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Identification of Safety Belt Restraint Usage Characteristics Related to Four- to Thirteen-Year-Olds

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Final Report

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PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

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Acknowledgments

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Abstract

Involvement in road traffic crashes as vehicle occupants is a leading cause of death and serious injury among children. The objective of this study was to investigate child safety restraint-use characteristics and crash-severity factors in order to identify effective countermeasures to increase children's safety. Crash data were obtained from the Kansas Department of Transportation from 2004 to 2008. Children were divided into two groups, aged four to seven and eight to 13, considering Kansas child restraint laws. Frequencies, percentages, and odds ratios were used to investigate restraint-use characteristics, seating positions, and injury severity. Logistic regression models were developed to identify risk factors which increased injury severity. Results showed children not restrained, riding with drunk drivers, and riding in older vehicles were more vulnerable for injuries when they were in crashes. The most frequent contributory causes related to children involved in crashes in Kansas were inattention in driving, failure to yield right of way, driving too fast, wet roads, and animals in the road. Based on the identified critical factors, countermeasures to improve child traffic safety were suggested which included age- and size-appropriate seat belt restraints, and the child being in the rear seat. It is important for parents and children to gain better education about these safety measures that are helpful to increase child safety on the road.

Chapter 1: Introduction

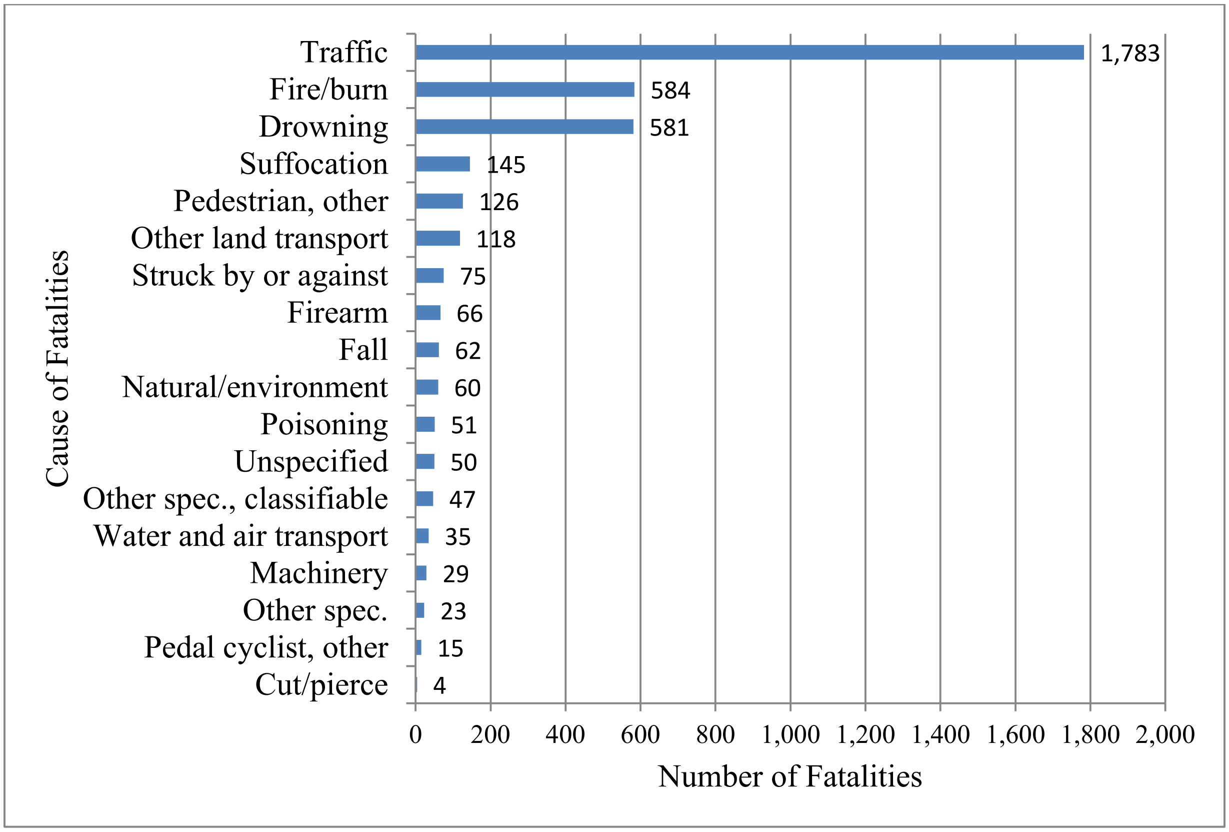
1.1 Background

Traffic safety is a global concern due to its magnitude of social and economic impact. Each year nearly 1.3 million fatalities, or more than 3,000 fatalities per day, occur due to traffic crashes in the world (United Nations 2011). In addition, 20 to 50 million more people suffer injuries from motor vehicle crashes and some of these injuries lead to disabilities. Global Plan for the Decade of Action for Road Safety 2011–2020 states that highway crashes are predicted to become the fifth leading cause of death worldwide unless immediate action is taken (United Nations 2011). The same report mentions that injuries suffered in highway crashes are among the three leading causes of deaths for people between five and 44 years of age.

Even though overall level of safety on United Sates roadways has improved over the last few decades because of significant vehicle and occupant safety regulations and programs, further improvement is needed. In 2009, 33,808 fatalities and another 2.2 million injuries were reported on U.S. roadways due to motor vehicle crashes. Ninety percent of victims in traffic crashes were occupants, accounting for 24,474 fatalities in 2009 (NHTSA 2009b). Injuries to occupants of motor vehicle crashes claim the lives of more people between five and 34 years of age than any other cause of injury (CDC 2010). An average of four children, 14 years and younger, are killed and 490 are injured each day in United States (U.S.) traffic crashes, based on 2009 statistics. Child passengers are innocent victims in crashes because they may not be the decision makers for the trips or any other factors associated with the trip (NHTSA 2009b).

1.2 Children's Safety

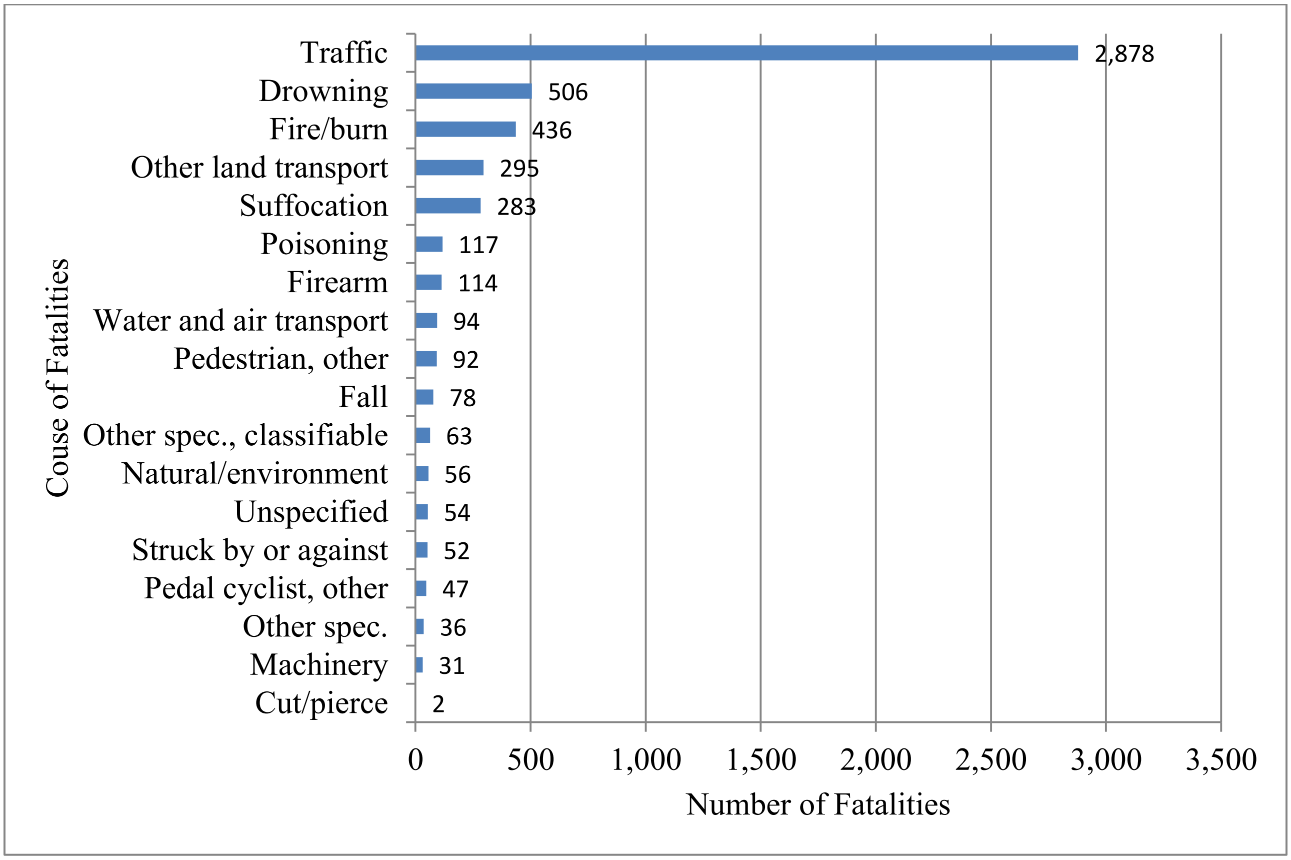
The national Center of Injury Prevention and Control has reported 10 leading causes of death for each age, which includes traffic fatalities, under the unintentional injury category (CDC 2010). At the time of this study, data were available up to 2007 for web-based injury statistic queries. Unintentional injury was the leading cause of death for children ages four to seven, and this was 2.9 times higher than the second cause, malignant neoplasms. From 2004 to 2007, there were 3,809 fatal, unintentional injuries among children between four and seven years old. In the unintentional injury category, motor vehicle-related injuries were the leading cause, accounting for about 46% of injuries as shown in Figure 1.1.



