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Technical Report

# Using Linked Data To Evaluate Traumatic Brain Injuries in New Mexico

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

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16. Abstract

The 1995 crude mortality rate of physician diagnosed traumatic brain injury (TBI) in New Mexico is estimated to be 21 deaths per 100,000 population and the crude incidence of both hospitalized and fatal TBI is 110 cases per 100,000 population (1,856 TBI cases). This is elevated above a 1992 published figure for the national TBI fatality rate of 19 deaths per 100,000 population, and below at least one study reporting 180 medically confirmed cases of TBI per 100,000 population. The New Mexico rates are felt to be low because none of the available data sets contained complete coverage of the entire New Mexico population and some data coding practices preclude complete case ascertainment. Statewide hospital emergency department and emergency medical services data were not adequately developed for inclusion in these 1995 analyses.

Economic analyses of both fatal and non-fatal TBI in New Mexico were conducted. Using a conservative human capital approach, the mortality costs of TBI in New Mexico during 1995, were approximately $162 million, and the morbidity costs were approximately $128 million. Half (49%) of these costs, $142 million, resulted from motor vehicle crashes. Traumatic brain injuries frequently occur in younger populations and represent a large cost for New Mexicans. Given the high costs and disability associated with TBI, promotion of prevention programs should include a cost comparison.

The leading causes of hospitalized and fatal TBI in New Mexico were motor vehicle traffic crashes 791 (43%); non-traffic transportation, 85 (5%); falls, 240 (13%); hitting and striking, 141 (8%); and, firearms, 66 (4%). Occurrence of traumatic brain injury resulting from motor vehicle crashes was significantly associated with non-use of safety belts and being in a crash severe enough to require towing. TBI is twice as likely in towaway crashes. Overall, occupants in motor vehicle crashes were 12.4 times more likely to sustain a serious or fatal TBI if they were not using a safety belt. Safety belt effectiveness in terms of TBI or for the reduction of TBI was not associated with seating position in the vehicle, gender or age of the vehicle occupant.

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## Preface

This project was funded by a cooperative agreement from the National Highway Traffic Safety Administration to demonstrate the uses of electronically linked motor vehicle crash reports and medically documented data sets, referred to as the Crash Outcome Data Evaluation System (CODES) approach. New Mexico has been linking police crash reports to medical records since 1995 under the sponsorship of the New Mexico Highway and Transportation Department and Traffic Safety Bureau. This project used 1995 records to determine the incidence and contributing factors of traumatic brain injury in New Mexico. Police motor vehicle crash reports were electronically linked with four other data sets, derived in medical settings, to research the associations between motor vehicle crash characteristics, medical and economic outcomes.

The use of multiple information sources requires the cooperation and contribution of many organizations and individuals. Protection of confidential provider and patient data has been the first priority, followed by accurate and useful analyses and reporting. This was made possible by all team members listed as contributors to this report, in addition to the other members of the New Mexico Injury Surveillance Alliance. The work and trust of the many contributors is appreciated.

Dr. Philip Somervell provided extensive editing of this document. We thank him for his many hours of diligent review.

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## Contents

## Summary

The 1995 crude mortality rate of physician diagnosed traumatic brain injury (TBI) in New Mexico is estimated to be 21 deaths per 100,000 population and the crude incidence of both hospitalized and fatal TBI is 110 cases per 100,000 population (1,856 TBI cases). This is elevated above a 1992 published figure for the national TBI fatality rate of 19 deaths per 100,000 population, and below at least one study reporting 180 medically confirmed cases of TBI per 100,000 population. The New Mexico rates are felt to be low because none of the available data sets contained complete coverage of the entire New Mexico population and some data coding practices preclude complete case ascertainment. Statewide hospital emergency department and emergency medical services data were not adequately developed for inclusion in these 1995 analyses.

Economic analyses of both fatal and non-fatal TBI in New Mexico were conducted. Using a conservative human capital approach, the mortality costs of TBI in New Mexico during 1995, were approximately $162 million, and the morbidity costs were approximately $128 million. Half (49%) of these costs, $142 million, resulted from motor vehicle crashes. Traumatic brain injuries frequently occur in younger populations and represent a large cost for New Mexicans. Given the high costs and disability associated with TBI, promotion of prevention programs should include a cost comparison.

The leading causes of hospitalized and fatal TBI in New Mexico were motor vehicle traffic crashes 791 (43%); non-traffic transportation, 85 (5%); falls, 240 (13%); hitting and striking, 141 (8%); and, firearms, 66 (4%). Occurrence of traumatic brain injury resulting from motor vehicle crashes was significantly associated with non-use of safety belts and being in a crash severe enough to require towing. TBI is twice as likely in towaway crashes. Overall, occupants in motor vehicle crashes were 12.4 times more likely to sustain a serious or fatal TBI if they were not using a safety belt. Safety belt effectiveness in terms of TBI or for the reduction of TBI was not associated with seating position in the vehicle, gender or age of the vehicle occupant.

## General

### Introduction

Traumatic Brain Injury (TBI) is known to result in pain, loss of productivity and intense use of medical resources. Many of these injuries are preventable; however, a clear understanding of the causes and consequences is necessary. Much information regarding TBI is available but is captured in different and administratively unrelated databases. This project gathers information on individuals with a physician-diagnosed TBI from five separate and retrospectively integrated databases. Cases are linked, aggregated, analyzed, and reported for the purpose of demonstrating the utility of electronic data linkage, estimating costs, directing prevention of TBI efforts, and assessing the need for services of people with TBI.

In researching the costs associated with TBI, Thompson[1] and Bennett[2] cited fundamental papers which set the framework for this evaluation. Nationally, TBI ranked highest amongst the injury categories for years of potential life lost, 58% of 1985 life years lost due to injuries[3]; and fatal head injuries are the most costly on a per-person basis, accounting for 29% of costs although comprising 13% of injuries. Further, TBI ranked fourth among the most disabling categories for restricted activities and bed disability: neck fractures, trunk and upper limb fractures, lower limb fractures, dislocations and TBI. 1996 estimates indicate the majority (33%) of TBI's in the U.S. are related to motor vehicles, followed by 26% from household accidents.[4]

Locally, the New Mexico Brain Injury Advisory Council needs specific numbers on TBI to enhance the number and quality of services through legislative appropriations. Additionally, local traffic safety and healthcare policy advocates have need for New Mexico specific numbers to further establish the extent and cost-benefit implications for law and budget makers.

In this report we present the findings regarding TBI incidence, descriptive TBI characteristics, economic impact, and relationships to motor vehicle and occupant crash factors.

Four of five independent data sets were electronically linked together using *Automatch®* computer software. Attempts were made using deterministic methods with SAS® software to include Medicaid claims data. Data sets were inclusive of calendar year 1995 and the data consisted of statewide police crash reports; a system trauma registry representing 69% of the state's non-federal acute care hospital beds; statewide hospital inpatient discharges (exclusive of federal facilities); a limited number of injury related Medicaid claims; and all deaths covered by the state's Office of the Medical Investigator (OMI).

Injury outcomes include the occurrence of traumatic brain injury, as defined by the Centers for Disease Control and Prevention, and measures of brain injury severity. The economic analyses includes an assessment of both age and gender specific morbidity and mortality costs. Motor vehicle crash characteristics of particular interest include an evaluation of safety belt effectiveness.

## Background

New Mexico is one of the fastest growing states in the country. In comparison to the U.S. population's growth over the past four years of 4.7%, the population in New Mexico has increased 11.4%, to a 1995 population estimate of 1,685,401 individuals. The population in the state has the greatest cultural diversity of any state in the nation. According to the 1990 Census, the ethnic population of New Mexico consisted of 38.2% Hispanic, 8.9% American Indian, 2.0% Black, and 50.4% non-Hispanic whites.[5]

Based on national data, in 1995 New Mexico had the fourth highest fatality rate from unintentional injuries in the country (54.02/100,000).[6] In 1993 New Mexico had the second highest motor vehicle fatality rate (26.67/100,000). In 1997 it was 28.0/100,000 (compared to the national death rate of 15.6/100,000).[7] Alcohol has been reported to be a significant factor in many crashes and the state has consistently ranked as having one of the highest alcohol involved motor vehicle fatality rates in the nation.

Despite all that is known about New Mexico fatal injuries, it is only since 1994 that resources allowed efforts to begin to establish sound knowledge about injury morbidity, including incidence, severity, cost, and risk factors. The state has several databases that collect information related to the incidence of injuries, motor vehicle crashes, and trauma hospitalizations. Each of these databases has different inclusion criteria, different case definitions, and different variable definitions.

## New Mexico CODES Project Background

In an effort to improve what is known about injury in the state, in October 1994, the New Mexico Traffic Safety Bureau awarded a contract to the New Mexico Department of Health's Office of Epidemiology to initiate a Crash Outcome Data Evaluation System (CODES) project modeled after the National Highway Traffic Safety Administration's automotive crash evaluation projects. Analyses performed on the CODES linked databases demonstrate: 1) the ability to link data even with scant personal identifiers available; 2) provide descriptive information about the incidence and severity of injury; and, 3) uncover data quality issues both within and among databases. The first round of data linkage and analysis included 1994 data from three statewide databases and included crash, medical examiner, and trauma registry data. The results are encouraging--using 1995 data, two additional data sets are added; hospital inpatient discharge data and Medicaid data. These two new data sets provide a broader base for data linkage and analysis as well as providing information about individuals hospitalized in the state due to injury.

The University of New Mexico's Division of Government Research (DGR) processed and linked the 1995 data files. A detailed discussion of the data sources, linking of the data, an assessment of the matching results, and data quality is reported in their technical document.[8]

**Problem Statements**

This report was prepared to address each of the following questions.

1. How many people sustained fatal or serious (hospitalization required) TBI in 1995, and what were the statewide rates?

2. What were the demographic and geographic distribution of these TBI cases?

3. What were the causes of TBI?

4. What was the extent of hospitalization?

5. How many were in a coma for any length of time?

6. When discharged from a hospital, what was the discharge status?

7. How many cases were work-related and who were the primary payers?

8. How many had public sources as primary payor? What were the other payor sources?

9. How many cases had multiple payors?

10. What was the estimated cost associated with TBI?

11. How many individuals had alcohol related injury, (by cause of injury)?

In addition to these 11 research question, data are analyzed for associations between TBI and use of restraint devices, whether or not the vehicle is towed from the crash scene and police categorization of injury severity.

# METHODS

## TBI Case Definition

The standards for TBI case identification have been clearly defined.[9] A case of TBI is either an injury to the head that is documented in a medical record with one or more of the following conditions:

- observed or self-reported decreased level of consciousness
- amnesia
- objective neurological or neuropsychological abnormality
- diagnosed intracranial lesion
- skull fracture

or a death resulting from trauma, with head injury listed on the death certificate, autopsy report, or medical examiners report in the sequence of conditions that result in death.

Corresponding codes from the *International Classification of Diseases, Ninth Revision* (ICD-9) or the *International Classification of Diseases, Ninth Edition, Clinical Modification* (ICD-9-CM). The codes are:

| | |
|---|---|
| 800.0-801.9 | Fracture of the vault or base of the skull |
| 803.0-804.9 | Other and unqualified and multiple fractures of the skull |
| 850.0-854.1 | Intracranial injury, including concussion, contusion, laceration, and hemorrhage |

These codes are used as the basis for non-fatal TBI case identification and analysis in New Mexico. Mortality data from the Office of the Medical Examiner do not report ICD-9 or ICD-9-CM codes. Instead, they report a codified narrative cause of death code (Appendix A). Codes for head or neck injury and subdural hematoma are used.

## The 1995 CODES Linked Data

Five 1995 data sources were obtained for preparation and linkage. These include: the State of New Mexico Crash Files, the New Mexico System Trauma Registry (STR), the New Mexico Office of the Medical Investigator (OMI), the Hospital Inpatient Discharge Data file (HIDD), and the Medicaid claims file (see Exhibit 1, page 6). A detailed analysis of the process and findings of the data linkage methods is reported in the Technical Report on New Mexico Crash Outcome Data Evaluation System (CODES): Data Linkage for 1995. Details regarding data sources, definitions, assumptions, and limitations are found in Appendix C.

The injury analysis file contains 4,129 linked records. They were obtained from the following five data bases:

- Crash: 31,481 people killed or injured; 2,178 crash records linked to OMI, STR, or HIDD, and 29,303 unlinked;
- STR: 3,612 Person Records: 3,214 linked and 398 unlinked STR records representing the complete, unduplicated 1995 STR file;
- HIDD: 16,205 injury hospital discharge records; 3,499 HIDD records linked to STR or Crash Driver/Occupant, and 12,706 unlinked records;
- OMI: 1,498 Records: 586 linked and 912 unlinked OMI records representing the complete, unduplicated 1995 OMI "injury" file;
- Medicaid: 97,819 claim records: 380 records linked to a HIDD record containing STR or Crash information, and 97,439 unlinked claim records.

Exhibit 1 summarizes the size of the five data sources at each level of integration.

## Exhibit 1. New Mexico Data Sources, 1995

| LEVEL OF INTEGRATION | CRASH | STR (TRAUMA) | HIDD DATA | OMI | MEDICAID |
|---|---|---|---|---|---|
| *Primary Data* | 52,377 Motor vehicle crashes | 3,831 records | 186,287 discharges | 4,200 deaths | 1.9 million claims |
| *Injury Data* | 31,481 killed or injured | 3,612 encounters | 16,205 discharges | 1,498 deaths | 97,819 claims |
| *Linked Records* | *2,178 people killed or injured* | 3,214 people injured | 3,499 discharges | 586 deaths | 380 aggregated claims |

### Analytical Approaches

TBI cases were identified from one or more of three data files. They included capturing relevant ICD-9 codes in the STR or the HIDD. Since the Office of the Medical Investigator does not use ICD-9 coding, it was necessary to search for cases with a reported cause of death as head injury or neck injury or subdural hematoma (see Appendix A, Cause of Death Codes).

TBI population demographics, causes, and locations are described using frequency counts, proportions and odds. General loglinear and special loglinear logit analysis models are used to identify and quantify relationships (excluding pedestrians, motor cycles and bicycles), between use of safety belts, seating position in the vehicle, whether or not the vehicle is towed from the scene of the crash (a proxy measure for impact severity), age, gender, and TBI outcome. Analysis modeling uses *SPSS*® computer software.[10] A detailed description of the modeling is found in Appendix D.

## RESULTS AND DISCUSSION

### TBI Case Ascertainment

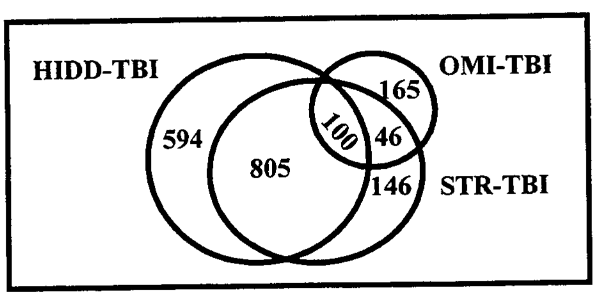
Studies of head injury rates in the general population have estimated the crude head injury rate to be 200 cases per 100,000 individuals, but there is considerable variation in rates between geographic regions.[11] However, much of this research used data more than 10 years old. A more recent study reported a crude head injury rate of 132 per 100,000 individuals.[12] Generally head injury rates are much higher in younger individuals, and overall rates in males are reported to be twice those in females. Kraus (1993) reports that approximately 50% of head injuries result from motor vehicle crashes, 25% from falls, and 10% to 15% from sports/recreational injuries. Assaults and other causes make up the remainder.

Max, MacKenzie and Rice (1991) analyzed data on 327,907 people who sustained traumatic brain injuries. 36,712 died (11%) and 291,195 survived, resulting in a rate of 15 deaths per 100,000 and 123 live hospital discharges per 100,000 population.[13] In a review of national death certificates Sosin (1995) found TBI death rates declined from 24.6 per 100,000 in 1979 to 19.3 per 100,000 in 1992.[14]

This report identifies 1,856 TBI cases, including 349 (19%) deaths (Exhibit 2).

### Exhibit 2. New Mexico TBIs Resulting in Death or Hospitalization, 1995

| DATA BASE | NON-FATAL | FATAL | TOTAL |
|---|---|---|---|
| HIDD ONLY | 562 | 32 | 594 |
| STR ONLY | 144 | 2 | 146 |
| OMI ONLY | -0- | 165 | 165 |
| HIDD & STR | 801 | 4 | 805 |
| STR & OMI | -0- | 46 | 46 |
| HIDD & STR & OMI | -0- | 100 | 100 |
| TOTAL TBIs | 1,507 | 349 | 1,856 |



Cases are obtained from both linked and unlinked database files. Exhibit 2 shows the contributions from the different databases. Counts are mutually exclusive and should not represent multiple counting. They yield a crude incidence rate of 110 TBI cases per 100,000 population. These cases are physician diagnosed and comparable to the rate of 132 per 100,000 population reported by MacKenzie (1989). The New Mexico TBI fatality rate of 21 per 100,000 population is above the rate reported by Max (1991), but within that range reported by Sosin (1995).

