
```

Add ***VAR QHatC RHatC ;*** *to get the means for only the essential variables.*

```
DATA ;
      SET WI_OUTD ;
LnPHatD= LOG( PHatD / ( 1 - PHatD )) ;    /*Compute Logit of est. prob.*/
LnQHatD= LnPHatD - BeltUse * -2.3652 ;   /*Subtract Beta(BeltUse) if Belted*/
LnRHatD= LnPHatD + (1-BeltUse) * -2.3652 ;        /*Add Beta(BeltUse) if NOT Belted*/
QHatD = Exp(LnQHatD)/(1 + Exp(LnQHatD)) ; /*Estimate PHat if NO ONE Belted */
RHatD = Exp(LnRHatD)/(1 + Exp(LnRHatD))  ; /*Estimate PHat if EVERYONE Belted */
TITLE1 ' CODES: WI: Hospital (Large) dataset. PROC MEANS for the odds of
dying for Car/van/pickups drivers. ' ;
RUN ;

PROC MEANS ;
```

Add ***VAR QHatD RHatD ;*** *to get the means for only the essential variables.*

Relative Risk equals RHat divided by QHat. RR = RHat/QHat.

Effectiveness = (1 - RR) * 100.

To find the Odds Ratio equivalent to this Relative Risk, use the following formula:
OR = RHat/(1-RHat) / (QHat/(1-QHat)).

The odds ratios that result from this formula, which should be identical to the odds ratios from PROC LOGISTIC, are slightly higher, which means, given that all the odds are less than 1.0, they are slightly conservative. The “new” odds ratios average 5 percent higher relative to the original odds ratios. The range over 28 data points (four analyses times seven states) is 1.6 percent to 9.1 percent. However, the differences in effectiveness estimates are not as great. A 5 percent increase in odds ratios roughly translated to a 1 percent decrease in effectiveness.

Fleiss's procedure (for averaging the odds ratios) gave a weighted average of the risk ratios among the states. However, the standard errors from the odds ratios had to be used, because there were no appropriate standard errors from the relative risk computations. The effectiveness estimates in the final report are derived from these weighted averages.

REFERENCES (for Appendix A)

1. *SAS/STAT® User's Guide, Version 6, Fourth Edition, Volume 2.* SAS Institute Inc. Cary, NC: SAS Institute Inc., 1989.

2. *SAS® Language Guide for Personal Computers, Release 6.03 Edition.* SAS Institute Inc. Cary, NC: SAS Institute Inc., 1988.

3. This step could be added to the SAS® program by generating an output data set in PROC MEANS, and adding another DATA step to manipulate the means. In the present case it was more convenient to transfer the means to a computer spreadsheet where the weighted averages of the risk ratios from all states were later computed and graphed.