Source: http://www.cdc.gov/ncipc/wisqars [CDC 2010]

FIGURE 1.1
Unintentional Injuries among Children Ages 4–7

From 2004–2007, a total of 5,234 deaths of children between the ages eight to 13 were reported due to unintentional injuries, which was 2.3 times more than the second cause (CDC 2010). Even for this age category, motor vehicle injuries were the leading cause of death among causes of all unintentional injuries as shown in Figure 1.2. Traffic injury-related fatalities consisted of 55% of unintentional injury fatalities among children ages eight to 13. Annual data by age of the child, which were obtained from the National Center of Injury Prevention and Control, are plotted in Figure 1.3 to provide an indication of national trends. Percentages of traffic injury deaths from unintentional injury among children eight to 13 years are steady.



Source: http://www.cdc.gov/ncipc/wisqars [3]

FIGURE 1.2
Unintentional Injuries among Children Ages 8- 13

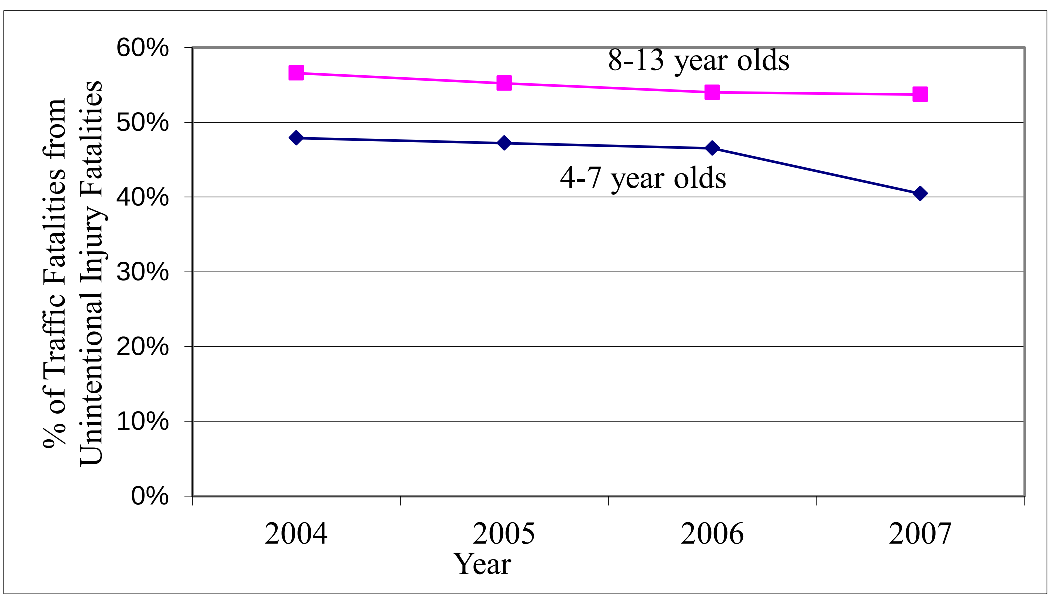


FIGURE 1.3
Percentages of Traffic Fatalities in Unintentional Injuries

There has been a slight decline in those percentages and numbers of traffic fatalities within the four to seven years old category. Over the last few decades, safety of child occupants in motor vehicle crashes has been a major concern. Despite efforts to investigate methods to improve child passenger safety, it is still a critical national issue needing further improvement.

Effectiveness of seat belt restraints in reducing crash injuries needs to be further investigated. Child seatbelt restraints are specially designed for the anatomies of infants and small children (Johnston, Rivara, and Soderberg 1994; IIHS 2011). Child restraints are expected to hold children in place and prevent them from being ejected from the vehicle or hitting the vehicle interior, while not loading dangerous levels of crash force on vulnerable parts of a child's body. Use of child seatbelt restraints has been found to be effective in reducing fatalities and injuries in crashes (Johnston, Rivara, and Soderberg 1994). However, the children involved would not be properly protected if their weights and heights differ from design standards of the restraint. Child restraint systems involve use of child safety seats restrained by seat lap belts based on Federal Motor Vehicle Safety Standards (Johnston, Rivara, and Soderberg 1994). Child passenger restraint requirements vary across the country based on a child's age, weight, and height. The District of Columbia and 47 states require booster seats for children who have outgrown their child safety seats but are still not grown enough to use an adult seat belt. However, Arizona, Florida, and South Dakota are lacking in booster seat laws as of 2011 (IIHS 2011). A summary of child passenger seat restraint laws among different states as of 2011 is given in Appendix A. It shows many state laws require all children to ride in the rear seat, and most states permit children over a particular age, height, or weight to use an adult safety belt.

Number of research studies have evaluated the association between child restraint use and crash characteristics. Many of these studies have been conducted using roadside observation or through interviews with parents, or using data sources. Observational surveys of child seatbelt restraint use in vehicles are widely used in traffic injury prevention efforts. For example, Moeller et al. conducted a statewide child seatbelt restraint use observation study covering infants, toddlers, school ages, and teens (Moeller et al. 2002). However, it was stated that observational surveys are labor intensive, costly, and pose risk to data collectors. Also, in observational child restraint-use surveys, determination of occupant age is a key concern. Data from the National

Occupant Protection Use Survey (NOPUS), which collects detailed information on a national-level shoulder belt, child restraint, and motorcycle helmet use as required by the National Highway Traffic Safety Administration, is often used by researchers to study child seatbelt restraint characteristics of children under 12 years old. According to NOPUS data in 2009, observed child seatbelt restraint use among children aged four to seven years was 87%, which is slightly higher than 85% usage by children aged eight to 12 years (NHTSA 2011b).

The Kansas Department of Transportation (KDOT) conducts child occupant protection observational surveys annually regarding child seatbelt restraint use (KDOT 2010). Three age groups are observed, all of which include children subjected to primary seatbelt laws, meaning a vehicle transporting a child younger than 14 years may be stopped and ticketed for not using a seatbelt restraint. The three age groups are children aged zero to four years, children aged five to nine years, and children aged 10 to 14 years. Beginning in 2008, an additional age group was added due to changes in Kansas law, making drivers 15 to 17 years subject to primary seatbelt laws. As shown in Table 1.1, Kansas child observational seatbelt restraint-use percentages have increased each of the past five years. However, according to Kansas observational seatbelt surveys in 2009, average child seatbelt restraint use for four- to13-year-olds is about 70% in Kansas, and it is lower than the national average rate of 86% among four- to13-year-olds in the same year, even though considerable attention has been given to child occupant safety during the last few decades in Kansas (KDOT 2010).