The New Mexico TBI counts presented in this report are considered quite conservative for many reasons. TBI case recognition and capture are problematic. First, only TBI resulting in death or hospitalization, with some exceptions noted above, are available for inclusion in this demonstration project report. It is likely that many TBI cases are unknown because cases treated and released from hospital emergency departments are not included. Second, only TBI incidence figures for one year are included in this report. This report does not address the issue of TBI prevalence in the state. There is also a concern regarding in and out migration. A person could sustain a TBI in New Mexico, be counted in the incidence figures for this report, but receive long term care, and associated costs, out-of-state. Similarly, a New Mexico resident could be injured elsewhere, yet return to the state for rehabilitation. At this time no attempt has been made to calculate in and out migration with the assumption that they will tend to cancel one another. Finally, death coding practices at the OMI preclude TBI identification when it results from a firearm wound or is one of multiple injuries. As many as 265 (87%) of 305 deaths from "multiple injury" causes were not included in our count of TBI related deaths.

## Exhibit 3. New Mexico TBIs by Age and Gender, 1995

| Age | Male | | | Female | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Non-Fatal | Fatal | Total | Non-Fatal | Fatal | Total | No. | % |
| 0-4 | 73 | 12 | 85 | 46 | 11 | 57 | 142 | (7.7) |
| 5-14 | 109 | 13 | 122 | 59 | 3 | 62 | 184 | (9.9) |
| 15-24 | 252 | 66 | 318 | 89 | 21 | 110 | 428 | (23.1) |
| 25-44 | 367 | 78 | 445 | 106 | 32 | 138 | 583 | (31.4) |
| 45-64 | 138 | 29 | 167 | 50 | 7 | 57 | 224 | (12.1) |
| 65-74 | 48 | 15 | 63 | 34 | 8 | 42 | 105 | (5.7) |
| 75+ | 66 | 26 | 92 | 69 | 28 | 97 | 189 | (10.4) |
| Unk | 1 | 0 | 1 | 0 | 0 | 0 | 1 | (<0.1) |
| Total | 1,054 | 239 | 1,293 | 453 | 110 | 563 | 1,856 | (100) |

The TBI case ascertainment in this report is limited to hospitalizations or death; however, the relative frequencies are similar to those of other studies. In general, most of the TBIs happen to those between the ages 15 and 44 years (55%), males make up more than half of the TBI's (57%), and a disproportionate number of those ages 15 to 44 years are male (76%), Exhibit 3, above. That is an odds of three to one for males between the ages 15 and 44 years compared to females. Exhibit 3 shows the gender and age of all but one of the 1,856 TBI cases identified in 1995.

**Causes and Incident location of TBI in New Mexico**

Exhibits 4 and 5 show the preponderance of TBI cases attributable to motor vehicle traffic crashes. The "cause of injury" variable was determined from E-codes contained in either the STR or HIDD, or cause of death coding in the OMI, Exhibit 4. E-codes were grouped in accordance with the *Recommended Framework for Presenting Injury Mortality Data* published by the Centers for Disease Control and Prevention.[15] Because these causes are identified by reported E-codes, and not police crash reports, "traffic" includes all traffic crashes, including those on private property, military and Indian reservations.

## Exhibit 4. Causes of TBI In New Mexico, 1995

| E-Coded Cause | Non-Fatal | Fatal | Total |
|---|---|---|---|
| Traffic Crashes* | 583 (38.7%) | 208 (59.6%) | 791 (42.6%) |
| Non-Traffic Transportations | 78 (5.2%) | 7 (2.0%) | 85 (4.6%) |
| Falls | 198 (13.1%) | 42 (12.0%) | 240 (12.9%) |
| Hitting/ Striking/Cut | 112 (7.4%) | 29 (8.3%) | 141 (7.6%) |
| Firearm | 29 (2.0%) | 37 (10.6%) | 66 (3.6%) |
| Other | 160 (10.6%) | 16 (4.6%) | 176 (9.5%) |
| Unknown | 347 (23.0%) | 10 (2.9%) | 357 (19.2%) |
| **Total** | 1,507 (100%) | 349 (100%) | 1,856 (100%) |

*Data are from STR, HIDD or OMI. 791 TBI cases were identified as "traffic related" from E-codes or OMI cause of death coding (Appendix A), and may include injuries occurring on private property or Indian jurisdictions. The 616 TBI cases shown in Exhibits 9, 12, and thereafter were identified from linkage with police crash reports.

Exhibit 5 is also derived from location E-codes (849) found in either the STR or HIDD. Although location is not determined for many of the TBI cases (40%), the largest coded group are those occurring on a street or highway (34%). It is noteworthy that location E-codes are available in addition to E-codes for causes in most of the cases. This is in part because the STR has fields for both location and cause, and in part because within the HIDD there are sometimes place and cause E-codes, despite only one designated field for E-codes in the HIDD.

## Exhibit 5. Location of TBI In New Mexico, 1995*

| E-Coded Location | Non-Fatal | Fatal | Total |
|---|---|---|---|
| Home | 141 (9.4%) | 29 (8.3%) | 170 (9.2%) |
| Farm | 20 (1.3%) | 2 (0.6%) | 22 (1.2%) |
| Mine or Quarry | 1 (0.0%) | - (0.0%) | 1 (0.0%) |
| Industrial Place | 17 (1.1%) | 3 (0.9%) | 20 (1.1%) |
| Place for Recreation | 66 (4.4%) | 3 (0.9%) | 69 (3.7%) |
| Street or Highway | 546 (36.2%) | 93 (26.6%) | 639 (34.4%) |
| Public Building | 31 (2.1%) | 4 (1.1%) | 35 (1.9%) |
| Residential Institution | 18 (1.2%) | 4 (1.1%) | 22 (1.2%) |
| Other Specified Place | 28 (1.9%) | 8 (2.3%) | 36 (1.9%) |
| Unspecified Place | 101 (6.7%) | 6 (1.7%) | 107 (5.8%) |
| No Information | 538 (35.7%) | 197 (56.4%) | 735 (34.6%) |
| **Total** | 1,507 (100%) | 349 (100%) | 1,856 (100%) |

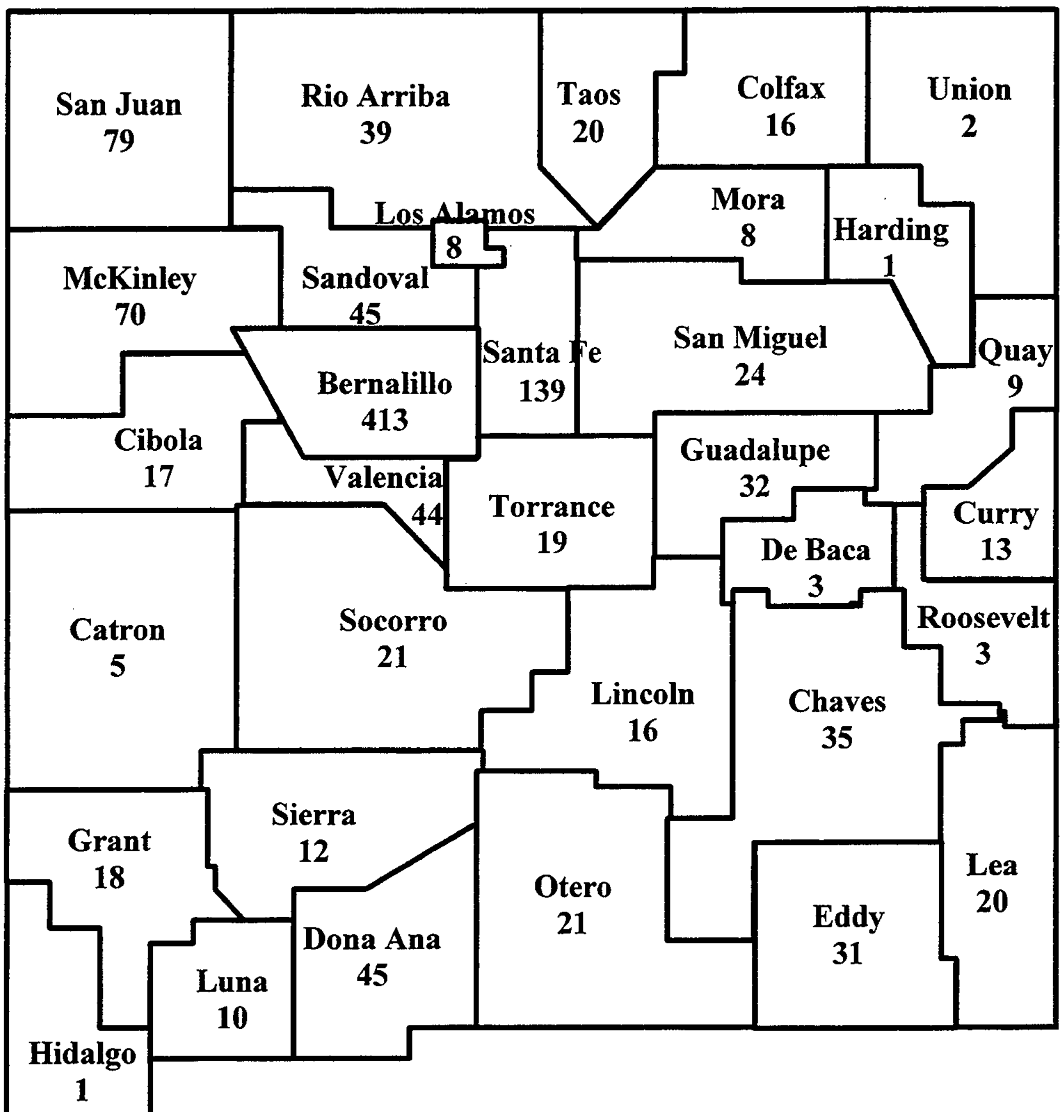
*Data from OMI, STR and HIDD

The following map shows the county location of all identified TBI cases. County location of TBI incident was determined for 1,239 (67%) of the 1,856 cases (Exhibit 6). County of incident for TBI was obtained in the following order; first from police crash reports, then STR, then OMI.

## Exhibit 6

# TRAUMATIC BRAIN INJURY
# COUNTY OF INCIDENT

### New Mexico, 1995




(N=1,239)

### Hospital Length of Stay and Discharge Status

Hospital length of stay was calculated for all TBI individuals admitted to the hospital. Data are presented for both STR and HIDD individually, and then by discharge status. Exhibit 7 provides the details.

### Exhibit 7. New Mexico TBI Hospital Length of Stay and, Discharge Status, 1995

| Source | Number | Mean (days) | Median (days) | Maximum (days) | Total (days) |
|---|---|---|---|---|---|
| System Trauma Registry | 1048 | 6.1 | 3.0 | 97 | 6,408 |
| Hospital Inpatient Discharge Data | 1370 | 8.0 | 4.0 | 161 | 10,928 |
| Discharge Status | | | | | |
| Home | 1080 | 5.4 | 3.0 | 161 | 5,889 |
| Transfer | 400 | 14.4 | 9.0 | 108 | 5,766 |
| Left AMA | 24 | 3.9 | 2.0 | 22 | 94 |
| Expired | 349 | 1.8 | 0 | 42 | 628 |
| Expired in hospital | 180 | 3.4 | 1.0 | 42 | 613 |
| Unknown | 3 | | | | |
| Total | 1,856 | | | | 12,377 |

The data show a median stay of 3 to 4 days. Because the median is essentially half the mean, stays are skewed significantly toward longer stays. The longest appears to be 161 days. A total of 12,377 hospital days were used for TBI. Sixty four percent (64%) are discharged home.

## Severity of TBI Cases

TBI severity may be estimated by length of time the individual is unconscious following a TBI and the level of the return to normal functioning following the injury. New York state developed and reported a clustering of the ICD-9 TBI diagnoses into mild, moderate-severe, and undetermined based on the fifth digit of the ICD-9 code.[16] Likewise, Ommaya, et. al.(1996) reported in the Journal of Trauma a similar matrix determining severity of head trauma.[17] Exhibit 8 shows the codes for the TBI ICD-9 codes fifth digit.

The New Mexico linked data were examined to determine TBI injury severity based on the 5th digit of the ICD-9 code. Exhibit 9 provides the results. Because length of unconsciousness can be determined from ICD-9 codes, fewer cases fall into the "unknown" category than when restricted to OMI or STR data elements.

## Exhibit 8. ICD-9 Code 5th Digit Definitions

| 5th Digit | Definition |
|---|---|
| xxx.x0 | Unspecified state of consciousness |
| xxx.x1 | No loss of consciousness |
| xxx.x2 | Brief (<1 hour) loss of consciousness |
| xxx.x3 | Moderate (1 to 24 hours) loss of consciousness |
| xxx.x4 | Prolonged (>24 hours) loss of consciousness and return to pre-existing conscious level |
| xxx.x5 | Prolonged (>24 hours) loss of consciousness, without return to pre-existing conscious level |
| xxx.x6 | Loss of consciousness of unspecified duration |
| xxx.x9 | With concussion, unspecified |

## Exhibit 9. New Mexico TBI Length of Unconsciousness Cases, 1995

| | All TBI Cases | | | TBI Cases in MVC | | |
|---|---|---|---|---|---|---|
| **Loss of Consciousness** | **Non-Fatal** | **Fatal** | **Total** | **Non-Fatal** | **Fatal** | **Total** |
| Prolonged, No Recovery | 95 | 130 | 225 | 30 | 61 | 91 |
| Prolonged, > 24 hours | 25 | 2 | 27 | 12 | 1 | 13 |
| Moderate, 1-24 hours | 69 | 4 | 73 | 29 | 3 | 32 |
| Brief, < 1 hour | 197 | 3 | 200 | 66 | 2 | 68 |
| No consciousness loss | 427 | 12 | 439 | 107 | 4 | 111 |
| Unspecified Duration | 154 | 12 | 166 | 47 | 5 | 52 |
| With Concussion, unspecified duration | 92 | 0 | 92 | 36 | 0 | 36 |
| Unknown | 448 | 186 | 634 | 103 | 110 | 213 |
| Total | 1,507 | 349 | 1,856 | 430 | 186 | 616 |

In Exhibit 9, 33% of TBI's are in police reported motor vehicle crashes (MVCs) overall, yet MVC related TBIs account for 40% or more in the most severe categories, suggesting MVC TBIs tend to be more severe.

**Work Related Injury**

In an attempt to determine if the TBI occurred while the individual was at work, the variable "work related" was examined from the STR. Only 51(5%) of the 1,097 TBI cases in the STR were reported as being "work related". Payor source for those 51 cases were 18 (35%) specified health plans; 5 (10%) self pay; 5 (10%) workers compensation; 3 (6%) in other; and 9 (18%) unknown. It seems very likely that many more cases were work related, particularly those occurring as the result of a motor vehicle crash. It would appear that further investigation of work related TBI must include examination of workers' compensation files. Payor information indicates workman's compensation funds payed for 33 cases, Exhibit 10.

**Payors and Multiple Payors**

In general, TBIs are covered 40% by private means; insurance 19%, health plans 11%, and self pay 9% (Exhibit 10). Public resources appear to pay for a third (33.4%); Medicaid 15%, Medicare 13%, Indian Health Services 6%, and a small 2% by county indigent funds. A relatively large proportion are blank, 24% unknown. Categorization of primary payor information is inexact because of the often ambiguous or unrecognizable nature of coverage given only the name of the payor. For example, Castle Drilling is presumed to be an employer and draws upon some kind of insurance resource, but could be drawing upon workman's compensation.

**Exhibit 10. New Mexico TBI Primary Payor Categories and Types, 1995**

| Primary Payor | Non-Fatal | Fatal | Total |
|---|---|---|---|
| Public | 557 (37.0 %) | 63 (18.1 %) | 620 (33.4 %) |
| County Indigent Funds | 27 (1.8%) | 4 (1.1%) | 31 (1.7%) |
| Indian Health Services | 69 (4.6%) | 6 (1.7%) | 102 (5.5%) |
| Medicaid | 265 (17.6%) | 16 (4.6%) | 271 (14.6%) |
| Medicare | 196 ( 13.0%) | 37 ( 10.6%) | 233 (12.6%) |
| Governmental | 62 ( 4.1%) | 3 ( 0.9%) | 65 (3.5 %) |
| Military/Champus | 22 (1.5%) | 0 (0.0%) | 20 (1.1%) |
| Federal/State/City Employee | 10 (0.7%) | 0 (0.0%) | 10 (0.5%) |
| Workman's Compensation | 30 (2.0%) | 3 (0.9%) | 33 (1.8%) |
| Private | 660 (43.8%) | 66 (18.9%) | 726 (39.1%) |
| Health Plan | 181 (12.0%) | 21 (6.0%) | 202 (10.9%) |
| Insurance | 339 (22.5%) | 20 (5.7%) | 359 (19.3%) |
| Self Pay | 140 (9.3%) | 25 (7.2%) | 165 (8.9%) |
| Other | 3 ( 0.2%) | 0 (0.0% ) | 3 ( 0.2%) |
| Unknown | 225 (14.9%) | 217 (62.2%) | 442 (23.8%) |
| **Total** | 1,507 (100.0%) | 349 (100.0%) | 1,856 (100.0%) |
| Multiple Payors | 385 (25.5 %) | 48 (13.8 %) | 433 (23.3%) |

## Alcohol

Although alcohol and alcohol involvement are of interest for many reasons, investigation is thwarted because of conflicting information within and between integrated files. Reconciliation of information should be conducted but will require significant research time and resources in addition to those already performed.

## Estimating the Costs of TBI

The individual direct and indirect total costs of traumatic brain injury are unknown, but are at least on the order of 300 million dollars for all TBIs (Exhibit 11). These costs include estimated rescue and acute care, rehabilitation, chronic care, and indirect costs in lost personal and family income and productivity. The total national cost of head injuries estimated by Max (1991) for 1985 was $37.8 billion, $4.5 billion for direct costs, $20.6 billion for mortality costs, and $12.7 billion for morbidity cost. In 1985, head injuries were estimated to account for 29% of the total injury cost and 25% of the injury death rate, while representing only 13% of the injury incidence rate.[18] These estimates fail to account for the extraordinary losses experienced by the families and friends of those who have died prematurely from traumatic brain injury. The physical and emotional toll from permanent and severe disability and the associated changes in lifestyle for injured survivors and their loved ones are profound, but impossible to quantify. These costs, too, must be considered as part of the public health impact of TBI.

This report uses the 1995 New Mexico fatal and hospitalized TBI incidence count to estimate the annual cost of this injury. Morbidity costs are estimated from expected lifetime earnings and medical expenditures (Appendix E). Mortality costs are estimated using a human capital approach developed by Dr. Dorothy Rice. A table was developed showing the estimated loss of lifetime earnings and housekeeping services based on gender and age. A conservative 6% discount rate is applied to both morbidity and mortality costs. New Mexico TBI incidence rates, both total and caused by motor vehicle crashes, were applied to the tables in Appendix E to produce very conservative estimates of cost (Exhibit 11). The average cost per TBI related death is $463,500. Because the majority, 978 (54%) of the fatal and hospitalized TBI cases, were in the most economically productive age group (15-44), they account for 78% of the total estimated costs.

## Exhibit 11: New Mexico TBI Morbidity and Mortality Cost Summary, 1995

| | TOTAL TBI | CRASH SPECIFIC TBI |
|---|---|---|
| MORBIDITY | $127,808,670 | $ 42,488,014 |
| MORTALITY | $161,762,445 | $99,106,693 |
| TOTAL | $289,571,115 | $141,594,707 |

### Discussion of Cost Estimates

This report presents the relatively conservative human capital, or monetary, approach for assessing mortality costs. Incorporated into the calculation is the assumption of an annual growth in productivity of 1% and a discount rate of 6%. The discount rate is a way to convert a future stream of dollars into the present value equivalent. The higher the discount rate, the lower the present value of a given stream of dollars (Rice, 1989). Economists have used discount rates of 2%, 4% and 6% to estimate morbidity and mortality costs. Significant variability exists depending on which discount rate is chosen. For example, Rice (1989) demonstrates that lifetime productivity losses for 30-34 year old males are 27 percent higher using a 4 percent, versus a 6 percent discount rate. In this report the authors have chosen to consistently use the most conservative, yet defensible, assumptions in estimating costs.

Willingness to pay is another alternative for estimating the economic impact associated with a death. From a theoretical point of view, willingness to pay can be viewed as the stronger of the two alternatives.[19] However, the practical aspects of collecting meaningful data about willingness to pay are more difficult. Reviews by Miller (1989)[20] and (1990)[21], Miller and Guria (1991)[22], and Miller, Viner, et al (1991)[23] found 52 studies which estimated the value of fatal risk reduction between $1 and $3.75 million, with a mean of $2.3 million per fatality (1989 dollars). That is $1.8 million or 5 times more than the $463,500 human capital approach used in this report. One way to convert the "human-capital"-based estimate to the "willingness to pay" estimate would be to multiply the $162 million human capital mortality figures by 5. This would produce a willingness to pay estimate of $810 million for the economic value of the 349 deaths from TBI in 1995. When this is added to the estimated $128 million from morbidity costs, the total annual cost to the state would come to $938 million.

## TBI and Motor Vehicle Crashes

The following analyses and discussions are focused on those cases of TBI which result from motor vehicle crashes as estimated by linkage. Exhibit 12 shows the number of records in police crash reports, the linked files and the TBIs in those police reported injury categories.

### Exhibit 12. New Mexico Crash Linked Data Analysis, 1995

| Police Reported Injury Category | Occupant Total | Number Linked | TBIs Linked | | % TBI of Linked | % TBI of Injury Category |
|---|---|---|---|---|---|---|
| | | | Total | Killed | | |
| Killed (K) | 485 | 465 | 179 | 179 | 38% | 37% |
| Incapacitating (A) | 5,649 | 1,047 | 326 | 7 | 31% | 6% |
| Visible Injuries (B) | 6,449 | 385 | 86 | 0 | 22% | 1% |
| Complaint of Injury (C) | 18,898 | 192 | 20 | 0 | 10% | 0.1% |
| Other, No Injuries (0) | 113,682 | 89 | 5 | 0 | 6% | 0.004% |
| Total | 145,163 | 2,178 | 616 | 186 | 28% | 0.4% |

The number of linkages is very high in the police reported killed category (96%), a fifth (19%) of the incapacitated occupants are linked, only a seventeenth (6%) of the visibly injured occupants are linked, and drops to a low of 1% in the "Complaint" category. This is an expected outcome since the linkage process was based on hospitalized and killed individuals. However, Exhibit 12 also shows a total of 89 occupants in the police reported category of "other, no injury." Five of those 89 cases were found to be TBI cases, raising questions as to the reliability of either police reporting, timing of medical treatment, or of the linkage process. This suggests that while there are discrepancies that deserve further investigation, Exhibit 12 provides evidence of the general utility of linkage and an association of TBI frequency with the more serious categories of police reported crashes.

Most (96%) of the 616 crash associated TBI cases were identified by the police as fatal or serious (K, A, & B) injuries. TBI is most frequently linked with K, but it is disproportionately frequent in linkage with A, B and C injuries. While TBIs account for 37% of those killed, 38% of those linked. In increasing disproportions, TBIs account for 6% of the incapacitated and 31% of those linked, only 1% of the visibly injured yet 22% of those linked, and 0.1% of the complaint of injury yet 10% of those linked. The odds of TBI in these linkages increases from 2.6 to 3.2, to 4.5, to 9.6, respectively.

Crash locations were obtained from 573 (93%) of 616 TBI-crash records (Exhibit 13). Although 313 (51%) of the TBI associated crashes were in urban areas as a likely result of population density, the remaining 303 (49%) rural are disproportionately fatal, as a likely result of the higher speeds and resulting higher crash energies and less access to emergency medical services. Overall 30% of crash related TBIs are fatal, but 35% of the TBIs on rural non-interstate and 50% on the rural interstate are fatal. The odds overall for non-fatal TBI to fatal TBI are 2.31. The same non-fatal TBI to fatal TBI odds for rural non-interstate, rural interstate, and urban road system are 1.90, 0.98 and 3.82, respectively. The odd ratio for rural interstate versus urban roads is 3.9 times higher for fatal TBI versus non-fatal TBI.

**Exhibit 13. New Mexico Road Systems and Crash Related TBI , 1995**

| Road System | TBI | | Total |
|---|---|---|---|
| | Non-Fatal | Fatal | |
| Rural, non-interstate | 131 (30%) | 69 (37%) | 200 (32%) |
| Rural, interstate | 51 (12%) | 52 (28%) | 103 (17%) |
| Urban | 248 (58%) | 65 (35%) | 313 (51%) |
| Total | 430 (100%) | 186 (100%) | 616 (100%) |

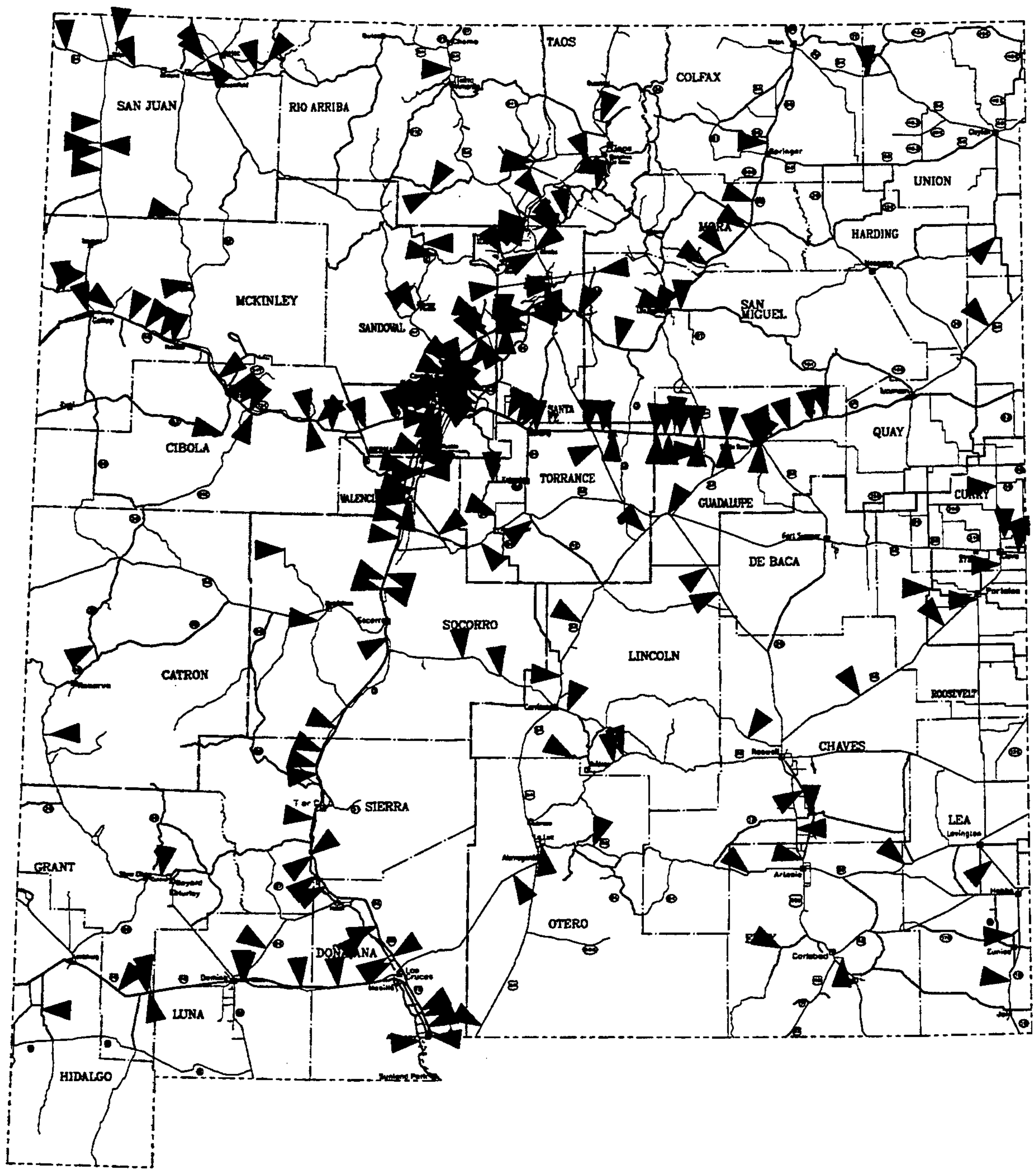
Exhibits 13, 14, and 15, show the road systems, location and vehicle types involved in crashes resulting from the 616 TBI cases linked to police crash reports.

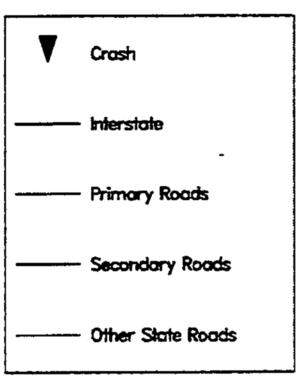
EXHIBIT 14



# Crashes Causing Traumatic Brain Injury, 1995

**New Mexico State Highway System**





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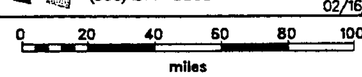


## Exhibit 15. New Mexico Crash Vehicle Type of 616 TBI Cases, 1995

| VEHICLE TYPE | NON-FATAL | | FATAL | | TOTAL | |
|---|---|---|---|---|---|---|
| Motor Vehicle Occupant | | | | | | |
| Front Seat | 270 | 63% | 109 | 59% | 379 | 62% |
| Rear Seat | 34 | 8% | 16 | 9% | 50 | 8% |
| Pedestrian | 34 | 8% | 27 | 14% | 61 | 10% |
| Bicycle | 19 | 4% | 2 | 1% | 21 | 3% |
| Motorcycle | 64 | 15% | 15 | 8% | 79 | 13% |
| Other | 9 | 2% | 17 | 9% | 26 | 4% |
| Total | 430 | 100% | 186 | 100% | 616 | 100% |

Exhibit 16 provides a detailed description of the 429 people injured as occupants in motor vehicle crashes. These individuals are generally male (63%) and in the age groups 15 to 24 (35.9%) and 25 to 44 (36.1%), for a total of 72%, see Exhibit 18. They were most often in collisions severe enough for the vehicle to be towed from the scene (89%), were seated in the front of the vehicle (88%), and only half (49%) were reported by the police as using a seatbelt. Following medical treatment in a hospital, most (49%) were discharged home. However, 131 (30%) died and an unknown number were transferred to acute care rehabilitation.

## Exhibit 16. New Mexico Crash Occupant Characteristics of 429 TBIs, 1995

| CHARACTERISTIC | | NON-FATAL | | FATAL | | TOTAL | |
|---|---|---|---|---|---|---|---|
| Vehicle Towed: | Yes | 261 | (86%) | 119 | (95%) | 380 | (89%) |
| | No | 43 | (14%) | 6 | ( 5%) | 49 | (13%) |
| Seat Position: | Front | 270 | (89%) | 109 | (87%) | 379 | (88%) |
| | Back | 34 | (11%) | 16 | (13%) | 50 | (12%) |
| Safety Belt: | Yes | 165 | (54%) | 45 | (36%) | 210 | (49%) |
| | No | 136 | (12%) | 80 | (64%) | 216 | (50%) |
| | Unk. | 3 | | 0 | | 3 | (1%) |
| Discharged: | Home | 215 | (50%) | | | 215 | (50%) |
| | Transferred | 83 | (19%) | | | 83 | (19%) |
| | AMA | 5 | ( 1%) | | | 5 | ( 1%) |
| | Expired | | | 125 | (30%) | 125 | (30%) |
| Crash Class: | Other Vehicle | 150 | (49%) | 40 | (32%) | 190 | (44%) |
| | Overturn | 94 | (31%) | 71 | (56%) | 165 | (38%) |
| | Fixed Object | 45 | (15%) | 7 | ( 6%) | 52 | (12%) |
| | Other | 15 | ( 5%) | 7 | ( 6%) | 22 | ( 5%) |
| Total | | 304 | (100%) | 125 | (100%) | 429 | (100%) |

## TBI-Crash Logits

General loglinear and specific logit models are used to identify and quantify relationships between TBI and occurrence of safety belts use, age of the crash occupant, gender, seating position in the vehicle, whether or not the vehicle was towed from the scene of the crash (a proxy measure for impact severity), and police reported occupant injury categories (KABCO scale). Modeling uses *SPSS®* computer software. A description of the analyses and modeling is found in Appendix D. Three simple models are found that enabled TBI to be analyzed with regard to the six factors noted above.