TABLE 1.1
Kansas Child Observational Safety Belt Restraint Usage in Percentages

Age of Children in Years	2004	2005	2006	2007	2008	2009	2010
0-4	81	81	83	88	93	96	97
5-9	50	49	53	62	69	73	76
10-14	50	47	48	55	63	67	67
15-17	-	-	-	-	-	61	65
Overall Belted %	61	59	61	68	75	75	77

Source: http://www.ksdot.org/burtrafficsaf/safblt/safbltusag.asp (KDOT 2010)

In July 1981, the Kansas Legislature approved KSA 8-1343, which required use of "a federally approved child safety seat/booster seat for children up to four years of age." Amendments to the law in 1984, 1989, 1992, and 1997 strengthened the 1981 child passenger safety act, where booster seats were strongly suggested for children aged four to seven years, but citations were not issued until 2006 (Kansas Legislature 2011). The Kansas Child Passenger Safety Act was then amended during the 2006 legislative session to require children ages four to seven years to be in secured booster seats, unless the child weighed more than 80 pounds or was taller than 4 feet 9 inches. Within the first year of the approval of the law, if a motorist with a four- to seven-year-old child was observed to be in violation of the law, a law enforcement officer had the discretion to stop the motorist and give the violator a “verbal warning” on the dangers of nonrestraint. After July 1, 2007, law enforcement officers could issue a fine for all ages covered under the act, including four- to seven-year-old children. The Kansas Child Passage Safety Act (KSA 8-1344) is quoted below in detail (Kansas Legislature 2011).

8-1344. Child passenger safety; restraining systems for children under the age of four; use of booster seats, when; use of seat belts by children, when; exceptions.

(a) Every driver as defined in K.S.A. 8-1416, and amendments thereto, who transports a child under the age of 14 years in a passenger car as defined in K.S.A. 8-1343a, and amendments thereto, on a highway as defined in K.S.A. 8-1424, and amendments thereto, shall provide for the protection of such child by properly using:

(1) For a child under the age of four years an appropriate child passenger safety restraining system that meets or exceeds the standards and specifications contained in federal motor vehicle safety standard no. 213;

(2) for a child four years of age, but under the age of eight years and who weighs less than 80 pounds or is less than 4 feet 9 inches in height, an appropriate child passenger safety restraining system that meets or exceeds the standards and specifications contained in federal motor vehicle safety standard no. 213; or

(3) for a child eight years of age but under the age of 14 years or who weighs more than 80 pounds or is more than 4 feet 9 inches in height, a safety belt manufactured in compliance with federal motor vehicle safety standard no. 208.

(b) If the number of children subject to the requirements of subsection (a) exceeds the number of passenger securing locations available for use by children affected by such

requirements, and all of these securing locations are in use by children, then there is not a violation of this section.

(c) If a securing location only has a lap safety belt available, the provisions of subsection (a)(2) shall not apply and the child shall be secured in accordance with the provisions of subsection (a)(3).

Source: http://kslegislature.org/li/m/statute/008_000_0000_chapter/008_013_0000_article/008_013_0044_section/008_013_0044_k.pdf (Kansas Legislature 2011)

As explained in the previous section, Kansas law prohibits children under 14 years from riding in any part of the vehicle not intended for passengers, including the bed of a pickup truck. The July 2006 amendment brought Kansas in line with child passenger safety recommendations from the National Highway Traffic Safety Administration (NHTSA) (NHTSA 2011c). The Kansas Department of Health and Environment recommends restraint use for children as follows:

Infant – under age one restrained in rear-facing child seats

Children – age one to three restrained in forward-facing child seats

Children – age four to seven restrained in booster seats

Children – ages eight to13 restrained in seat belts

Children aged four to seven are required to use booster seats. Booster seats elevate the child to fit appropriately with the lap and shoulder belts in the vehicle. The child safety restraint system requirements in Kansas are summarized in Figure 1.4 (IIHS 2011).

<table>
<tr><td>Age of Child (Years)</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td></tr>
<tr><td>Car Seat Restraint</td><td colspan="4">Required</td><td colspan="11">Optional</td><td colspan="4">Not Necessary</td></tr>
<tr><td>Seat Belt Restraint</td><td colspan="4">Not Permissible</td><td colspan="4">Permissible</td><td colspan="11">Required</td></tr>
<tr><td>Front Seat Allowance</td><td colspan="13">Not Recommended</td><td colspan="6">Permissible</td></tr>
<tr><td>Booster Seat Law</td><td colspan="4">Not Available</td><td colspan="4">Required</td><td colspan="11">Not necessary</td></tr>
</table>

Source: http:/www.infant-car-seats.com (Kansas Car Seat Laws 2010)

FIGURE 1.4
Safety Restraint System Recommendations for Kansas

Use of seat belts and child restraints is one of the most important actions taken to reduce injury to children involved in motor vehicle crashes. While seat belts and child restraints do not prevent crashes from taking place, they play a major role in reducing severity of injury to vehicle occupants involved in a crash. An occupant's chance of survival increases dramatically when he or she is appropriately restrained (Johnston, Rivara, and Soderberg 1994).

1.3 Problem Statement

The most effective strategy for preventing injury and death, and reducing costs associated with children involved in crashes, is using age- and size-appropriate restraints. Despite many efforts and the expenditure of substantial resources, safety restraint use in 2010 among Kansas children ages five to 14 years is about 71 percent based on observational surveys. Reasons for this shortfall are complex and vary among individuals, vehicles, and many other factors. It may include lack of understanding that seat belt restraints prevent injury, low perceived risk, ignorance of seat belt restraint laws, perception that the child restraint law is not enforced, inconvenience, parental permissiveness, and situational factors (Glass, Segui-Gomez, and Graham, 2000). Kansas safety restraint use among children has risen slowly over the past years and has saved more lives; however, additional measures are needed in order to further increase safety restraint use. A number of countermeasures are available that have great potential to increase safety restraint use and to sustain the increase. The challenge is to select the best set of countermeasures that achieve short-term benefits, sustain higher use over time, alter behavior among nonusers, and finally change the way safety restraint use is reviewed.

This goal could be reached by identifying nonuse of occupant restraints by different characteristic like age of children, vehicle type, time of the day, day of week, and driver restraint use. Identifying causes of restraint nonuse will provide promising approaches to address this problem. Also, it is important to investigate characteristics and contributory circumstances related to child passengers involved in crashes and associated severities, while identifying critical factors. Evidences for effectiveness of seat belts and child restraints in reducing severities need to be investigated.

1.4 Objectives of the Study

The main objective of this study was to investigate child safety restraint-use characteristics in Kansas in order to identify effective countermeasures to increase passenger safety of Kansas children aged four to 13 years. Objectives of this study included the following:

- To investigate child safety restraint-use characteristics in Kansas;
- To investigate characteristics and contributory causes related to crashes involving children in Kansas;
- To examine risk factors for crashes involving children such as failure to use restraint; riding with a drunk driver; and various other driver, environmental, and vehicle characteristics;
- To investigate seating position of the child passenger in the vehicle, as seating position in the vehicle at a crash may contribute to the risk for injury; and
- To investigate potential actions that might be helpful in increasing child safety belt restraint usage rates.

1.5 Organization of the Report

This report consists of five chapters and an appendix. Chapter one contains background information and objectives of the study. Chapter two provides a summary of previous studies conducted in relation to the topic. Chapter three presents details of data, databases used to facilitate this study, and methodologies used in achieving objectives of this study. Chapter five details the summary, conclusions, and recommendations for improving child passengers' safety.

Chapter 2: Literature Review

This section discusses previous findings about the effect of a restraint system and seating positions for reducing child injury risk on highways. Driver-related characteristics such as driver alcohol involvement, which can be influence child passenger safety, and various countermeasures that have the potential to increase child safety restraint-use rates were also reviewed and presented in this chapter.

2.1 Effect of Restraint Use

Since 1988, the National Automotive Sampling System's General Estimates System (NASS, GES) database has been a popular source for crash data in the United States. Data for the GES come from a national representative sample of police-reported motor vehicle crashes of all types, from minor injury to fatal, that happened when motor vehicles were traveling on a trafficway. These police crash reports were chosen from 60 areas that represent the geography, roadway mileage, population, and traffic density of the U.S. data collectors made weekly visits to approximately 400 police jurisdictions in 60 areas across the U.S. where they randomly sampled about 50,000 police accident reports each year. In child traffic safety literature, several studies which investigated child restraint-use characteristics using subsets of the GES data can be found. For example, Hanna (2010) investigated incidence rates of incapacitating injuries and risk ratios to evaluate differences in risks of injuries in different body regions based on restraint use among children. The study showed that head injuries were the most common injuries sustained by children in motor vehicle crashes. The results indicated that use of child safety seats is effective in reducing incapacitating injuries of children involved in crashes, whether those are frontal crashes, side impacts, or rollovers.

Valent et al. (2002), using GES data, evaluated differences in risks of injuries in different body regions according to restraint use among children. Characteristics of the occupant, vehicle, and collision were compared across different categories of restraint use. As compared to unrestrained children, properly restrained children had significantly lower overall injury risk, indicating a Risk Ratio (RR) of 0.37. Significant risk reductions were also observed for injuries to the head (RR= 0.18), lower extremities (RR= 0.26), thorax (RR= 0.35), and mortality (RR= 0.26) among properly restrained children.

Starnes (2002) examined 10 year fatal crash data starting from 1991 to investigate the association between restraint use of fatally injured child passengers in crashes and their drivers. Data were obtained from the Fatality Analysis Reporting System (FARS), which is a national database of fatal crashes occurring on the public roadway network. It is maintained and operated by the National Highway Traffic Safety Administration (NHTSA) (FARS 2011). FARS contains data of all fatal traffic crashes within the 50 states and the District of Columbia. Each state provides specific fatal crash information, which originates from state crash reports and is presented, in a standard format to FARS. Starnes used the driver and passenger double-pair comparison method to examine restraint-use patterns among child occupants involved in crashes where a child was fatally injured. According to the results, restraint use of fatally injured child passengers and their drivers were strongly correlated.

Olsen et al. (2010) examined the association between driver restraint use and child emergency department evaluations following a motor vehicle crash, using crash data from Utah from 1999 to 2004. Children aged 0–12 years riding with an adult driver older than 21 years were taken into account. Generalized estimating equations were used to estimate the relative risk for the child, driver, and crash characteristics for restrained drivers as compared to unrestrained drivers. It was concluded that driver restraint use is associated with decreased risk of emergency department evaluation for the child passenger in the event of a motor vehicle crash.

Restraint use for children in fatal crashes was also investigated by Agran, Anderson, and Winn (1998) using FARS data from 1994. The objective of this study was to characterize and examine restraint use of children zero to nine years old, in relation to vehicle and driver characteristics. The number and percentage of crashes under each characteristic were determined. The results showed that restraint use declined with increasing age of the child and increasing number of occupants in the vehicle. Restraint use of children in fatal crashes was as low as 31% in older vehicles, 54% in rural areas, and 23% between the hours of 3 AM and 6 AM. The logistic regression models developed in this study showed that restraint use declined with increasing number of occupants. Restraint use decreased with increased age of child. The study concluded that child occupant protection counseling must stress restraint use under all conditions of travel.

Miller, Spicer, and Lestina (1998) examined the motor vehicle driver characteristics of crashes involving children and teenagers. Data was obtained from GES and FARS from 1992 to 1993. Children and teen passengers were divided into four groups: ages less than four years, ages five to nine years, ages 10–14 years, and ages 15–19 years. Using logistic regression, the significant risk factors of children involved in crashes were identified and included driver being male, nighttime traveling, driver being under the influence of alcohol, other moving or nonmoving violations, and driver being unrestrained. Results showed that as drivers get older, they are more likely to restrain a baby in a child seat than to ensure the older children buckle up. It was also observed that older drivers in suburban areas were significantly more likely to restrain their children than other drivers.

Decina et al. (2009) investigated factors that contribute to nonuse of child occupant seat belt restraints in motor vehicles, and identified cost, inconvenience, child discomfort, lack of understanding of the child restraint law, lack of understanding of how booster seats work, and low perceived risk of being ticketed for a booster seat law violation as reasons why five- to seven-year-old children were not restrained in booster seats. According to the study, child occupants traveling with grandparents were much less likely to use child safety seats and booster seats, and were more likely to be unrestrained. According to an observational study conducted Ramsey, Simpson, and Rivana (2000) parents thought the child was large enough to use the regular lap seat belt system, which was the most common reason for lack of booster seat use. This study also revealed that parental misconceptions about size and safety of regular restraint equipment were reasons why children were not properly restrained in the vehicles.

Kuhn and Lam (2010) conducted interviews of children aged eight to 15 which included both seat belt regular users and non-regular seat belt users. According to regular users, they use seat belts without thinking about it. Parental direction, habit, safety, and fear of flying out of the vehicle or through the windshield were cited by children in this age group as reasons to wear seat belts. Some of them cited they wore seat belts to protect their parents, and they feared flying into the front seat and hurting their parents in a crash. Non-regular seat belt users cited reasons for not wearing seat belts as forgetting to put a belt on, did not see reasons to always wear seat belts as they may be going on only a short or local trip, eating or sleeping in the car, and shortage of enough seat belts in the vehicle to accommodate all children riding in their car such as situations where after-school or sports car pooling was taking place.

The literature recommends that child-occupant restraint use for all seating positions under all travel conditions must be stressed by child-occupant protection counseling (Miller, Spicer, and Lestina 1998).

2.2 Seating Position

Existing literature on child safety shows that seating position has an effect on injury severity and fatality rate of child passengers. Whether restrained or unrestrained, rear seating had a reduced fatality risk for children involved in crashes because fully powered passenger-side airbags in the front create a significant risk to children (Glass, Segui-Gomez, and Graham 2000). Evan and Frick (1988) showed that center rear seat was the safest seating position, then left or right rear seats for unrestrained passengers, indicating a fatality risk of 1.17 for the left rear seat versus center rear seat, and fatality risk of 1.19 for the right rear seat versus center rear seat. However, Lund (2005) studied the risk of injury of restrained child passengers using multiple logistic regression and showed that rear outbounds, that is, rear left and rear right seating locations, were much safer. The finding was supported by the argument that being seated in the outbound was disadvantageous with respect to injury, because the passenger was in close proximity to the position of impact when the point of impact was on either side of vehicle, but the passenger may be seated further away from the point of impact if this point was other side of the vehicle. Also, the study showed the relative risk of being ejected from a vehicle for rear outbound-seated passengers versus rear center-seated passengers was much less when passengers were restrained than when they were unrestrained.

Wittenberg, Goldie, and Graham (2001) studied factors associated with the seating behavior of five to 14-year- old children in front seats of vehicles involved in fatal crashes between 1990 and 1998. They found the proposition of the vehicle carrying children in the front seat declined from 42% to 31% over this nine-year period. Multivariate logistic regression was also used to model the association between child seating position and vehicle, driver, and occupant characteristics. They found the important factor for child seating position to be presence of multiple passengers, especially an older passenger. Children were at higher risk of front seat seating when they traveled alone with the driver. Children travelling in vans or sport utility vehicles were less likely to be seated in front seats than children travelling in passenger cars. Male drivers were found to be less likely to seat children in the front seat compared to women drivers. The study concluded these traveling situations should be used for behavior safety intervention.