### Age, Gender, Safety Belts and TBI

Exhibit 18, next page, shows the observed TBI frequency counts for 32,315 drivers of passenger vehicles involved in injury producing crashes by five age categories, gender, and safety belt use in injury producing crashes. Loglinear modeling and analysis finds that dichotomous TBI is inversely associated with safety belt use, shown in Exhibit 17, independent of gender and age. The analysis of TBI in three categories, No-TBI, non-fatal TBI and fatal TBI, also finds TBI is independent of gender and age, and inversely associated with safety belt use, also in Exhibit 17.

From Exhibit 18, we can show the unadjusted odds ratio for No-TBI versus TBI when belted versus unbelted female drivers between the ages 16 to 24 years is 11.79 ((3,923/16)/(312/15)). For all females it is 12.69 ((13,542/51)/(816/39)). These odds ratios are the inverse of the effect of being belted on the odds of TBI, that is, the effect of being belted on the odds of TBI are 0.08, approximately one twelth. Analysis shows the various unadjusted odds ratio for No-TBI versus TBI when belted versus unbelted are statistically the same as the loglinear logit estimated 12.43, Exhibit 17 and 19, when adjusting for safety belt use differences by age and gender.

**Exhibit 17. New Mexico Adjusted TBI and Safety Belt Non-Use Odds Ratios and Their 95% Confidence Intervals, 1995**

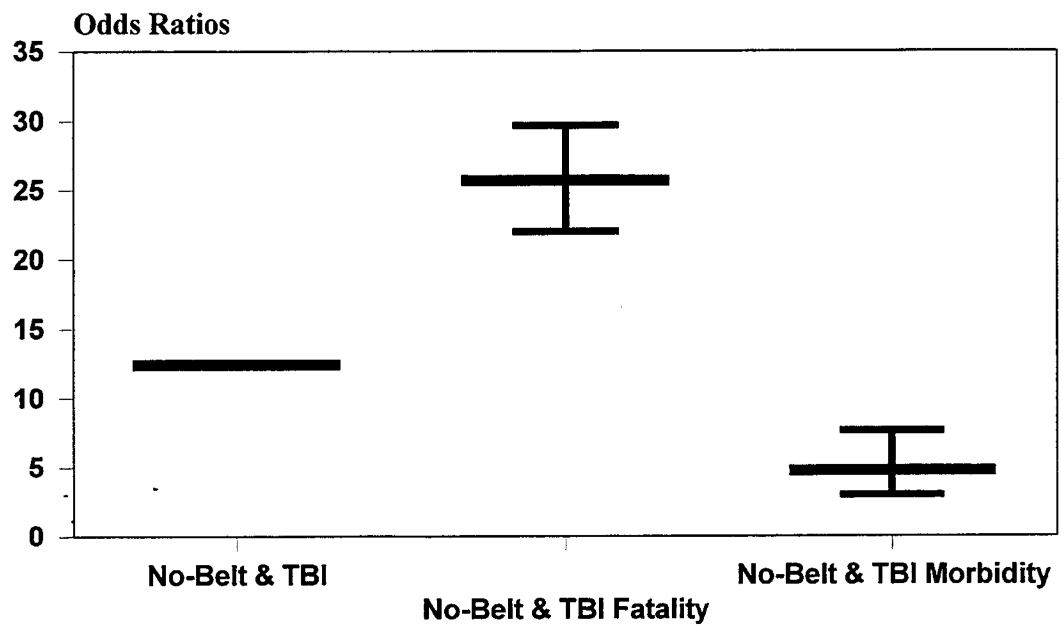


**Exhibit 18. New Mexico Driver Age, Gender, Safety Belt Use and TBI Status, 1995**

| Age | Gender | Safety belt | Observed Frequency | |
|---|---|---|---|---|
| | | | No TBI | TBI |
| 16 - 24 Years | Female | Not used/not reported | 312 | 15 |
| | | Safety Belt/Restraint | 3,923 | 16 |
| | Male | Not used/not reported | 724 | 33 |
| | | Safety Belt/Restraint | 4,538 | 18 |
| 25 - 44 Years | Female | Not used/not reported | 347 | 17 |
| | | Safety Belt/Restraint | 6,247 | 22 |
| | Male | Not used/not reported | 820 | 55 |
| | | Safety Belt/Restraint | 6,865 | 27 |
| 45 - 64 Years | Female | Not used/not reported | 116 | 2 |
| | | Safety Belt/Restraint | 2,465 | 10 |
| | Male | Not used/not reported | 276 | 9 |
| | | Safety Belt/Restraint | 2,965 | 14 |
| 65 - 74 Years | Female | Not used/not reported | 22 | 1 |
| | | Safety Belt/Restraint | 549 | 2 |
| | Male | Not used/not reported | 52 | 3 |
| | | Safety Belt/Restraint | 921 | 4 |
| 75 + Years | Female | Not used/not reported | 17 | 3 |
| | | Safety Belt/Restraint | 357 | 1 |
| | Male | Not used/not reported | 34 | 2 |
| | | Safety Belt/Restraint | 504 | 7 |
| Total | Female | Not used/not reported | 816 | 39 |
| | | Safety Belt/Restraint | 13,542 | 51 |
| | Male | Not used/not reported | 1,904 | 101 |
| | | Safety Belt/Restraint | 15,792 | 70 |

Exhibit 19 shows the adjusted, loglinear modeled, odds ratio for dichotomous TBI and non-use of safety belts is 12.4 (see Appendix D for more details). This is the estimated odds ratio of No-TBI to TBI when belted compared to not belted, the odds of No-TBI to TBI when safety belt is used, estimated at 242.26 to 1, divided by the odds of No-TBI to TBI when safety belt is not used, estimated at 19.49 to 1. The interpretation is that a person is 12.4 times more likely to sustain a TBI, adjusting for age and gender use rates, if they are not using a safety belt at the time of a crash, and they are one twelth as likely to sustain a TBI if they are using a safety belt.

**Exhibit 19. New Mexico Adjusted Dichotomous TBI and Safety Belt Non-Use Odds and Odds Ratio, 1995**

| TBI | Safety Belt | | Odds Ratio |
|---|---|---|---|
| | Used | Not Used | |
| Odds No-TBI | 242.26 | 19.49 | 12.43 |

Using the same data and considering TBI in three categories, No-TBI, non-fatal TBI and fatal TBI, the loglinear tools allow us to estimate the odds ratios between no-TBI and fatal TBI, non-fatal TBI and fatal TBI, and no-TBI and non-fatal TBI in regard to safety belt use and non-use, Exhibit 20. Drivers in passenger vehicle crashes are 26 times more likely to have no-TBI versus a fatal TBI if safety belts are used. Drivers are 2.7 times more likely to sustain a non-fatal TBI-injury than a fatal TBI when belted. Note the ratio of the two odds ratios is the same as the odds ratio that drivers are 9.6 times more likely to have a non-fatal TBI-injury than a fatal TBI if safety belts are used.

**Exhibit 20. New Mexico Adjusted Polychotomous TBI and Safety Belt Non-Use Odds and Odds Ratios, 1995**

| TBI | Safety Belt | | Odds Ratio |
|---|---|---|---|
| | Used | Not Used | |
| Odds No-TBI | 1,394.09 | 54.60 | 25.53 |
| Odds TBI-Injury | 4.76 | 1.79 | 2.66 |

### Safety Belts, Seat Position, Towaway, and TBI

TBI examined with regard to towaway status (a proxy measure of crash severity), seat position and safety belt use, Exhibit 21, finds both towaway and safety belt status are associated while seat position is not. In the loglinear logit models, see Appendix D, seat position had little or no relationship with TBI. This finding was not expected and may be the result of the fact that all of the included occupants were in injury producing crashes. It should also be noted (Exhibit 21) that only a small number of the TBIs were in the rear seat position 49 (11%), which increases the difficulty of establishing a statistical difference. In order to address seat position, constraints on age and seat position were lifted, allowing 57,205 crash occupants to be included in analysis with regard to polychotomous TBI outcome.

**Exhibit 21. New Mexico TBI by Safety Belt, Seat Position and Towaway Status, 1995**

| Safety Belt | Seat Position | Tow | Observed Frequency | | |
|---|---|---|---|---|---|
| | | | No TBI | TBI-Injury | TBI Fatality |
| Not used /not reported | Front | No | 3,607 | 14 | 5 |
| | | Yes | 2,861 | 116 | 72 |
| | Back | No | 684 | 4 | 0 |
| | | Yes | 691 | 15 | 13 |
| Safety Belt /Restraint | Front | No | 27,300 | 21 | 1 |
| | | Yes | 15,970 | 118 | 31 |
| | Back | No | 3,684 | 4 | 0 |
| | | Yes | 1,982 | 9 | 3 |
| Totals | | | 56,779 | 301 | 125 |

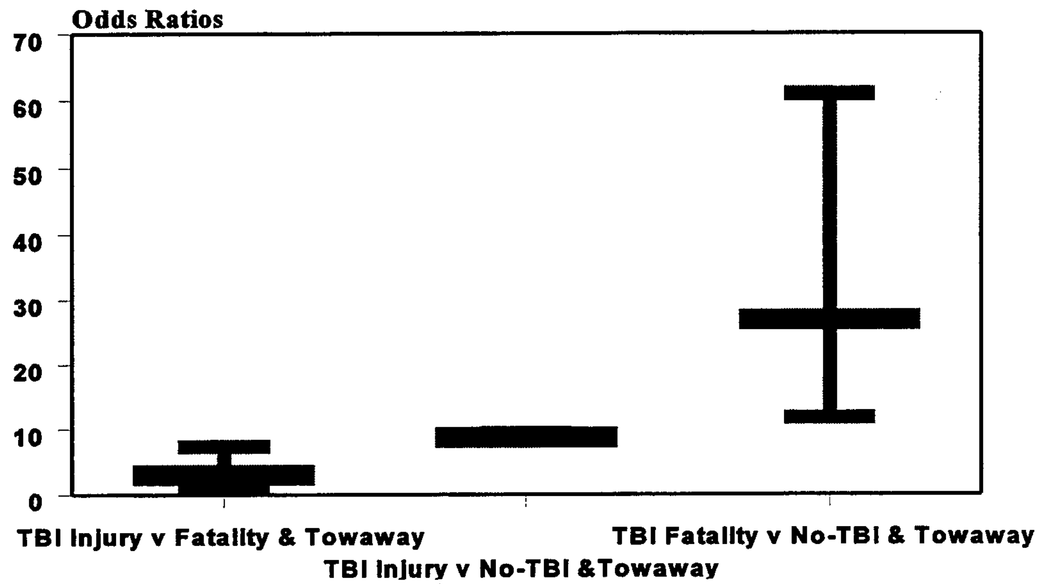
**Exhibit 22. New Mexico Adjusted Safety Belt, Towaway and TBI Odds and Odds Ratios, 1995**

| TBI | Safety Belt | | Odds Ratio |
|---|---|---|---|
| | Used | Not Used | |
| Odds No-TBI | 544.57 | 41.26 | 13.20 |
| Odds TBI-Injury | 3.86 | 1.52 | 2.54 |
| **TBI** | **Towaway** | | **Odds Ratio** |
| | Towed | Not Towed | |
| Odds No-TBI | 1.00 | 26.84 | 0.04 |
| Odds TBI-Injury | 1.00 | 3.06 | 0.33 |

The odds ratio of no-TBI versus TBI fatality in a crash when belted versus not belted is 13.2, adjusting for towaway crashes, Exhibit 22. The odds ratios of no-TBI to TBI injury and TBI injury to fatal TBI when belted versus unbelted are 5.2 (not shown) and 2.5, respectively.

The odds of No-TBI versus a fatal TBI in non-towaway crashes is 26.8 to one, Exhibit 22. The odds ratio of No-TBI injury versus a fatal TBI in towaway crashes versus non-towaway crashes is 0.04, that is, TBI mortality is 26.8 times as likely in towaway crashes. The odds ratio for TBI-injury compared to TBI fatality in towaway versus non-towaway crashes is 0.3, or roughly three times more fatal TBIs in towaways than in non-towaways in comparison to injuries. TBI-injury compared to No-TBI is 8.8 as likely in towaway crashes.

**Exhibit 23. New Mexico Adjusted TBI and Towaway Odds Ratios And Their 95% Confidence Intervals, 1995**




## Safety Belt, Towaway, KABCO, TBI

Analyses were conducted on the same 57,205 occupants in injury producing crashes to examine the relationships between the dichotomous occurrence of TBI, the police reported crash severity score of killed (K), incapacitating (A), visible (B), complaint (C), and no apparent injury (O), and safety belt use (Exhibits 24 through 26). TBI is found to be associated with Towaway status, as before, and it is involved in a more complex relationship with KABCO scores and Safety Belt use.

Analysis provides an estimate of 2 times as many TBI in towaway crashes, adjusting for safety belt use and KABCO. Exhibit 25 shows the odds of No-TBI versus TBI in towaway crashes is 3,197 to one and 6,310 to one in non-towaway, for an odds ratio of 0.51.

Safety belt use has significant and positive interaction with KABCO injury categories and TBI outcomes. The odds ratio for no-TBI versus TBI by belted versus not belted occupants of motor vehicles is largest in C, A, and B categories, 6.81, 3.54, and 3.23 respectively. Those killed are 1.04 times as likely to be TBI when not belted, illustrated in Exhibit 25.

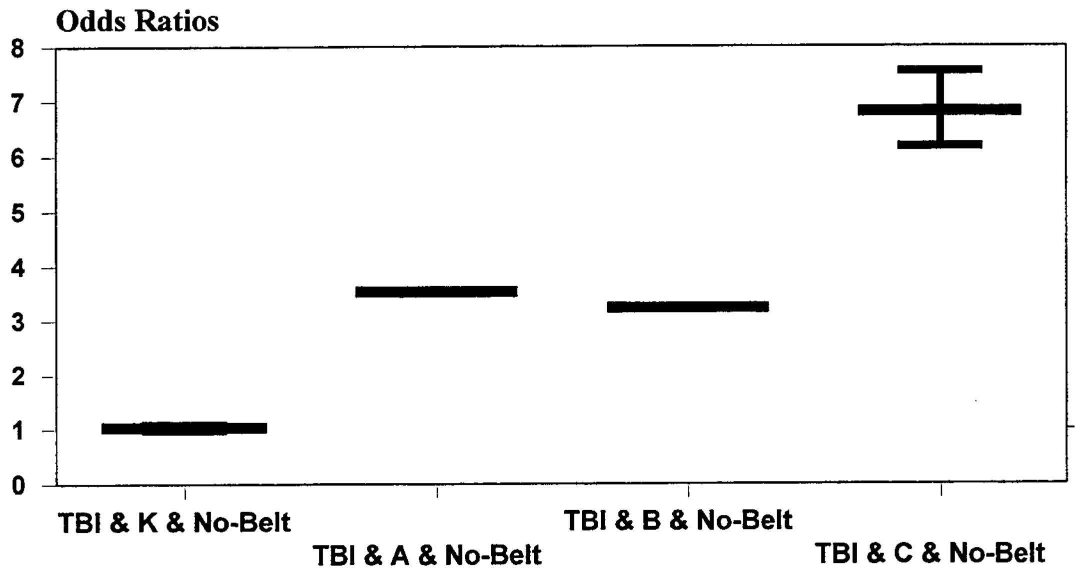
**Exhibit 24. New Mexico TBI By KABCO, Towaway and Safety Belt Status, 1995**

| Safety Belt | Towaway | KABCO | Observed Frequency | |
|---|---|---|---|---|
| | | | No - TBI | TBI |
| not Used | not Towed | K | 5 | 5 |
| | | A | 147 | 13 |
| | | B | 342 | 4 |
| | | C | 703 | 1 |
| | | O | 3,094 | 0 |
| | Towed | K | 139 | 80 |
| | | A | 838 | 104 |
| | | B | 883 | 26 |
| | | C | 707 | 6 |
| | | O | 985 | 0 |
| Belt Used | not Towed | K | 2 | 1 |
| | | A | 868 | 16 |
| | | B | 1,112 | 4 |
| | | C | 10,334 | 2 |
| | | O | 18,668 | 3 |
| | Towed | K | 59 | 34 |
| | | A | 2,506 | 91 |
| | | B | 2,737 | 25 |
| | | C | 6,160 | 9 |
| | | O | 6,490 | 2 |
| Total | | | 56,779 | 426 |

## Exhibit 25. New Mexico Adjusted TBI, Towaways, Safety Belts and KABCO Odds and Odds Ratios, 1995

| **TBI** | **Towaway** | | **Odds Ratio** |
|---|---|---|---|
| | Towed | Not Towed | |
| Odds No-TBI | 3,197.11 | 6,310.69 | 0.51 |
| **TBI and KABCO Injury** | **Safety Belt** | | |
| | Used | Not Used | |
| Odds No-TBI and Killed | 0.00054 | 0.00052 | 1.04 |
| Odds No-TBI and A | 0.00865 | 0.00243 | 3.56 |
| Odds No-TBI and B | 0.03579 | 0.01100 | 3.25 |
| Odds No-TBI and C | 0.32628 | 0.04783 | 6.81 |

## Exhibit 26. New Mexico Safety Belts and Odds Ratios and Their 95% Confidence Intervals, 1995




The odds for TBI and killed, 1.04, raises questions regarding the ascertainment. Investigation revealed a substantial number of ambiguous cases coded in OMI as multiple injuries. Forty (40) of 305 cases were linked with other records with ICD-9 codes indicating that TBI was a factor. The 265 remaining multiple injury deaths could be TBIs, resulting in an increase in the estimated incidence rates and a decrease in safety belt effectiveness.

## RECOMMENDATIONS

1. Specific motor vehicle crash characteristics and geographic locations can be associated with injury outcomes, such as traumatic brain injury. Police crash reports should be linked with trauma registry, hospital discharge or death files to determine types and severity of injury associated with police collected crash characteristics. Further linkages with EMS data would also greatly enhance locational data. This should be possible in New Mexico for 1996 or 1997 data from Albuquerque Ambulance and it is expected to be quickly approaching statewide coverage with 1999 data. In addition, Office of the Medical Investigator data should be linked with Department of Health's Vital Statistics death data for ICD-9 codes.

2. Data from this study show the risk of traumatic brain injury is increased by 12 times if safety belts are not used. Use of occupant restraint (safety belts) should continue to be promoted as a means of reducing traumatic brain injury. However, the odds ratios presented in this paper are based on the assumption that non-linked crash records did not result in a TBI. Given the inherent problems with data linkage, it is likely that some TBI cases have been missed and the odds ratios may state a slightly overly protective effect from safety belt use. Future studies with linked data should incorporate data validation for cases and non-cases.

3. The occurrence of TBI in the New Mexico population has a significant economic impact. This report estimates the mean cost per TBI related death at $463,000. Since most TBIs occur in the young population, society loses many potentially productive individuals in the prime of life. Interventions known to reduce the occurrence and severity of TBI include the use of safety belts and helmets when riding bicycles and motorcycles. Policy makers should have TBI cost figures available when considering implementing safety promotion laws and programs.

4. Police injury categorization approximates severity when TBI is used as an indicator of fatal or serious injury. The severity indicators should be statistically analyzed for comparability.

5. Data managers should strive to better document work related injuries. Only 51 (5%) of the trauma registry files have an indication of work-related injury, and there is scant indication in the hospital inpatient discharge data and no information Medicaid files. This information could be extremely helpful in directing prevention programs, and possibly cost recovery. Future data linkage efforts should consider the possible benefits associated with inclusion of Workers' Compensation data files.

6. Many debilitating traumatic brain injuries do not result in immediate hospitalization or death. However, they are medically evaluated in hospital emergency departments. Efforts should continue to capture information on patients treated in hospital emergency departments.

7. Multiple-year linked-data incidence measures should be compiled and analyzed, 1) to begin to identify the extent of calendar year effects such as incomplete and or unavailable records because of the beginning or ending of the year and seasonal patterns, and 2) to overcome table sparsity in seven-way and higher order categorical contingency tables.

8. Data managers of the Hospital Inpatient Discharge Data should consider requiring an E-code for those discharges with an injury diagnostic code and adding a field for the location E-code, E849.

9. Payor and charge data are problematic when it comes to defining categories and types of payors, amounts paid, amounts charged, premium amounts or other real costs. While the HIDD data managers are engaged in addressing these problems, it is recommended that wide recognition be given to identifying and implementing information regarding payor types such as private and public with futher categorizations for indemnity versus health plan.

10. Linkage and analyses of data can be quite complex. It would be desirable to have both functions conducted by the same individuals.

11. Investigate further the multiple injury causes of death in the OMI files which allows for resolution of ambiguity regarding TBI .

12. Loglinear analyses of categorical contingency tables should be used more often by researchers in order to address polychotomous outcomes, complex numbers of interaction effects and non-continuous data problems.

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UNM SCHOOL OF MEDICINE
ALBUQUERQUE, NM 87131-5091



CAUSE OF DEATH CODE LIST

Note: Jurisdiction terminated cases take an asterisk in front of the Cause Code, i.e. *N1.

NATURAL

| | |
|---|---|
| N1 | Heart disease (ASHD, cardiac, myocardial infarcts) |
| N2 | Presumably natural disease (no longer used) |
| N3 | Hypertension (hypertensive cardiovascular disease) |
| N4 | Cerebrovascular (CVA, stroke, anoxia, hypoxia, encephalopathy, brain death, coma, cerebral palsy, multiple sclerosis, Huntington's chorea) |
| N5 | Ethanolism (chronic, alcoholism, alocoholic liver) |
| N6 | Carcinoma (CA, cancer, malignancy) |
| N7 | Diabetes |
| N8 | Epilepsy (seizure disorder) |
| N9 | Sudden Infant Death Syndrome (SIDS, crib death) |
| N10 | Pneumonia (bronchitis) |
| N11 | Renal failure (kidney, nephritis, uremia) |
| N12 | Emboli (thromboli, phlebitus) |
| N13 | Congenital defect (Down, Marfan's, Arnold-Chiari, Turners, Ehlers Danlos, cystic fibrosis, muscular dystrophy) |
| N14 | Respiratory Distress Syndrome (RDS, IRDS, ideopathic pulmonary fibrosis, alveolar damage, insufficiency) |
| N15 | Aneurysm (cerebral hemorrhage, Berry) |
| N17 | Intrauterine fetal death (stillborn) |
| N18 | Gastrointestinal hemorrhage (gastroenteritis, ulcers, diverticulitis) |
| N19 | Pulmonary edema |
| N20 | Certification for record purposes only |
| N21 | Aspiration (stomach contents, blood, mucus) |
| N22 | Emphysema |
| N23 | Tuberculosis |
| N24 | Leukemia |
| N25 | Chronic obstructive pulmonary disease (COPD) |
| N26 | Prematurity |
| N27 | Parkinson's disease |
| N28 | Hodgkin's disease |
| N29 | Obesity |
| N30 | Hepatic failure (liver, cirrhosis) |
| N31 | Reye's Syndrome |
| N32 | Spontaneous hemorrhage |
| N33 | Sepsis |
| N34 | Meningitis (Waterhouse-Friderichsen Syndrome) |
| N35 | Plague |
| N36 | Acquired Immune Deficiency Syndrome (AIDS, HTLV-III, HIV, positive serology) |
| N37 | Alzheimers (senility, dementia, Organic/Chronic Brain Syndrome) |
| N38 | Asthma |
| N39 | Adverse reaction (allergy) |
| N40 | Dehydration (hyperthermia, heat stroke) |
| N41 | Malnutrition (cachexia, anorexia) |

Date run: 11/12/92

# CAUSE OF DEATH LIST

N42 Obstruction (blockage)
N44 Maternal and fetal complications of birth
N46 Arthritis (degenerative joint disease, Lupus)
N47 Pathologic injuries
N48 History of illness or injury
N49 Amyotrophic Lateral Sclerosis
N50 Pancreas
N51 Medical treatment
N99 Natural-specify____________________

UNNATURAL

C1 Gunshot wound of ____________________
C2 Stab wound (slash, penetrating cut)
C3 Multiple injuries (fractures, lacerations to internal organs)
C4 Head and neck injuries (cervical, cranio-, cerebral)
C5 Electrocution
C6 Exposure
C7 Drowning
C8 Asphyxia (suffocation, strangulation)
C9 Hanging
C10 Thermal injuries (burns)
C11 Narcotic abuse
C12 Carbon monoxide intoxication (smoke and soot inhalation)
C13 Insanguination
C14 Exsanguination
C15 Subdural hematoma
C16 Aspiration (stomach, gastric, foreign objects)
C17 Substance intoxication (drug, poison, alcohol, etc.)
C18 Child abuse
C19 Ethanol (alcohol) intoxication
C99 Unnatural-specify____________________

UNDETERMINED

U1 Skeletal/mummified remains
U2 Undetermined after autopsy and/or toxocology
U99 Undetermined-specify
____________________

OTHER

X1 Non-human remains, animal or extraterrestrial
X2 Skeletal remains (ancient)
X3 Insufficient remains for determination of death (hands, feet, placenta)

Date run: 11/12/92

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MANNER OF DEATH CODE LIST

ACCIDENT

| | |
|---|---|
| A1 | Driver of auto in collision with moving vehicle |
| A2 | Passenger in auto in collision with moving vehicle |
| A3 | Driver of auto in collision with fixed object |
| A4 | Passenger in auto in collision with fixed object |
| A5 | Driver of auto that left roadway (and overturned) |
| A6 | Passenger in auto that left roadway (and overturned) |
| A7 | Driver of motorcycle in collision with motor vehicle |
| A8 | Passenger on motorcycle in collision with motor vehicle |
| A9 | Driver of motorcycle in non-motor vehicle accident |
| A10 | Passenger on motorcycle in non-motor vehicle accident |
| A13 | Driver of truck in collision with moving vehicle |
| A14 | Passenger in truck in collision with moving vehicle |
| A15 | Driver of truck in collision with fixed object |
| A16 | Passenger in truck in collision with fixed object |
| A17 | Driver of truck that left roadway (and overturned) |
| A18 | Passenger in truck that left roadway (and overturned) |
| A19 | Pedestrian struck by motor vehicle |
| A21 | Pedestrian (non-motor vehicle) |
| A22 | Driver of motor vehicle struck by train |
| A23 | Passenger in motor vehicle struck by train |
| A24 | Pilot of aircraft (balloons, hang gliders) |
| A25 | Passenger in aircraft (balloons, hang gliders) |
| A26 | Exposed to elements (outdoors, indoors, hyperthermia, hypothermia |
| A27 | Ingested alcohol (ethanol) |
| A28 | Ingested or injected medication |
| A30 | Ingested or injected illict substance |
| A36 | Inhaled _______(Abusive) (Volatiles, hydrocarbons, toxic substances) |
| A37 | Inhaled __________ (Non-abusive) |
| A40 | Victim of ______ fire |
| A41 | Struck by flying or falling object(s) |
| A42 | Fall from same height |
| A43 | Fall from height |
| A44 | Contacted electrical current (high voltage/household) |
| A45 | Drowned while swimming |
| A46 | Non-swimming drowning |
| A47 | Accidental discharge of firearm |
| A51 | Foreign object in airway (aspirated ----) |
| A52 | Non-collision motor vehicle accident |
| A53 | Explosion of __________ |
| A54 | Crushed/suffocated by __________ |
| A55 | Cyclist struck by ______ (motor vehicle) |
| A56 | Cyclist in collision with _____ (non-motor vehicle) |
| A57 | Bitten/stung by _________ |
| A58 | Farm/Industrial machinery accident (wheeled) |
| A59 | Animal involved accident |
| A60 | Struck by lightning |
| A61 | Accidental hanging/strangulation |

Date run: 6/25/91

# MANNER OF DEATH LIST

A62 Scalded by ___________
A65 Driver of pickup in collison with moving vehicle
A66 Passenger of pickup in collision with moving vehicle
A67 Driver of pickup in collision with fixed object
A68 Passenger of pickup in collision with fixed object
A69 Driver of pickup that left roadway (and overturned)
A70 Passenger of pickup that left roadway (and overturned)
A71 Passenger who fell from moving vehicle
A72 Poisoned by __________
A73 Medical treatment
A74 Received blow/collided with
A75 Cut self
A77 Suffocated by_______________
A99 Accident-specify ________________

## SUICIDE

S1 Shot self with firearm
S5 Ingested or injected medication
S6 Ingented, injected or inhaled non-prescription medication (illicit, volatiles)
S7 Hanged self with ________________
S8 Inhaled (via _______)
S9 Slashed __________ with __________
S10 Driver of motor vehicle
S11 Drowned self in __________
S12 Stabbed self with __________
S13 Burned self with __________
S14 Jumped from __________
S15 Suffocated self with __________
S16 Suicide as pedestrian
S99 Suicide-specify __________

## HOMICIDE

H1 Shot by assailant(s) with firearm (specify type, if known)
H3 Beaten by assailant(s)
H5 Stabbed by assailant(s)
H7 Strangled by assailant(s)/Suff.
H9 Struck with auto by assailant(s)
H17 Assaulted with/by _______
H18 Neglect/Starvation
H99 Homicide-specify ________________

## UNDETERMINED

U1 Skeletal, mummified or decomposed remains
U2 Undetermined after autopsy and/or toxocology
U3 Narcotic abuse
U4 Ingested/injected medication
U5 Ingested/injected/inhaled illicit drug or volatile
U6 Poisoned
U7 Gunshot wound

Date run: 6/25/91

CODELST

## MANNER OF DEATH LIST

| | |
|---|---|
| U8 | Drowning |
| U9 | Explosion/Victim of fire |
| U10 | Blunt trauma/multiple injuries/subdural hematoma |
| U11 | Inhaled fumes/auto exhaust |
| U12 | Stillborn/live birth/fetus |
| U13 | Fall from height/same height |
| U14 | Pedestrian |
| U15 | Exposure |
| U16 | Stab/incised wounds |
| U17 | Asphyxia/airway obstruction/suffocation |
| U18 | Hanged/strangled |
| U19 | "Natural" ASCVD/COPD/Seizure disorder |
| U20 | Driver/passenger motor vehicle |
| U21 | Ingested alcohol |
| U99 | Undetermined-specify ________ |

OTHER

| | |
|---|---|
| X1 | Non-human remains, animal or extraterrestrial |
| X2 | Skeletal remains (ancient) |
| X3 | Insufficient remains for determination of death |

Date run: 6/25/91

# APPENDIX C

## 1995 CODES Data Sources, Definitions, Assumptions, and Limitations

**(1) New Mexico Traffic Crash Data:** Data provided in the 1995 crash data are captured on the Uniform Accident Reports which are completed by traffic officers throughout the state.

***Case Definition*:** These reports are completed only for crashes that occur on public roadways and which resulted in death, personal injury, or $500 or more in property damage according to the investigating officer's judgement. No account is kept of unreported crashes or crashes that occurred on private property. Traffic crash data are compiled and processed by the Transportation Statistics Bureau of the New Mexico State Highway and Transportation Department, and are analyzed by the Division of Government Research for the New Mexico Traffic Safety Bureau.

***Data Quality:*** Crashes occurring in pueblos or reservations may be under reported. Also, property damage crashes may be under reported for small towns and cities.

***Summary of Data*:** In 1995, there were a total of 52,377 crashes reported. Of these, 425 (0.8%) were fatal crashes [including 485 fatalities], 19,757 (37.7%) were injury crashes [including 30,996 injured persons], and 32,195 (61.5%) were property damage only.

**(2) New Mexico Systems Trauma Registry Data:** The New Mexico Systems Trauma Registry (STR) is maintained by the New Mexico Department of Health, Injury Prevention and Emergency Medical Services Bureau, Trauma Section. Uniform data in 1995 were collected in 17 hospitals throughout the state. Of these hospitals, seven were designated trauma centers, which are mandated to submit trauma data to the state. The remaining ten hospitals voluntarily submitted data and are considered to be STR participating hospitals. Of the seven designated trauma centers, one was a Level I Trauma Center, five were Level II Trauma Centers, and one was a Level III Trauma Center. The STR coverage represents 69% of the state's non-federal acute care hospital beds. All records are E-coded.

***Case Definition:*** Trauma patient criteria encompass recommended guidelines from both the American College of Surgeons (ACS) and the Centers for Disease Control and Prevention (CDC-P). A trauma case is defined as a patient admitted to the hospital or admitted for observation of 12 hours or greater and/or meets further triage criteria and/or multi-system injury, or a patient who sustained a head or spinal cord injury and is pronounced dead in the emergency department.

The STR excludes the following cases: patients who were discharged from the emergency department; patients who sustained minor single body region injury; geriatric pathologic hip fractures; simple closed fractures; burns not associated with other injury; near drowning victims, and poisonings.

***Data Quality:*** The STR has a built-in edit check mechanism that flags incorrect or incomplete data entry for particular data points. Mechanisms and nature of injury are defined and entered using International Classification of Diseases Version 9 (ICD-9) coding. Subjective/interpretative coding still occurs. A Policy Manual has been written and distributed to all users in an attempt to keep trauma data abstraction uniform and consistent statewide. Quarterly workshops concentrate on reviewing coding definitions and methodologies, creating reports, using the trauma registry for quality assurance management and general information sharing. Trauma Registry data are checked at the state level for completion and accuracy and feedback is given on a regular basis to users in an effort to continue refining and maintaining uniform data.