Glass et al. investigated seating locations which minimize the risk of fatality to children involved in crashes (Glass, Segui-Gomez, and Graham 2000). Seating position, restraint use, vehicle, and crash characteristics were investigated while calculating the probability of a child dying in a crash. For these calculations, multivariate logistic regression and odds ratios were used. Restrained, nine- to 12-year-old children seated in the rear of the vehicle were chosen as the reference group. The study found that restraint use and rear seating were associated with statistically significant reductions in the odds of a child dying in a crash. For children younger than 12 years, the rear seat offered more protection to both restrained and unrestrained passengers compared to the front seat without airbags. When airbags were introduced to right front seat, increased protection could be seen among the children under nine years old, but for children nine to12 years old, rear seat effectiveness became negative. Result also showed that restraint use and rear seating were associated with statically significant reductions in the odds of a child dying in a crash. Passenger airbags were associated with an increase in child fatality risk of 31% for restrained children and 84% for unrestrained children. Based on the findings, researchers recommended parents should seat children in the rear of vehicle, while using proper restraints in order to minimize child fatality risk.

The effect of car restraints for children aged zero to 14 years who were involved in crashes was analyzed using logistic regression analysis by Johnton, Rivana, and Soderberg (1994). Age, gender, seating position, rural-urban nature, and speed limit at the crash site were examined in order to identify car restraint effectiveness in preventing all types of traffic injury. It was found that only 57% of restrained child passengers were in the back seats and only 19% of back-seated children were injured. In particular, increased age of the child passenger was associated with increased front seat occupancy. According to this study, the single strongest risk factor for traffic injury was the non-use of restraints. The use of a car seat reduced injuries by 60% for zero to four year olds, whereas the lap shoulder harness was only 38% effective for children five to 14. Greater involvement in car crashes and less use of car restraints explain the higher rate of injury for three-year-old child passengers than for infants.

The effect of restraint use and seating position on injuries to children in motor vehicle crashes was investigated by Berg et al. (2000) using Utah motor vehicle crash records. Odds ratios were calculated to compare seating positions and restraints used. Results of the study showed that rear seating position and restraint use provided a significant protective effect. Restraint use varied by age and seating location in the vehicle. Braver et al. (Braver, Whitfeild, and Ferguson 1998) determined the effect of seating position, restraint use, and airbag status on children's risk of fatal crashes. The risk of death was compared using odds ratios among front- and rear-seated children, aged 12 years and younger, who were involved in fatal crashes. It showed that children in the rear, seats had the lowest risk of dying in fatal crashes. Children were about 10–20% less likely to die in rear center seating position than in rear outbound positions. Hence, the study recommended that people who transport children should be strongly encouraged to place them in rear seats.

Glass and Graham (1999) examined the risk of fatality to children younger than 13 years sitting in passenger vehicles, using fatal crashes occurring from the 1985 to 1996. The children under 13 years were divided into four groups: less than one year of age as infants, one to three years old as toddlers, four to eight years old as young children, and nine to 12 years old as subteens. The percentage of children seated in the front seat varied by age of child and percentages were 45%, 31%, 30%, and 3% for infant, toddlers, young children, and subteens, respectively. Roughly one-third of children under the age of 13 were seated in the front. The percentage of children in the front seat ranged from 40% in Massachusetts to 24% in Hawaii. It was observed that a substantial percentage of children were in the front seat when travelling in motor vehicles. The study concluded this behavior was influenced to some extent by age of the child, vehicle type, and age of the passengers in the vehicle.

2.3 Driver Factors

2.3.1 Alcohol Involvement

Quinlan et al. (2000) examined characteristics of crashes involving child passenger death and injuries associated with drunken drivers, and identified of opportunities to prevent them. Data were obtained from FARS from 1985 to 1996 and GES from 1988 to 1996. Percentages were tabulated and crash rates calculated for each year. Results showed 64% of fatal crashes occurred when the child was riding with a drunken driver. It was concluded that a majority of drunken driver-related child passenger deaths happened when the child was unrestrained.

Driver alcohol-related fatalities among child passengers were studied by calculating frequencies and percentages (CDC 1997). From 1985 to 1996, 2,280 child passengers died while riding in the same vehicle with a drunk driver. This was 60% of the total number of children who died in crashes. Only 16% of these children were restrained at the time of the crash. Restraint use was lowest (11%) for children aged 10–14 years whose drivers had blood alcohol concentrations (BACs) ≥0.10 g/dL. It was concluded that rigorous enforcement of primary seat belt laws and reducing incidences of driving under influence of alcohol were much needed.

Voas, Fisher, and Tippetts (2002) checked differences between riding with a drunk driver and failure to use restraints for crash-related injuries of children, using crash data obtained from FARS. Data on driver BAC was obtained from the National Center for Health Statistics and socioeconomic information was obtained from the U.S. Census. This study covered 160,770 drivers and 12,266 children younger than 16 years killed in motor vehicle crashes from 1990 to 1996. Two logistic regression analyses were carried out for a detailed investigation of restraint-use characteristics and drinking risk factors. The response variable in the logistic model was the driver being under the influence of alcohol, or when not considering the drinking risk factor. Child restraint use or not was selected as the response variable when considering child restraint use. Results showed drivers who were under the influence of alcohol were less likely to be transporting children and those children, were less likely to be restrained.

2.3.2 Driver Sex/Age

Studies have found a positive relationship between driver age, and child safety seat and booster seat use (Decina 2009). Children aged five to seven years were most likely to travel unrestrained (50%) if the driver was 16 to 29 years old. The percentage of unrestrained children decreased to 34% with drivers 30 to 59, and to 21% with drivers 60 and older. The National Occupant Protection Use Survey (NOPUS) found a higher percentage of restrained children less than eight years old when the driver was male than when the driver was female (86% versus 82%) in 2006 (Glaabrenner and Ye 2007). Using the 2008 NOPUS, it was found that a higher percentage of restrained children less than eight years old were associated with female drivers compared to male drivers (88% versus 85%) (NHTSA 2009a). Based on an observation study conducted in 2004 by the University of Michigan, restraint use by children of booster-seat age varied widely by age of the driver (NHTSA 2011a). Children in the four to seven age group were most likely to travel unrestrained (50%) if the driver was 16 to 29 years old. The percentage of unrestrained children decreased to 34% with drivers' age from 30 to 59, and to 21% with drivers 60 and older.

2.3.3 Driver Seat Belt Use

Few studies showed a strong connection between driver seat belt use and child passenger seat belt use. According to the 2010 Oklahoma child restraint-use study, 94% of children were restrained when the drivers were restrained while only 45% children were restrained when the drivers were not (James and Hall 2011).

2.4 Other Factors

In addition to the factors mentioned in previous sections, many other things affect the risk to children as unrestrained passengers. According to exposure-based crash rates such as crash rates per billion vehicle-miles of travel and crash rates per 100,000 persons, Black and Hispanic children are at higher risk of dying in motor vehicle crashes (Baker et al. 1998). Head injuries were the most common injuries sustained by children in motor vehicle crashes. Distribution of different vehicle types on roadways and different use pattern of those vehicles were also important factors in assessing restraint use among child occupants involved in crashes. Later model vehicles may be equipped with more advanced safety features such as a system that automatically brakes the car before an impending crash, and rear passenger air bags, as compared to older cars. Vehicle-use patterns also differ in such a way that sport utility vehicles and pickup trucks may be used on rural roads more often than on urban roads. Frontal crashes account for one in six road fatalities, or about 7,200 deaths per year, according to the Insurance Institute for Highway Safety (NHTSA 2011a).

Motor vehicle crashes resulting in fatalities were more likely to occur in rural areas compared to urban areas, and rural fatalities account for 57% of all fatalities (Huseth 2010). Also, some studies found that restraint use among children in rural areas was lower than in urban areas (Agran, Anderson, and Winn 2012). However, the 2008 NOPUS found a four-percentage-point difference between urban (80%) and suburban (76%) restraint use by children four to seven years and an eight-percentage-point difference between urban (85%) and rural (93%) restraint use by children one to three years (NHSTA 2009a).

Chapter 3: Data and Methodologies

The following sections provide detailed discussion of the data used in this study and relevant methodologies. In summary, this study used the Chi-Square test and binary logistic regression to identify crash characteristics of children involved in crashes.