Prior to using STR data, the data were cleaned to identify and develop a subset of duplicate records. Three types of duplicate records were identified: transfer duplicates, repeat visit duplicates, and same-visit duplicates. Transfer duplicates are expected in the STR data since it contains more than one record for individuals who are transferred from one STR facility to another.

***Summary of Data:*** A total of 3,831 records were reported by the STR in 1995, containing 3,612 individual trauma cases. Of these, 1,077 (30%) were female and 2,535 (70%) were male. The overall mortality for individuals entered into the STR was 243 (7%). 1,790 (49.6%) were motor vehicle traffic related (E810-E819 (.0-.9), E958.5, E988.5).

**(3) New Mexico Hospital Inpatient Discharge Data:** All non-federal, licensed general and speciality hospitals throughout the state are required to report to the New Mexico Health Policy Commission a subset of 38 variables from the UB-92 form for every inpatient discharge. In 1995 there were 34 general acute care hospitals and 21 speciality hospitals required to report.

***Case Definition:*** Inpatient discharge occurs when a person who was admitted to a hospital leaves that hospital.

***Data Quality:*** All but one general hospital reported acceptable data to this database. Hospitals have opportunities to correct systems or data quality problems before their data are added to a permanent database.

***Summary of Data:*** In 1995, the general and speciality hospitals reported a total of 186,287 discharges of New Mexico residents. There were 20,630 "injury" discharges with 4,425 having a classification of "medical misadventures", "complications" or "adverse effects", leaving 16,205 (8.7%) discharges with a diagnoses of injury or poisoning (ICD-9 CM 800 through 959.99). Of the 16,205 there were 10,306 (63.6%) having an E-code; 1,793 (17.4%) had a E-code of motor vehicle traffic (E810-E819 (.0-.9)), E958.5, E988.5). The hospital discharge data (HIDD) includes three additional cases of injury from motor vehicle crashes than the STR because only 17 (50%) of hospitals are included in the System Trauma Registry for 1995.

**(4) New Mexico Office of the Medical Investigator (OMI):**

***Case Definition:*** The OMI investigates any death occurring in New Mexico that is sudden, violent, or untimely, or where a person is found dead and the cause of death is unknown. The jurisdiction of the OMI does not include deaths occurring on federal reservations/property (American Indian Reservations and military) or in veteran's administration hospitals, unless the OMI is asked to investigate these deaths by respective federal authorities.

***Data Quality:*** The OMI databases are an excellent source of information on injury fatalities. The OMI database has been consistent data from year to year. This is true because (1) nearly all deaths are confirmed by autopsy reports; (2) a single person from OMI is responsible for entering data regarding cause of death; and, (3) the contents of databases are audited and corrected every year.

These data contain a toxicology report on all deaths and are an excellent source on alcohol-related deaths. Unfortunately, the deaths do not contain ICD-9 codes for cause of death. OMI cause of death codes are found in Appendix A, and manner of death in Appendix B.

***Data Summary:*** In 1995, the OMI investigated 4,200 deaths in New Mexico. Of these, 1,498 (36%) were injury related and 525 (35%) of those were motor vehicle traffic related.

**(5) New Mexico Medicaid Data:** The 1995 Medicaid file initially contained 1,908,528 separate medical claims that were submitted to Medicaid during the 1995 calendar year.

***Case Definition:*** Claims related to the following services were included for analysis: Hospital (inpatient and outpatient); federally qualified health clinic visits; physician services; laboratory and radiographic evaluations; ambulatory surgical charges; and transportation. Only claims for which the first diagnosis was an: E-Code or a diagnostic code of ICD-9 800.00 through 960.99 or 980.00 were included in the analysis. Those with a payment of less than $17 were excluded.

***Data Quality:*** Individual patient service encounter claims were aggregated to provide one episode encounter related to the injury event.

***Data Summary:*** Based on the aggregation of encounter claims, there were a total of 77,065 aggregate records comprising 97,819 claims. Deterministic linkage of Medicaid claims with HIDD records located only 380 records for the CODES linked data file. Of these, 159 (48%) were crash related.

# APPENDIX D

# TBI LOGLINEAR AND LOGIT MODELS

## General Loglinear and Logit Models

Two steps are taken in estimating TBI and crash factor logits. The two step method uses general loglinear modeling first to identify significant interactions and parsimonious model selection and, second, the special class of loglinear logit models to estimate significant TBI crash factor logits.

In these general loglinear modeling the dependent measure is the categorical crash-outcome contingency table cell count. Cell counts are based on the anti-log of lambdas, $\lambda$, estimates via Raphson-Newton algorithms used in SPSS (1994),

*Equation 1. Expected frequency for Loglinear Model*

$$\text{Expected} \quad m_{ij}\ldots = e^{\mu + \Sigma\lambda_{ij\ldots}}$$

$$\ln(m_{ij}\ldots) = \mu + \lambda_i + \lambda_j + \lambda_{ij} + \ldots$$

*where*

$\mu$ *is the grand mean,*

$\lambda_i s$ *are main effects,*

$\lambda_{ij} s$ *are* $2^{nd}$*-order interaction effects.*

Model selection takes advantage of goodness of fit statistic likelihood-ratio chi-square because it may be partitioned by effects and, therefore, the relative contributions of effects may be evaluated in reducing saturated models to more parsimonious models. Saturated models are those that contain all possible effects; grand mean, main, two-way and higher order interactions, up to the K-th order effect (the same as the number of categorical variables included in the model). The most insignificant effects are removed one at a time until the fewest necessary remain which provide for overall model fitness. The goodness of fit statistic likelihood-ratio chi-square is

$$G^2 = 2\sum_i O_i \ln\left(\frac{O_i}{E_i}\right).$$

The special class of loglinear models that model one or more dependent categorical variables and a set of independent categorical variables are logit models. In these models it is the ratio of the counts of the dependent variable for each of the combinations of the independent variables that is being fit. The product is the log of the odds, hence the name logit;

$$\ln(m_{11}) = \mu + \lambda_{1\cdot} + \lambda_{\cdot 1} + \lambda_{11}$$

$$\ln(m_{21}) = \mu + \lambda_{2\cdot} + \lambda_{\cdot 1} + \lambda_{21}$$

$$\ln\left(\frac{m_{11}}{m_{21}}\right) = \ln(m_{11}) - \ln(m_{21}) = LOGIT$$

SPSS sets baseline estimates to 0 (the anti-log is 1) in both the general and the special loglinear logit models and are presented in that manner in the results. In polychotomous variable contingency tables, SPSS sets the reference cell to the last category for that variable. The result is that comparisons are easily made using the logit estimates, either by interpreting the anti-log directly when comparing the first category to the last, or by interpreting the anti-log of the difference between estimates.

**New Mexico TBI Loglinear Analysis and Logits**

Initial efforts intending to evaluate TBI and crash factors targeted the following dichotomous and polychotomous categorical variables:

- gender (Female and Male),
- age (grouped in the manner that life-time morbidity costs are presented, ages 0-4, 5-14, 15-24, 25-44, 45-64, 65-74, and 75+),
- safety belt use (no use and belt use),
- towaway (crash energy proxy), vehicle damage equal to disabling, indicating the occupant's vehicle had to be towed away from the crash scene,
- seat position (a categorical measure intending to partition front seat and back seat motor vehicle occupants as well as motorcyclists, bicyclists, pedestrians, or other),
- KABCO police reported injury categories (K-Killed, A-incapacitating injuries, B-Visible Injuries, C-Complaint of Injuries, and O-Other, no injury), and
- TBI, clinically determined outcome by physician diagnoses.

Shown in Exhibit 1 are the significant relationships indicated by the results of a general loglinear model reduced from the saturated seven-way contingency model representing all occupants in fatal and injury crashes in 1995. The table also indicates those relationships most relevant to TBI with check marks in the right-most column.

While it was and is still desirable that modeling further include categorical elements for crash classification (such as rollovers, head-on, and angle collisions), other injuries (such as upper and lower limb fractures), alcohol involvement, and vehicle speed, analysis efforts for modeling those initial seven variables identified above are plagued by sampling and structural zeros, making specific loglinear logit parameters unestimatable. In particular, age, gender/sex, and seat position contingency tables contain structural zeros (0). However, the general loglinear model reductions of initial seven-way polychotomous contingency table does show promise of relatively simple three- and two-way dependencies involving TBI. Therefore, methodologically we simplified analysis modeling by targeting less complicated models, but less plagued with zeros, rather than expand to more complex sets of variables.

**Exhibit 1. Significant Interaction Effects in 7-way Contingency Table, New Mexico, 1995**

| Age, Gender, KABCO, Position, Towaway, Safety Belt and TBI | |
|---|---|
| Age, Gender and KABCO | |
| Age, Gender and Safety Belt | |
| Age, Gender and Position | |
| Age, Gender and Towaway | |
| Age, KABCO and Safety Belt | |
| Age, KABCO and TBI | ✔ |
| Age, KABCO and Towaway | |
| Age, Safety Belt and Position | |
| Age, Safety Belt and Towaway | |
| Age, Position and Towaway | |
| Gender, KABCO and Safety Belt | |
| Gender, KABCO and TBI | ✔ |
| Gender, Safety Belt and Towaway | |
| KABCO, Safety Belt and TBI | ✔ |
| KABCO, Safety Belt and Towaway | |
| KABCO, Position and Towaway | |
| Safety Belt, Position and Towaway | |
| TBI and Position | ✔ |
| TBI and Towaway | ✔ |

Three less-inclusive-of-all-variables models are identified from those including TBI effects found in the general loglinear reduced seven-way contingency table model and analyzed. The less-inclusive models are considered "mid-range" models. Analysis of the three "mid-range" loglinear models, in the two step methodology, test the initial variables for interaction with and then effect on TBI outcome.

The first "mid-range" models examine TBI, demographics and safety belt use. Two closely related models are presented; the first presents TBI as a dichotomous outcome, the second provides TBI outcome in terms of morbidity and mortality polychotomous categories. Then, the following presentations provide information from general and loglinear logit analyses of TBI with regard to seat position, towaway status, and TBI outcome. Finally, TBI is modeled in relation to towaway status, KABCO injury categories and safety belt use.

### Age, Gender, Safety Belt and TBI

In examining the basics for age, gender, safety belt use and TBI contingencies, we again encounter the problem of structural zeros which requires some additional constraints. We further constrain variables to pertain to just passenger vehicle types (cars, pickup trucks, vans and four wheel vehicles, excluding pedestrians, bicyclists, motorcyclists and others) and drivers (ages 16 or older). There are 32,315 drivers included, with a few sparse cells remaining, see Exhibit 5.

General loglinear techniques used to reduce the saturated model to the simplest set of effects explaining the observed cell frequencies indicate that only K-th order two effects are necessary. Abstracted below are the tests that saturated K-way and lower order effects are zero (Exhibit 2). This means that the moderately complicated contingency table posed by the Age, Gender, Safety Belt, and TBI, Exhibit 5, may be modeled adequately with at most six two-way effects, Exhibit 2.

**Exhibit 2. Tests that Saturated K-way and Lower Order Effects are Zero, NM, 1995**

| K-way Tests for Age, Gender, Safety Belt, and TBI | | | |
|---|---|---|---|
| **K -th Order** | **DF** | **L.R. Chisq** | **Prob** |
| 4 | 4 | 4.719 | .3174 |
| 3 | 17 | 17.622 | .4131 |
| 2 | 32 | 870.073 | .0000 |
| 1 | 39 | 89,898.133 | .0000 |

Backward elimination of all six two-way effects finds four significant and sufficient two-way interaction effects, Exhibit 3. Only one relationship involves TBI, Safety Belt and TBI. When the Safety Belt and TBI effect is examined as a loglinear logit, the parameter estimates are non-zero and significant, Exhibit 4. The fit of the model is adequate, goodness-of-fit statistic likelihood ratio Chi-square = 26.5260, DF = 22, p = .2298, indicating there are no unexplained dependencies. There is some error, but it is small and random, as shown in the difference between the expected cell counts estimated by the loglinear logit model and the observed shown parenthetically in Exhibit 5.

**Exhibit 3. Significant Interaction Effects in 4-way Contingency Table, NM, 1995**

| **Age, Gender, Safety Belt and TBI** | |
|---|---|
| Age and Gender | |
| Gender and Safety Belt | |
| Age and Safety Belt | |
| Safety Belt and TBI | ✔ |

The presence of Age and Gender, Gender and Safety Belt, and Age and Safety Belt effects indicates there are disproportions between genders at various age groupings, and, that safety belt use and non-use are related to gender and age. More fundamental is the indication that TBI is dependent on safety belt use and non-use, independent of gender and age.

**Exhibit 4. Safety Belt and Dichotomous TBI Logits, Odds and Odds Ratios NM, 1995**

| **TBI** | **Safety Belt** | | | | **Odds Ratio** | |
|---|---|---|---|---|---|---|
| | Used | | Not Used | | | |
| Odds No-TBI | ($e^{5.49}$ =) 242.26 | | ($e^{2.97}$=) 19.49 | | 12.43 | |
| **Logits** | | | | | Asymptotic 95% CI | |
| Parameter | Estimate | SE | Z-value | | Lower | Upper |
| $\lambda_{Belt_0} \times_{TBI_0}$ = | 2.97 | .0867 | 34.23 | | 2.80 | 3.14 |
| $\lambda_{Belt_1} \times_{TBI_0}$ = | 5.49 | .091 | 60.27 | | 5.31 | 5.67 |

The logit estimates, the lambdas above, provide anti-logs equivalent to the odds shown and odds ratio derivable from the Exhibit 5, while adjusting for age and gender, gender and safety belt, and age and safety belt effects. The shown odds are calculated by dividing the expected number of non-TBI by the number of expected TBI cases in the row. Note the nearness and repeating occurrences in Exhibit 5 of these odds. We see essentially the same relationship regardless of gender and age throughout the table. This is more directly measured with the lambdas. The natural anti-log of 2.97 is 19.49, and 5.49 is 242.26, Exhibit 4, reference cells are not shown. In Exhibit 5, when the first two odds are ratioed, we see an odds ratio of TBI given not belted as 12.48 times as great as when belted for female drivers ages 16 through 24 years. Again, from the model, Exhibit 4, it is the anti-log of the difference of 5.49-2.97, 2.52, that provides an odds ratio of 12.43, adjusting for age, gender and safety belt use contingencies.

**Exhibit 5. Age, Gender, Safety Belts, Expected and Observed TBI Frequencies, NM, 1995**

| Age | Gender | Safety belt | TBI Expected (Observed) Frequency | | Odds |
|---|---|---|---|---|---|
| | | | No TBI | TBI | |
| 16 - 24 years | Female | Not used/not reported | 306.93 (312) | 15.80 (15) | 19.42 |
| | | Safety Belt/Restraint | 3,927.07 (3,923) | 16.20 (16) | 242.41 |
| | Male | Not used/not reported | 724.01 (724) | 37.27 (33) | 19.42 |
| | | Safety Belt/Restraint | 4,533.03 (4,538) | 18.70 (18) | 242.41 |
| 25 - 44 years | Female | Not used/not reported | 361.70 (347) | 18.62 (17) | 19.43 |
| | | Safety Belt/Restraint | 6,227.00 (6,247) | 25.69 (22) | 242.39 |
| | Male | Not used/not reported | 816.65 (820) | 42.03 (55) | 19.43 |
| | | Safety Belt/Restraint | 6,879.94 (6,865) | 28.38 (27) | 242.42 |
| 45 - 64 years | Female | Not used/not reported | 110.87 (116) | 5.71 (2) | 19.41 |
| | | Safety Belt/Restraint | 2,466.25 (2,465) | 10.17 (10) | 242.50 |
| | Male | Not used/not reported | 272.41 (276) | 14.02 (9) | 19.43 |
| | | Safety Belt/Restraint | 2,965.34 (2,965) | 12.23 (14) | 242.46 |
| 65 - 74 years | Female | Not used/not reported | 16.94 (22) | .87 (1) | 19.47 |
| | | Safety Belt/Restraint | 553.91 (549) | 2.28 (2) | 242.94 |
| | Male | Not used/not reported | 57.24 (52) | 2.95 (3) | 19.40 |
| | | Safety Belt/Restraint | 916.03 (921) | 3.78 (4) | 242.34 |
| 75 + years | Female | Not used/not reported | 13.86 (17) | .71 (3) | 19.52 |
| | | Safety Belt/Restraint | 361.93 (357) | 1.49 (1) | 242.91 |
| | Male | Not used/not reported | 39.40 (34) | 2.03 (2) | 19.41 |
| | | Safety Belt/Restraint | 503.50 (504) | 2.08 (7) | 242.91 |

The small differences found in Exhibit 5 are due to the small contributions of age, gender, and safety belt interactions. We turn to address the age, gender, and safety belt results with regard to the model, after introducing the TBI as a polychotomous variable.

In the same manner as above, we fit a general loglinear model of TBI having three categories; No-TBI, Non-Fatal TBI Injury/Morbidity, and fatal TBI/Mortality. The reduction from the saturated model also result in an adequate fit (likelihood ratio chi- square = 47.8371, DF = 40, P = .1845) with the same four two-way terms, see Exhibit 3, identified in the first analysis.

The lambda parameter estimates shown below, Exhibit 6 (reference cells are not shown) are obtained with a multinomial loglinear logit. The odds of No-TBI versus fatal TBI when belted are estimated to be 1,394.09 times. The odds of TBI injury morbidity versus mortality when belted are estimated to be 4.76 times. The odds are much less differentiated when safety belts are not used, the odds of No-TBI versus fatal TBI are 54.6 and TBI injury morbidity versus mortality are 1.79 when not belted. The logit estimates provide an odds ratio of 25.53 for No-TBI compared to fatal TBI (reference cells not shown) given safety belt use versus no safety belt use. This is calculated by subtracting 4.00 minus 0.0 from 7.24 minus 0, and taking the natural anti-log of 3.24. Diagnostics show the confidence interval for 3.25 is bounded by the lower and higher bounds of 3.09 to 3.39, (6.81-3.72) and (7.67-4.28). The odds ratio for TBI-injury compared to fatal TBI given safety belt use versus no safety belt use is 2.66. The odds ratio for No-TBI compared to TBI-injury is 9.60 (25.53/2.66).

**Exhibit 6. Safety Belt and Polychotomous TBI Logits, Odds and Odds Ratios, NM, 1995**

| **TBI** | **Safety Belt** | | **Odds Ratio** |
|---|---|---|---|
| | Used | Not Used | |
| Odds No-TBI | ($e^{7.24}$ =) 1,394.09 | ($e^{4.00}$=) 54.60 | 25.53 |
| Odds TBI-Injury | ($e^{1.56}$ =) 4.76 | ($e^{0.58}$=) 1.79 | 2.66 |

| **Logits** | | | | Asymptotic 95% CI | |
|---|---|---|---|---|---|
| Parameter | Estimate | SE | Z-value | Lower | Upper |
| $\lambda_{Belt_0 \times TBI_0}$ = | 4.00 | .1427 | 28.00 | 3.72 | 4.28 |
| $\lambda_{Belt_0 \times TBI_1}$ = | .58 | .1764 | 3.33 | .24 | .93 |
| $\lambda_{Belt_0 \times TBI_2}$ = | .00 | . | . | . | . |
| $\lambda_{Belt_1 \times TBI_0}$ = | 7.24 | .2183 | 33.18 | 6.81 | 7.67 |
| $\lambda_{Belt_1 \times TBI_1}$ = | 1.56 | .2400 | 6.50 | 1.09 | 2.03 |
| $\lambda_{Belt_1 \times TBI_2}$ = | 0.00 | . | . | . | . |

The logit estimates for safety belt benefits in preventing TBI are significant, but not the only effects existing, as indicated in the opening discussion of the general loglinear model. There are non-zero interactions also working among the relationships of gender and safety belt use, age and safety belt use, and age and gender that help account for the crash occupant characteristics and TBI. Though not as large as the specific safety belt and TBI effects, each of the other effects contribute to the general loglinear model's ability to adequately estimate cell frequencies. Here we present the general loglinear interaction effects generated using the polychotomous TBI variable for, gender and safety belt, age and safety belt, and age and gender.

Gender has a modest but believable role in safety belt use, females are twice as likely to be belted as males. The natural anti-log is 0.49, that is, females are half as likely as males (not shown) to be unbelted versus belted. The loglinear estimate for the odds of females not being belted is shown below in Exhibit 7, as found in the general loglinear model.

**Exhibit 7. Safety Belt and Gender Logits, Odds and Odds Ratios, NM, 1995**

| **Gender** | **Safety Belt** | | **Odds Ratio** |
|---|---|---|---|
| | Used | Not Used | |
| Odds Female | ($e^{0.00}$ =) 1.00 | ($e^{-0.71}$=) 0.49 | 2.04 |

| **Logits** Parameter | Estimate | SE | Z-value | Asymptotic 95% CI Lower | Upper |
|---|---|---|---|---|---|
| $\lambda_{Gender_{Female} \times Belt_0}$ = | -0.71 | .0426 | -16.76 | -.80 | -.63 |

**Exhibit 8. Safety Belt and Age Group Logits, Odds and Odds Ratios, NM, 1995**

| **Age Group** | **Safety Belt** | | **Odds Ratio** |
|---|---|---|---|
| | Used | Not Used | |
| Odds Ages 16-24 | ($e^{0.00}$ =) 1.00 | ($e^{0.71}$ =) 2.03 | 0.49 |
| Odds Ages 25-44 | ($e^{0.00}$ =) 1.00 | ($e^{-0.42}$=) 1.52 | 0.66 |

| **Logits** Parameter | Estimate | SE | Z-value | Asymptotic 95% CI Lower | Upper |
|---|---|---|---|---|---|
| $\lambda_{Age_{1624} \times Belt_0}$ = | 0.71 | .1420 | 5.02 | .44 | .99 |
| $\lambda_{Age_{2544} \times Belt_0}$ = | 0.42 | .1414 | 2.95 | .14 | .69 |
| $\lambda_{Age_{4564} \times Belt_0}$ = | 0.16 | .1476 | 1.09 | -.13 | .45 |
| $\lambda_{Age_{6574} \times Belt_0}$ = | -0.23 | .1808 | -1.24 | -.58 | .13 |
| $\lambda_{Age_{+75} \times Belt_0}$ = | 0.00 | . | . | . | . |

In the same way, drivers ages 16 to 24 years are found twice as likely to be unbelted as drivers ages 75 years or older (0.71 exponentiated), drivers ages 25 to 44 years are 1.52 times as likely to be unbelted as drivers ages 75 years or older and 0.32 time as likely to be unbelted as drivers ages 15 to 24 years (the exponential of .42 - .71, Exhibit 8). Because the parameters for non-safety belt use for the age groups 45 to 64 and 65 to 74 cannot be differentiated from zero, underlined in Exhibit 8, because their confidence intervals bracket zero, we cannot conclude safety belt use for those groups is any different from overall safety belt use.

There are also disproportions by gender in the age groups of drivers. There tend to be fewer female drivers than male, as indicated by the gender main effect (not shown), about .7 times the number of males. However, there are about 1.2 and 1.3 times more female drivers in the two youngest age groups of drivers.

The following are the two addition "mid-range" general loglinear analyses and related loglinear TBI logits. The models address four-way contingencies involving TBI, safety belt use, seat position, towaway (functional damage to a crashed vehicle), and police reported injuries (KABCO). The first investigates Safety Belt, Towaway, Seat Position, and polychotomous TBI morbidity and mortality contingencies and the second investigates Safety Belt, Towaway, KABCO and dichotomous TBI, a model using police reported injury categories instead of seat position. Constraints are loosened to include front seat and back seat occupants rather than just drivers. In addition, age constraints are lifted. This provides 57,205 motor vehicle occupants, still excluding motorcyclists, bicyclists and pedestrians.

**Safety Belt, Towaway, Seat Position and TBI**

Modeling Safety Belt, Towaway, Seat Position, TBI injury and mortality contingencies finds the four-way contingency reduces to three two-way interactions and one three-way term (likelihood ratio chi square = 10.2892, DF = 9, P = .3276). Those interaction terms are listed in Exhibit 9.

**Exhibit 9. Significant Interaction Effects in 4-way Contingency Table, NM, 1995**

| Safety Belt, Towaway, Seat Position and TBI | |
|---|---|
| Safety Belt, Towaway and Seat Position | |
| TBI and Safety Belt | ✔ |
| TBI and Towaway | ✔ |
| TBI and Seat Position | |

Two loglinear logit models are fit using TBI as the dependent, the second drops the TBI and Seat Position interaction term because the parameter estimates are not differentiable from zero. The resulting second model is adequate (Likelihood Ratio = 13.1059, DF = 10, p = .2178) and provides the estimated cell frequencies in Exhibit 10 and the parameter estimates in Exhibit 11. Note the nearness of the cell frequency estimates and the observed counts of TBI contingent on occupant's vehicle Towaway status and Safety Belt use. Observers will also note the consistency of the odds for both front and back seat positions regarding the likelihood of TBI given the contingencies of safety belt use and towaway status in Exhibit 10, below. This reflects the independence of seat position on TBI outcome.

**Exhibit 10. Safety Belt, Seat Position, Towaway and TBI Frequencies, NM, 1995**

| Safety Belt | Seat Position | Tow | TBI Expected /Observed Frequency | | | Odds | | |
|---|---|---|---|---|---|---|---|---|
| | | | No TBI | TBI-Injury | TBI Fatality | No/Injury | No/Fatal | Injury/Fatal |
| Not used /not reported | Front | No | 3,607.58 | 15.16 | 3.26 | 237.97 | 1,106.62 | 4.65 |
| | | | 3,607 | 14 | 5 | | | |
| | | Yes | 2,873.34 | 105.98 | 69.68 | 27.11 | 41.24 | 1.51 |
| | | | 2,861 | 116 | 72 | | | |
| | Back | No | 684.51 | 2.88 | .62 | 237.68 | 1,104.53 | 4.65 |
| | | | 684 | 4 | 0 | | | |
| | | Yes | 677.58 | 24.99 | 16.43 | 27.11 | 41.24 | 1.52 |
| | | | 691 | 15 | 13 | | | |
| Safety Belt /Restraint | Front | No | 27,298.14 | 22.00 | 1.87 | 1,240.82 | 14,597.94 | 11.76 |
| | | | 27,300 | 21 | 1 | | | |
| | | Yes | 15,976.69 | 113.05 | 29.26 | 141.32 | 546.02 | 3.86 |
| | | | 15,970 | 118 | 31 | | | |
| | Back | No | 3,684.78 | 2.97 | .25 | 1,240.67 | 14,739.12 | 11.83 |
| | | | 3,684 | 4 | 0 | | | |
| | | Yes | 1,976.40 | 13.98 | 3.62 | 141.37 | 545.97 | 3.86 |
| | | | 1,982 | 9 | 3 | | | |

Interpreting the loglinear logit parameters in Exhibit 11 illustrates how they determine all of the odds and odds ratios. For example, in the first row of odds in Exhibit 10, the logit of no-TBI to TBI injury when not belted and in non-towaway crashes is ((3.72-0.42) + (3.29- 1.12)=) 5.47, for an odds of 238.46. Similarly, the odds for no-TBI to fatal TBI when not belted and in non-towaway crashes are 1,105.44 ((3.7193-0.0) + (3.2887-0) = 7.0080). And for the last odds in the first row, the logit for TBI injury versus fatal TBI when not belted and in non-towaway crashes is ((0.42-0.0) + ( 1.12-0.0) =) 1.54, for an odds of 4.66.

**Exhibit 11. Safety Belts, Towaways and TBI Logits, Odds and Odds Ratios, NM, 1995**

| **TBI** | **Safety Belt** | | | | **Odds Ratio** |
|---|---|---|---|---|---|
| | Used | | Not Used | | |
| Odds No-TBI | ($e^{6.30}$ =) | 544.57 | ($e^{3.72}$ =) | 41.26 | 13.20 |
| Odds TBI-Injury | ($e^{1.35}$ =) | 3.86 | ($e^{-0.42}$=) | 1.52 | 2.54 |

| **TBI** | **Towaway** | | | | **Odds Ratio** |
|---|---|---|---|---|---|
| | Towed | | Not Towed | | |
| Odds No-TBI | ($e^{0.00}$ =) | 1.00 | ($e^{3.29}$ =) | 26.84 | 0.04 |
| Odds TBI-Injury | ($e^{0.00}$ =) | 1.00 | ($e^{1.12}$ =) | 3.06 | 0.33 |

**Logits**

| Parameter | | Estimate | SE | Z-value | Asymptotic 95% CI Lower | Upper |
|---|---|---|---|---|---|---|
| $\lambda_{TBI_0} \times _{SafetyBelt_0}$ | = | 3.72 | .1082 | 34.37 | 3.51 | 3.93 |
| $\lambda_{TBI_0} \times _{SafetyBelt_1}$ | = | 6.30 | .1711 | 36.84 | 5.97 | 6.64 |
| $\lambda_{TBI_1} \times _{SafetyBelt_0}$ | = | 0.42 | .1362 | 3.08 | 0.15 | 0.69 |
| $\lambda_{TBI_1} \times _{SafetyBelt_1}$ | = | 1.35 | .1911 | 7.07 | 0.98 | 1.73 |
| $\lambda_{TBI_2} \times _{SafetyBelt_0}$ | = | 0.00 | . | . | . | . |
| $\lambda_{TBI_2} \times _{SafetyBelt_1}$ | = | 0.00 | . | . | . | . |
| $\lambda_{TBI_0} \times _{Towaway_0}$ | = | 3.29 | .4189 | 7.85 | 2.47 | 4.11 |
| $\lambda_{TBI_0} \times _{Towaway_1}$ | = | 0.00 | . | . | . | . |
| $\lambda_{TBI_1} \times _{Towaway_0}$ | = | 1.12 | .4500 | 2.48 | 0.23 | 2.00 |
| $\lambda_{TBI_1} \times _{Towaway_1}$ | = | 0.00 | . | . | . | . |
| $\lambda_{TBI_2} \times _{Towaway_0}$ | = | 0.00 | . | . | . | . |
| $\lambda_{TBI_2} \times _{Towaway_1}$ | = | 0.00 | . | . | . | . |

The odds ratio of no-TBI versus TBI fatality in a crash when belted versus not belted are 13.20, adjusting for towaway crashes. The logits are found by taking the difference in estimates for no-

TBI versus fatal TBI when belted and no-TBI versus fatal TBI when not-belted ((6.30-0) -(3.72-0)). The odds ratio of no-TBI to TBI injury and TBI injury to fatal TBI when belted versus unbelted are 5.20 (not shown) and 2.54, respectively.

The odds ratio of non-fatal TBI injury likelihood in towaway crashes versus No-TBI injury in non-towaway crashes is the natural anti-log of the logit of 2.17(=(0-1.12)-(0-3.29)), or 8.76 times as likely. Essentially the same ratio is found in Exhibit 10 by comparing any of the odds for No-TBI compared to TBI injury for non-towaway and towaway crashes, within the same categories of seat position and safety belt use; 237.97/27.11 = 8.78 for front seat unbelted or 1,240.82/141.32 = 8.78 for backseat belted odds for TBI injury in towaway crashes. TBI mortality is 26.84 times as likely in towaway crashes. The odds ratio for TBI-injury compared to TBI death given towaway versus non-towaway use is 0.33, or roughly three times more fatal TBIs in towaways than in non-towaways in comparison to TBI injuries. Again, seat position has little or no relationship in determining TBI injury or TBI fatality outcomes, but TBI-injury is nine times and TBI deaths are three more times as likely in towaway crashes compared to non-towaway crashes.

**Safety Belt, Towaway, KABCO and TBI**

The general loglinear analysis of TBI, KABCO, Towaway, and Safety Belt use and non-use identified three interaction effects necessary to adequately model the data, shown in Exhibit 12. The loglinear logit model utilizes the two TBI-related interaction effects in a multinomial maximum likelihood estimation. The goodness-of-fit statistics for the loglinear logit model indicates no unaccounted for dependencies, likelihood Ratio Chi-Square = 13.11, df = 9, p = .22.

**Exhibit 12. Significant Interaction Effects in 4-way Contingency Tables, NM, 1995**

| Safety Belt, Towaway, KABCO and TBI | |
|---|---|
| KABCO, Safety Belt and Towaway | |
| KABCO, Safety Belt and TBI | ✔ |
| TBI and Towaway. | ✔ |

Exhibit 13, below, provides the resulting estimates and observed data under analysis. The population is the same 57,205 used before, for which there are two sampling zeros which cause one of the parameter estimates to be essentially unestimatable. The problem of sampling zeros is somewhat minimized by using a dichotomous TBI measure instead of polychotomous categories. However, note the absence of TBI's in Other/No Injury, O, category when safety belt is reported as not used. The sampling zeros may be the result of selecting non-property damage only crashes, and therefore are structural zeros, or of the perfect reporting of safety belt use by uninjured occupants. We suspect there is also some bias brought on by the perception that telling a police officer that one did not wear a safety belt could result in a traffic ticket and a penalty. While problematic, the two empty cells result in an unestimatable parameter, see Exhibit 14, the rest of the analysis is believed to be valid. Note in Exhibit 14 the parameter estimate for TBI (0), KABCO(O) and Safety Belt(0), underlined, is quite large and that the confidence limits include zero.