3.1 Data

This study used highway crash data from the Kansas Accident Reporting System (KARS) database, which comprises all police-reported crashes in Kansas. Children involved in crashes when traveling by automobile, van, pickup-truck, camper-RV, or sport utility vehicles, during 2004 to 2008, were extracted for this study. As of the beginning date of this study, 2009 crash data were not available for analysis. There were two reasons for this delay: in 2009 KDOT introduced a new Kansas Motor Vehicle Accident Report form (KDOT Form 850A Rev 1-2009). Concurrent with this, KDOT implemented a new crash database called Kansas Crash and Analysis Reporting System (KCARS). The other reason was during its 2010 session, the Kansas Legislature considered a bill that would eliminate KDOT's ability to use prison labor to enter crash data from the accident reports into the database. The bill was stopped with assurance from the Governor's office that KDOT would install the necessary safeguards to prevent prisoners from having access to personal information. As a result of this, KDOT staff needed to work on these safeguards instead of the 2009 data close-out (FWHA, 2011).

The study was originally proposed to investigate restraint use among children aged five to 14 years. However, later on, children between four and 13 years old group were selected as the focus group based on restraint-use requirements in Kansas, and different sub-age group categories were defined as follows:

- Children between four and seven years who are supposed to be restrained in booster seats, and
- Children between eight and 13 years who are supposed to be restrained in seatbelts.

The KARS database includes details about restraint use for all vehicle occupants, including non-injured occupants. Records also contained information about crash circumstances;

weather, road, and light conditions; vehicle damage descriptions; vehicle-related information; and driver-related information. Occupant information consisted of age, gender, exact position within the vehicle, use of safety restraints, and injury severity.

The KARS database from 2004 to 2008 contained 50,155 four- to 13-year-old children involved in crashes that included all level of injury severities such as fatalities, incapacitating injuries, non-incapacitating injuries, possible injuries, and uninjured as shown in Table 3.1.

TABLE 3.1
Children Involved in Crashes Based on Injury Severity

Age in Years	Fatal Injuries	Incapacitating Injuries	Non-Incapacitating Injuries	Possible Injuries	No Injuries	Unknown	Total
4	3	22	203	313	5,144	294	5,979
5	7	26	194	291	4,602	270	5,390
6	3	21	201	292	4,251	243	5,011
7	9	22	186	304	4,090	235	4,846
8	2	30	191	293	3,930	231	4,677
9	3	28	206	305	4,002	219	4,763
10	4	25	223	248	3,929	220	4,649
11	5	23	187	291	3,914	233	4,653
12	7	31	229	274	4,137	253	4,931
13	7	47	295	332	4,285	290	5,256
4-7 yr total	22	91	784	1,200	18,087	1,042	21,226
8-13 yr total	28	184	1,331	1,743	24,197	1,446	28,929
4-13 yr total	50	275	2,115	2,943	42,284	2,488	50,155
4-13 yr %	0.1	0.5	4.2	5.9	84.3	5.0	100.0

Relatively consistent distribution could be seen in each age of crash-involved children within each injury-severity level. Safety equipment use had been categorized into 18 groups in the dataset. However, in this study some of those groups were combined and redefined into five groups as follows: infant seat restraint, child seat restraint, booster seat restraint, seat belt, and non-used. Recent restraint-use percentages of children involved in crashes based on injury severity is shown in Table 3.2. Restraint use was low among fatally injured child occupants, whereas restraint use was higher in the not-injured group.

TABLE 3.2
Percentage Restraint Use among Children Involved in Crashes Based on Injury Severity

Year	Fatal Injuries	Incapacitating Injuries	Non-Incapacitating Injuries	Possible Injuries	No Injuries	Unknown	Total
2004	36%	43%	70%	83%	93%	87%	90%
2005	44%	50%	77%	88%	94%	92%	92%
2006	40%	63%	73%	88%	96%	87%	94%
2007	64%	59%	81%	87%	95%	89%	94%
2008	40%	55%	79%	90%	95%	84%	93%
Total	42%	53%	76%	87%	94%	88%	93%

Another way to obtain information about child restraint-use rates is roadside observational surveys (Kansas Car Seat Laws 2010). KDOT has performed observational surveys for child restraint use annually since 2004. The survey is designed and conducted based on federal guidelines provided in the Uniform Criteria for State Observational Surveys of Seat Belts (Federal Register 2011). This includes guidelines for geographic coverage of the sampling frame and identifying road types required to be included in a state's sampling frame. In Kansas, the survey was performed at 350 sites within the state where children are typically transported (i.e. day cares, department stores, elementary and middle schools) in 20 randomly selected counties, which encompasses 85% of the population of Kansas. In the past, three age groups were observed: zero to four years, five to nine years, and 10–14 years. Child passenger safety restraint use in Kansas has been a primary law since 1981. In 2008, Kansas law changed making 15- to 17-year-old drivers subject to the primary safety belt law. Hence after 2008, another age group, 15- to 17-year-olds, was added to the observational survey. Since 2010, Kansas seat belt use for all age groups, including adults, is primary law.

The survey was conducted in March, April, and May, and observed more than 19,000 children each year. Comparisons of child restraint-use percentages obtained from the observational study and from the KARS database are shown in Figure 3.1. According to observational surveys, child restraint system usage significantly increased after a new booster seat law was introduced in 2006. KARS data has reported higher percentages of safety belt restraint usage than observational studies. Perhaps this could be due to over-reporting of the use of child restraints by crash-involved drivers in order to prevent citations, particularly when injury-severity levels were lower. In the literature, it has been recognized that motorists tend to over-report their safety belt use to police when mandatory belt use becomes law (Li, Kim, and Nitz, 1999).

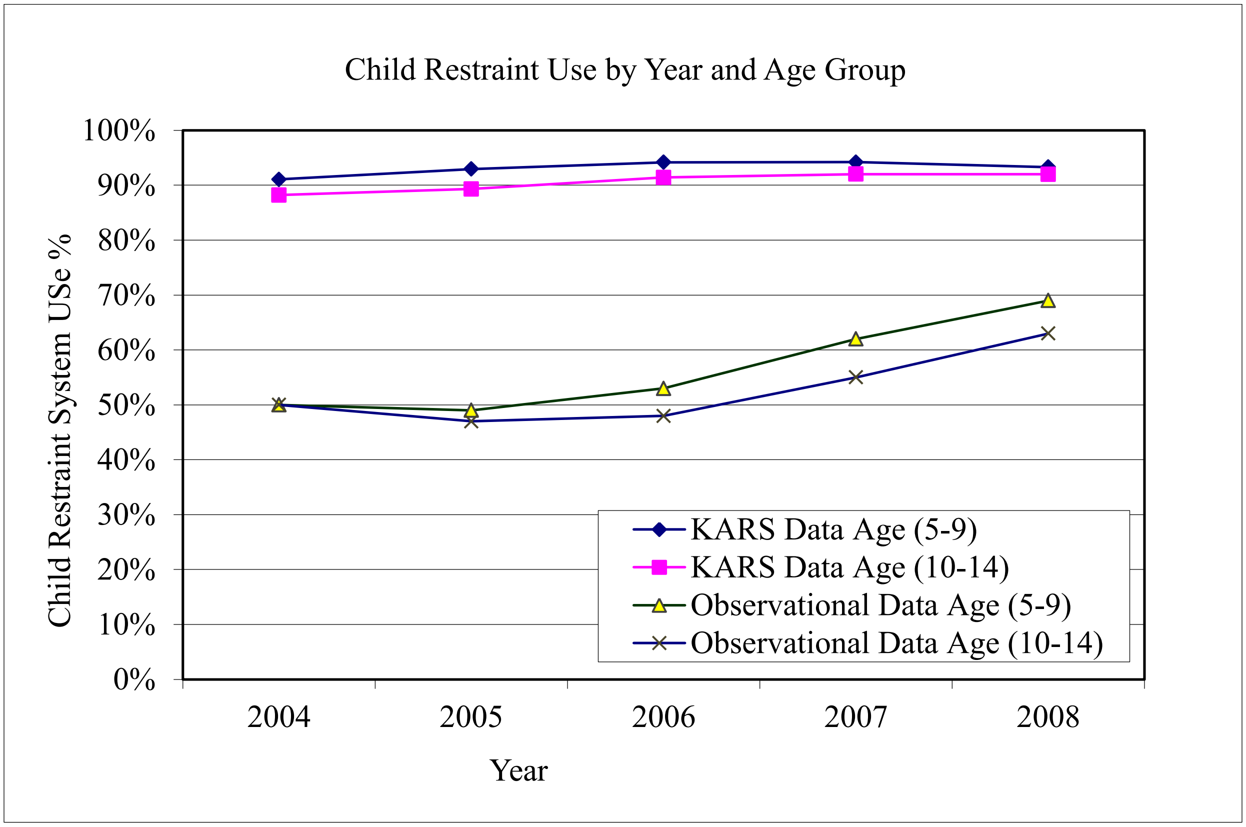


FIGURE 3.1
Child Restraint Usage Rates Based on KARS and Observational Survey Data

3.2 Methodologies

In this study, percentages of restraint use among child passengers in each age group were examined using the KARS data, by pairing drivers with each crash-involved child in the vehicle (Argan, Anderson, and Winn 1998). This method could be used if the driver and at least one child occupant were in the vehicle at the time of the crash. The two occupants in a vehicle are referred to as subject occupant and control occupant. Subject occupant is the person whose characteristics are used to determine the injury risk. The control occupant standardizes the conditions to investigate the restraint effectiveness of the subject occupant. In this study, the control occupant was the driver of the child involved in the crash, while the subject occupant was the child passenger. For example, a driver with two crash-involved children in the vehicle was included in two separate driver-passenger pairs, once for each child with the driver.

3.2.1 Chi-Square Test of Independence

The association between injury severity and characteristics of children involved in crashes were tested using the Chi-Square test statistic. The Chi-Square test of independence is a statistical test commonly used for the determination of significant association between two variables. Requirements to be satisfied to perform the Chi-Square test are as follows (PennState 2010; Anderson, Sweeney, and Williams 2005):

- There must be a representative sample.
- Data must be in frequency form, i.e. not percentages or ratios.
- Individual observations must be independent of each other.
- Sample size must be adequate, i.e. the expected value in any category is greater than 5.
- The sum of observed frequencies must equal the sum of expected frequencies.

As the Chi-Square test uses the contingency table format, it is sometimes referred to as the contingency table test. Let X and Y denote two categorical variables, X having i number of levels and Y having j number of levels. The ij possible combinations of outcomes could be displayed in a rectangular table having i rows for the categories of X and j columns for the categories of Y. As an example, Table 3.3 shows a contingency table of seating position (X) and restraint use (Y). The cells of the table represent the ij possible outcomes.

Characteristics of the occupant, environment, road, vehicle, and crash were compared across different categories of restraint use. The hypothesis assumed was as follows:

H_o : There is no relationship between restraint use and the variable considered.

H_a : There is a relationship between restraint use and the variable considered.

Expected frequencies for the cells of the contingency table are calculated based on the assumption that the null hypothesis is true.

TABLE 3.3
Example of Contingency Table for Seating Position and Restraint Use

Seating position (X)	Restraint use (Y)	
	Restrained	Not restrained
Center front	n_{11}	n_{12}
Right front	n_{21}	n_{22}
Left rear	n_{31}	n_{32}
Center rear	n_{41}	n_{42}
Right rear	n_{51}	n_{52}
Total	n_{+1}	n_{+2}

Then, expected frequencies are calculated as follows:

$$\boldsymbol{Expected\ frequency} = \frac{(\boldsymbol{Row\ i\ total})-(\boldsymbol{Column\ j\ total})}{\boldsymbol{Sample\ size}}$$ **Equation 3.1**

The Chi-Square value is then calculated using the formula

$$\mathbf{x^2} = \sum \frac{(\textbf{Observed frequency} - \textbf{Expected frequency})^2}{\textbf{Expected frequency}}$$ **Equation 3.2**

Where observed frequency is the frequency obtained for a sample and expected frequency is the one which is expected to occur under similar conditions. Testing the hypothesis and calculating Chi-Square are carried out as follows:

1. State the hypothesis being tested.
2. Determine expected numbers for each observational class.
3. Calculate Chi-Square using the formula (3.2).
4. Use the Chi-Square distribution table to determine the table value.
5. State the conclusion in terms of the hypothesis.

If the p-value for the calculated Chi-Square is greater than 0.05, the hypothesis is accepted at a 95% confidence level. If the p-value for the calculated Chi-Square is less than 0.05, the hypothesis is rejected and it is concluded that observed numbers are significantly different from the expected.

3.2.2 Logistic Regression Analysis

Logistic regression analysis was used to determine the relative effect of usage of child restraint systems when children are involved in crashes. Injury severity was selected as the dependent variable in the model, which investigated characteristics related to restraint use. The dependent variable, injury severity, has several discrete categories. The nature of the dependent variable facilitates the application of logistic analysis, for which the probability of severe injury against slight injury categories is estimated by the maximum likelihood method (45). Logistic-based models have been widely used for traffic safety analysis.

The logistic regression model takes the natural logarithm of the odds as a regression function of the predictors. The logistic model was first introduced in the context of binary choice where the logistic distribution is used. The binary logistic regression model has its basis in the odds of a two-level outcome of interest. Practitioners and researchers have used, refined, and extended the binary logistic model to obtain a class of models based on similar assumptions. This class of models is referred as the logistic family. In the logistic model, a dependent variable is formulated by the following expression (Long, 1997):

$$\boldsymbol{g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_j x_j + \cdots + \beta_p x_p},$$ **Equation 3.3**

where

x_j = value of the j^{th} independent variable,

β_j = corresponding coefficient of the j^{th} independent variable, and

p = number of independent variables.

With independent variables, the conditional probability of a positive outcome is determined by

$$\boldsymbol{\pi(x) = \frac{exp(g(x))}{1+exp(g(x))}}$$ **Equation 3.4**

where

$\pi(x)$ = conditional probability, and

The maximum likelihood method is then employed to measure the associations by constructing the likelihood function as follows:

$$\boldsymbol{l(\beta) = \prod_{i=1}^{n} \pi(x_i)^{y_i} (1 - \pi(x_i))^{1-y_i}} \qquad \textbf{Equation 3.5}$$

where

l (β) = likelihood function;

π (x_i) = conditional probability of the dependent variable;

y_i = i^{th} observed outcome, with the value of either 0 or 1 only; and

i = 1, 2, 3, …, n, where n is the number of observations.

The log likelihood expression is considered to maximize the likelihood function in order to obtain the coefficients estimates.

$$\boldsymbol{LL(\beta) = ln\big(l(\beta)\big) = \sum_{i=1}^{n}\{y_i ln\left(\pi(x_i)\right) + (1 - y_i) ln(1 - \pi(x_i))\}} \qquad \textbf{Equation 3.6}$$

where

LL(β) = log likelihood function;

l(β) = likelihood function;

π(x_i) = conditional probability of the dependent variable;

y_i = i^{th} observed outcome, with the value of either 0 or 1 only; and

i = 1, 2, 3, …, n, where n is the number of observations.

Maximization typically requires an iterative numerical method, which means it involves successive approximations. The best estimate of β could be obtained accordingly.

The goodness-of-fit of the predictive model should be assessed for significance and productive power.

3.2.2.1 G-Test

To evaluate the significance and predictive power of the logistic regression model, the change in deviance can be determined by comparing the log likelihood functions between the unrestricted model and the restricted model, under the null hypothesis that coefficients for the predictive model are equal to zero, with the following expression:

$$\boldsymbol{G = -2(LL(c) - LL(\theta))}$$ **Equation 3.7**

where

$LL(c)$ = log likelihood function of the restricted model,

$LL(\theta)$ = log likelihood function of the unrestricted model,

G = Chi-Square distributed with p degrees of freedom, and

p = number of variables that are considered.

If *G* is significant at the 5% level, then the null hypothesis would be rejected and one could conclude the proposed model generally fit well with the observed outcome.