**Exhibit 13. Expected TBI Frequencies From Loglinear Logit Model, NM, 1995**

| Safety Belt | Towaway | KABCO | TBI Outcome Expected (Observed) | | Odds |
|---|---|---|---|---|---|
| | | | No - TBI | TBI | |
| not Used | not Towed | K | 7.65 (5) | 2.35 (5) | 3.25 |
| | | A | 150.22 (147) | 9.78 (13) | 15.36 |
| | | B | 341.09 (342) | 4.91 (4) | 69.48 |
| | | C | 701.66 (703) | 2.34 (1) | 299.85 |
| | | O | 3,094.00 (3,094) | 2.32E-04 (0) | |
| | Towed | K | 136.35 (139) | 82.65 (80) | 1.65 |
| | | A | 834.78 (838) | 107.22 (104) | 7.79 |
| | | B | 883.91 (883) | 25.09 (26) | 35.23 |
| | | C | 708.34 (707) | 4.66 (6) | 152.00 |
| | | O | 985.00 (985) | 0.000146 (0) | |
| Belt Used | not Towed | K | 2.31 (2) | 0.69 (1) | 3.35 |
| | | A | 868.02 (868) | 15.98 (16) | 54.32 |
| | | B | 1,111.05 (1,112) | 4.95 (4) | 224.45 |
| | | C | 10,330.95 (10,334) | 5.05 (2) | 2,045.73 |
| | | O | 18,668.03 (18,668) | 2.97 (3) | 6,285.53 |
| | Towed | K | 58.69 (59) | 34.31 (34) | 1.71 |
| | | A | 2,505.98 (2,506) | 91.02 (91) | 27.50 |
| | | B | 2,737.95 (2,737) | 24.05 (25) | 113.84 |
| | | C | 6,163.05 (6,160) | 5.95 (9) | 1,035.81 |
| | | O | 6,489.97 (6,490) | 2.03 (2) | 3,197.03 |

The dichotomous TBI and Towaway effect in Exhibit 14 can again be seen when comparing odds ratio between towed and not towed KABCO injury-TBI categories in Exhibit 13. It is analytically a constant, in any injury category, 1.97 time greater odds in non-towaway than towawy crashes for no-TBI than TBI. For display simplicity, reference cells and lambda estimates are generally not shown. Specifically, not shown are the reference cells for TBI and the two towaway contingencies, as is the same of all the TBI positive estimates for interactions with KABCO and safety belt categories, because as logits they are zero. The odds in non-towaway crashes for no-TBI compared to TBI is calculated by taking, from Exhibit 14, the difference in the logits for TBI(1) and Towaway(1) (0 and not shown) and TBI(0) and towaway(1) relative to TBI(1) and Towaway(0) (0 and not shown) and TBI(0) and Towaway(0), and taking the anti-log; ((0- 8.07) - (0 - 8.75) = 0.68) 1.97. In other words, TBI is nearly twice as likely in towaway crashes, when adjusting for other effects, and half (0.51) in non-towawaycrashes.

Exhibit 14 also shows Safety belt use has significant and positive interaction with KABCO injury categories and TBI outcomes. Adjusting for towaway status, the odds ratio for no-TBI versus TBI by belted versus not belted occupants of motor vehicles is largest in C, A, and B categories, 6.81, 3.53, and 3.23 respectively. The odds of no-TBI when belted for Those killed are 1.04 times. In contrast, the odds ratios for KABCO and Towaway and Belt effect are less differentiated within the injury categories and more pronounced for those killed.

**Exhibit 14. TBI, Towaway, Safety Belts and KABCO Logits, Odds and Odds Ratios, NM, 1995**

| **TBI** | **Towaway** | | **Odds Ratio** |
|---|---|---|---|
| | Towed | Not Towed | |
| Odds No-TBI | ($e^{8.07}$ =) 3,197.11 | ($e^{8.75}$ =) 6,310.69 | 0.51 |
| **TBI and KABCO Injury** | **Safety Belt** | | |
| | Used | Not Used | |
| Odds No-TBI and Killed | ($e^{-7.53}$ =) 0.00054 | ($e^{-7.57}$ =) 0.00052 | 1.04 |
| Odds No-TBI and A | ($e^{-4.75}$ =) 0.00865 | ($e^{-6.02}$ =) 0.00243 | 3.56 |
| Odds No-TBI and B | ($e^{-3.33}$ =) 0.03579 | ($e^{-4.51}$ =) 0.01100 | 3.25 |
| Odds No-TBI and C | ($e^{-1.12}$ =) 0.32628 | ($e^{-3.04}$ =) 0.04783 | 6.81 |

**Logits**

| Parameter | | Estimate | SE | Z-value | Asymptotic 95% CI Lower | Asymptotic 95% CI Upper |
|---|---|---|---|---|---|---|
| $\lambda_{TBI_0 \times Towaway_0}$ | = | 8.75 | .4522 | 19.35 | 7.86 | 9.63 |
| $\lambda_{TBI_0 \times Towaway_1}$ | = | 8.07 | .4576 | 17.63 | 7.17 | 8.96 |
| $\lambda_{TBI_0 \times KABCO_K \times SafetyBelt_0}$ | = | -7.57 | .4766 | -15.88 | -8.50 | -6.63 |
| $\lambda_{TBI_0 \times KABCO_A \times SafetyBelt_0}$ | = | -6.02 | .4652 | -12.93 | -6.93 | -5.10 |
| $\lambda_{TBI_0 \times KABCO_B \times SafetyBelt_0}$ | = | -4.51 | .4890 | -9.21 | -5.46 | -3.55 |
| $\lambda_{TBI_0 \times KABCO_C \times SafetyBelt_0}$ | = | -3.04 | .5878 | -5.18 | -4.20 | -1.89 |
| $\lambda_{TBI_0 \times KABCO_O \times SafetyBelt_0}$ | = | 7.66 | 31.1773 | 0.25 | -53.45 | 68.76 |
| $\lambda_{TBI_0 \times KABCO_K \times SafetyBelt_1}$ | = | -7.53 | .5037 | -14.95 | -8.52 | -6.54 |
| $\lambda_{TBI_0 \times KABCO_A \times SafetyBelt_1}$ | = | -4.75 | .4636 | -10.25 | -5.66 | -3.84 |
| $\lambda_{TBI_0 \times KABCO_B \times SafetyBelt_1}$ | = | -3.33 | .4894 | -6.81 | -4.29 | -2.37 |
| $\lambda_{TBI_0 \times KABCO_C \times SafetyBelt_1}$ | = | -1.12 | .5399 | -2.08 | -2.18 | -0.07 |
| $\lambda_{TBI_0 \times KABCO_O \times SafetyBelt_1}$ | = | 0.00 | . | . | . | . |

## Appendix E. TBI Cost Estimates

The following tables were derived from a report titled, *The Economic Cost of Traumatic Brain Injuries in New Mexico*, prepared by Max Bennett, Ph.D., MHA, and submitted to the Office of Epidemiology on September 10, 1997. The summary costs are shown in Exhibit A. The work tables, and supporting documentation, are in Exhibits B, C, D, and F.

**Exhibit A: New Mexico, 1995 TBI Cases: TBI Morbidity and Mortality Cost Summary**

| | TOTAL TBI | CRASH SPECIFIC TBI |
|---|---|---|
| MORBIDITY | $127,808,670 | $ 42,488,014 |
| MORTALITY | $161,762,445 | $ 99,106,693 |
| TOTAL | $289,571,115 | $141,594,707 |

**Exhibit B: Per Person Life-Time Morbidity Costs of Nonfatal TBI, New Mexico, 1995**

(Present Values of Expected Future Lifetime Earnings and Medical Expenditures For Head Injuries (nonfatal) which Required Hospitalization, using 1984 dollars.

| AGE | MALE | | | FEMALE | | |
|---|---|---|---|---|---|---|
| | TBI COUNT* | +LIFE-TIME COST/PERSON | NM COSTS | TBI COUNT* | +LIFE-TIME COST/PERSON | NM COSTS |
| 0-4 | 67 | $49,528 | $3,318,376 | 46 | $42,522 | $1,956,012 |
| 5-14 | 110 | $71,395 | $7,853,450 | 53 | $61,221 | $3,244,713 |
| 15-24 | 238 | $117,014 | $27,849,332 | 87 | $95,986 | $8,350,782 |
| 25-44 | 354 | $130,355 | $46,145,670 | 102 | $93,764 | $9,563,928 |
| 45-64 | 132 | $74,848 | $9,879,936 | 47 | $55,174 | $2,593,178 |
| 65-74 | 45 | $39,925 | $1,796,25 | 36 | $32,805 | $1,180,980 |
| 75+ | 66 | $37,298 | $2,461,668 | 70 | $27,486 | $1,924,020 |
| | 1,012 | | $98,995,057 | 441 | | $28,813,613 |

*Counts for male and female add to 1,453 cases, 54 less than the 1,507 non-fatal cases identified in Exhibit 2 of the report. Fifty-three cases did not appear to be "admitted" into a hospital, but were evaluated in hospital emergency departments and captured by the STR. Neither age or gender could be determined for one case.

+Source: Wendy Max, Ellen MacKenzie and Dorothy Rice, "Head Injuries: Costs and Consequences," *Journal of Head Trauma Rehabilitation* 1991; 6(2):76-79. Assumes an annual growth in productivity of 1% and discount rate of 6%.

**Exhibit C: Per Person Life-Time Morbidity Costs of Nonfatal TBI In Crashes, NM, 1995**

(Present Values of Expected Future Lifetime Earnings and Medical Expenditures
For Head Injuries (nonfatal) which Required Hospitalization, using 1984 dollars).

| AGE | MALE | | | FEMALE | | |
|---|---|---|---|---|---|---|
| | CRASH TBIs | +LIFE-TIME COST/ PERSON | NM COSTS | CRASH TBIs | +LIFE-TIME COST/ PERSON | NM COSTS |
| 0-4 | 7 | $49,528 | $346,696 | 1 | $42,522 | $42,522 |
| 5-14 | 28 | $71,395 | $1,999,060 | 16 | $61,221 | $979,536 |
| 15-24 | 98 | $117,014 | $11,467372 | 54 | $95,986 | $5,183,244 |
| 25-44 | 110 | $130,355 | $14,339,050 | 39 | $93,764 | $3,656,796 |
| 45-64 | 37 | $74,848 | $2,769,376 | 15 | $55,174 | $827,610 |
| 65-74 | 4 | $39,925 | $159,700 | 6 | $32,805 | $196,830 |
| 75+ | 11 | $37,298 | $410,278 | 4 | $27,486 | $109,944 |
| | 295 | | $31,491,532 | 135 | | $10,996,482 |

+Source: Wendy Max, Ellen MacKenzie and Dorothy Rice, "Head Injuries: Costs and Consequences," *Journal of Head Trauma Rehabilitation* 1991; 6(2):76-79. Assumes an annual growth in productivity of 1% and discount rate of 6%.

**Exhibit D. New Mexico Mortality Costs of TBI , 1995**

(Present Values of Expected Future Lifetime Earnings and Housekeeping Services According to Age, Gender and Discount Rate Assuming an Annual Growth in Productivity of 1%, 1994.)

| MALE | | | | FEMALE | | |
|---|---|---|---|---|---|---|
| AGE | ALL TBI | +COSTS PER PERSON | AGE CATEGORY TOTALS | ALL TBI | +COSTS PER PERSON | AGE CATEGORY TOTALS |
| 0 | 3 | 284,265 | 852,795 | 3 | 240,270 | 720,810 |
| 1-4 | 8 | 321,559 | 2,572,472 | 8 | 271,685 | 2,173,480 |
| 5-9 | 6 | 400,239 | 2,401,434 | 2 | 338,036 | 676,072 |
| 10-14 | 7 | 510,172 | 3,571,204 | 1 | 430,744 | 430,744 |
| 15-19 | 33 | 632,009 | 20,856,297 | 14 | 524,383 | 7,341,362 |
| 20-24 | 33 | 731,405 | 24,136,365 | 8 | 583,923 | 4,671,384 |
| 25-29 | 21 | 786,185 | 16,509,885 | 9 | 600,945 | 5,408,505 |
| 30-34 | 23 | 798,672 | 18,369,456 | 9 | 586,020 | 5,274,180 |
| 35-39 | 15 | 768,670 | 11,530,050 | 10 | 542,375 | 5,423,750 |
| 40-44 | 19 | 696,453 | 13,232,607 | 3 | 475,919 | 1,427,757 |
| 45-49 | 6 | 582,982 | 3,497,892 | 1 | 394,099 | 394,099 |
| 50-54 | 9 | 439,127 | 3,592,143 | 5 | 299,616 | 1,498,080 |
| 55-59 | 7 | 285,634 | 1,999,438 | 1 | 208,357 | 208,357 |
| 60-64 | 7 | 152,925 | 1,070,475 | 1 | 131,803 | 131,803 |
| 65-69 | 10 | 73,685 | 736,850 | 0 | 75,077 | 0 |
| 70-74 | 5 | 35,376 | 176,880 | 8 | 39,644 | 317,152 |
| 75-79 | 10 | 18,624 | 186,240 | 8 | 20,465 | 163,720 |
| 80-84 | 8 | 9,385 | 75,080 | 8 | 9,972 | 79,776 |
| 85+ | 9 | 2,868 | 25,812 | 11 | 2,549 | 28,039 |
| TOTAL | 239 | | 125,393,375 | 110 | | 36,369,070 |

Source: Personal Communication from Dorothy Rice, Professor Emeritus, University of California, San Francisco, dated March 10, 1997. Assumes a 6% discount rate. Max Bennett, Ph.D. replicated these values from Rice's sources.

**Exhibit E. New Mexico Mortality Costs of TBI Resulting from Motor Vehicle Crashes, 1995**

(Present Values of Expected Future Lifetime Earnings and Housekeeping Services According to Age, Gender and Discount Rate Assuming an Annual Growth in Productivity of 1%, 1994.)

| MALE | | | | FEMALE | | |
|---|---|---|---|---|---|---|
| AGE | ALL TBI | +COSTS PER PERSON | AGE CATEGORY TOTALS | ALL TBI | +COSTS PER PERSON | AGE CATEGORY TOTALS |
| 0 | 1 | 284,265 | 284,265 | 3 | 240,270 | 720,810 |
| 1-4 | 5 | 321,559 | 1,607,795 | 4 | 271,685 | 1,085,072 |
| 5-9 | 6 | 400,239 | 2,401,434 | 2 | 338,036 | 676,072 |
| 10-14 | 2 | 510,172 | 1,020,344 | 1 | 430,744 | 430,744 |
| 15-19 | 22 | 632,009 | 13,904,198 | 12 | 524,383 | 6,292,596 |
| 20-24 | 18 | 731,405 | 13,165,290 | 9 | 583,923 | 5,255,307 |
| 25-29 | 16 | 786,185 | 12,578,960 | 1 | 600,945 | 600,945 |
| 30-34 | 13 | 798,672 | 10,382,736 | 6 | 586,020 | 3,516,120 |
| 35-39 | 8 | 768,670 | 6,149,360 | 8 | 542,375 | 4,339,000 |
| 40-44 | 8 | 696,453 | 5,571,624 | 3 | 475,919 | 1,427,757 |
| 45-49 | 4 | 582,982 | 2,331,928 | 1 | 394,099 | 394,099 |
| 50-54 | 3 | 439,127 | 1,317,381 | 5 | 299,616 | 1,498,080 |
| 55-59 | 2 | 285,634 | 571,268 | 1 | 208,357 | 208,357 |
| 60-64 | 4 | 152,925 | 611,700 | 0 | 131,803 | 0 |
| 65-69 | 6 | 73,685 | 442,110 | 0 | 75,077 | 0 |
| 70-74 | 3 | 35,376 | 106,128 | 3 | 39,644 | 118,932 |
| 75-79 | 3 | 18,624 | 55,872 | 1 | 20,465 | 20,465 |
| 80-84 | 0 | 9,385 | 0 | 2 | 9,972 | 19,944 |
| 85+ | 0 | 2,868 | 0 | 0 | 2,549 | 0 |
| TOTAL | 124 | | 72,502,393 | 62 | | 26,604,300 |

Source: Personal Communication from Dorothy Rice, Professor Emeritus, University of California, San Francisco, dated March 10, 1997. Assumes a 6% discount rate. Max Bennett, Ph.D. replicated these values from Rice's sources.