3.2.2.2 Likelihood Ratio (LR)

The likelihood ratio Chi-Square test shows at least one of the predictors' regression coefficients is not equal to zero in the model. The LR Chi-Square statistic can be calculated by

LR= -2 Log L(null model) - 2 Log L(fitted model) **Equation 3.8**

where

L(null model) = likelihood of the intercept only model, and

L(fitted model) = likelihood of the intercept and covariates model.

The LR test can be used to compare any pair of nested models, but it requires using the same sample for all models being compared. Hence, it is important to ensure the sample size does not change by excluding every observation that has missing values for any of the variables used in any of the models being tested (46).

3.2.2.3 Score

The Score Chi-Square test shows at least one of the predictors' regression coefficients is not equal to zero in the model.

3.2.2.4 Akaike Information Criterion (AIC)

This is calculated as

$$\mathbf{AIC = -2\ Log\ L + 2((k-1) + s)} \qquad \textbf{Equation 3.9}$$

where

L = maximized likelihood function,

k = number of levels of the dependent variable, and

s = number of predictors in the model.

AIC is used for comparison of models from different samples or non-nested models that cannot be compared with the LR test. Ultimately, the model with the smallest AIC is considered the best. All else being equal, the model with the smallest AIC is considered the better fitting model (46).

3.2.2.5 Schwarz Criterion (SC)

This is defined as

$$\mathbf{SC = -2\ Log\ L + ((k-1) + s) \times \log(\Sigma f_i)} \qquad \textbf{Equation 3.10}$$

where

L = maximized likelihood function,

f_i = frequency values of the ith observation,

k = number of levels of the dependent variable, and

s = number of predictors in the model.

Like AIC, SC penalizes for the number of predictors in the model and the smallest SC is most desirable.

3.2.2.6 Hosmer and Lamsehow (H-L) Statistic

The H–L statistic is a Pearson Chi-Square statistic, which is an inferential goodness-of-fit test for logistic regression models. The test evaluates whether the logistic regression model is well calibrated so that probability predictions from the model reflect the occurrence of events in the data. Obtaining a significant result on the test would indicate the model is not well calibrated, so the fit is not good. In other words, the null hypothesis of a good model fit to data was tenable. In this test, data are divided into approximately 10 groups of roughly the same size, based on the percentile of the estimated logistic probabilities. The predicted probability of having the event according to the model is as follows: group 1 has data with predicted probabilities in the 1st to 10th percentiles; group 2 has data with predicted probabilities in the 11th to 20th percentiles; and so on. If the observed and expected numbers of events are very different in any group, then the model is judged not to fit (Vally 2011).

3.2.2.7 Multicollinearity

In some cases, logistic regression results may seem paradoxical, which means the model fits the data well, even though none of the independent variables has a statistically significant impact on predicting the dependent variable (Long 1997). When two independent variables are highly correlated, they both convey essentially the same information. In this case, the variables may seem to have little effect simply because they overlap considerably in the model. If both variables were removed from the model, the fit would be much worse. When this happens, the independent variables are collinear and the results show multicollinearity.

In traffic safety analysis, the goal is to understand how various independent variables impact the dependent variable; hence, multicollinearity is a considerable problem. One problem is that even though the variable is important, model results may show that it is not significant. The second problem is that the confidence intervals on the model coefficients could be very wide. To help to assess multicollinearity, the correlation matrix of the independent variables can be investigated. If the element of correlation matrix has high value, model fit is affected by the multicollinearity of independent variables corresponding to that element. Also, each independent variable can be predicted from the other independent variables. If the model fit statistic such as individual R^2 value and a Variance Inflation Factor (VIF) are high for any of the independent variables, it could be concluded the variables are multicollinear.

3.2.3 Odds Ratio

To measure the strength of association between the variables, Odds Ratios (ORs) and 95% Confidence Intervals (CIs) are calculated. The OR is a widely used statistics in traffic safety studies for comparing whether the probability of a certain event is the same for two groups (Allison 2001). The "odds" of an event (y) is defined as the probability of the outcome event occurring $(y = 1/x_1, x_2, \ldots\ldots, x_p)$ divided by the probability of the event not occurring $(y = 0/x_1, x_2, \ldots\ldots, x_p)$. Then the odds ratio is given by

$$\boldsymbol{Odds} = \frac{\boldsymbol{P(y=1/x_1, x_2, \ldots\ldots\ldots, x_p)}}{\boldsymbol{P(y=0/x_1, x_2, \ldots\ldots\ldots, x_p)}}$$ **Equation 3.11**

where

$P(y = 1/x_1, x_2 \ldots, x_p)$ = probability of the outcome event occurring, and

$P(y = 0/x_1, x_2 \ldots, x_p)$ = probability of the outcome event not occurring.

The odds ratio for a predictor is defined as the relative amount by which the odds ($odds_1$) of the outcome increase (OR > 1.0) or decrease (OR < 1.0) when the value of one of the predictor variables ($odds_0$) is increased by 1.0 unit.

$$\boldsymbol{odds\ ratio} = \frac{\boldsymbol{odds_1}}{\boldsymbol{odds_0}}$$ **Equation 3.12**

In the logistic analysis, the influence of a particular attribute k on injury outcome could be revealed by the odds ratio (OR).

$$\boldsymbol{OR} = \boldsymbol{exp(\beta_j)}$$ **Equation 3.13**

where

β_j = the corresponding coefficient of the j^{th} independent variable of a logistic model.

The confident interval at 95% is given by

$$\left(\boldsymbol{exp}\left(\boldsymbol{\beta_j} - \mathbf{1.96}\boldsymbol{s_{\beta_j}}\right), \boldsymbol{exp}(\boldsymbol{\beta_j} + \mathbf{1.96}\boldsymbol{s_{\beta_j}} = \boldsymbol{exp}\left(\boldsymbol{\beta_j}\right)\right) \quad \textbf{Equation 3.14}$$

where

s_β = the standard error of the coefficient β.

An odds ratio greater than 1 indicates the concerned attribute leads to a higher injury risk, and vice versa. These might be better described as adjusted odds ratios because they control for other variables in the model.

Chapter 4: Results

This chapter presents a descriptive analysis of the data related to children involved in crashes, and results of Chi Square test statistics, odds ratios, and logistic analysis.

4.1 Characteristics of Children Involved in Crashes

This study was limited to child passengers aged four to13 traveling with drivers older than 13 years. Table 4.1 shows age of the driver for children involved in crashes from 2004 to 2008. A majority of the children (68%) were traveling with 25- to 44-year-old drivers at the time of the crashes, perhaps because the majority of parents are in that age group.

TABLE 4.1
Age of Driver for Children Involved in Crashes

Child Passenger Age		Driver Age (Years)							
Group	Years	<15	15-24	25-34	35-44	45-54	55-64	>65	Total
4 - 7	4	2	955	2,886	1,474	402	191	69	5,979
	5	7	723	2,467	1,490	416	212	75	5,390
	6	7	534	2,190	1,576	429	179	96	5,011
	7	10	401	2,035	1,662	437	210	91	4,846
8- 13	8	9	371	1,778	1,717	474	229	99	4,677
	9	11	411	1,541	1,876	562	239	123	4,763
	10	15	496	1,282	1,868	657	208	123	4,649
	11	31	601	1,098	1,879	723	205	116	4,653
	12	38	827	893	1,909	888	233	143	4,931
	13	70	1,432	718	1,785	882	227	142	5,256
Total		200	6,751	16,888	17,236	5,870	2,133	1,077	50,155
		0%	13%	34%	34%	12%	4%	2%	100%

Table 4.2 presents crash-related characteristics in which children were involved for the child age groups four to seven years, eight to13 years, and four to13 years. For crashes involving children, a majority of the vehicles were going straight at the time of crash. Vehicle maneuver is important because it offers an indication of the reasons that led to the crash in terms of

movements and actions a driver may have chosen to perform. Collision with a vehicle was the main crash type, and non-collision and overturned occurred less frequently.

TABLE 4.2
Crash-Related Characteristics for Crashes Involving Children

Crash-Related Characteristics	Children (aged 4-7 years)		Children (aged 8-13 years)		Children (aged 4-13 years)	
	Number	(%)	Number	(%)	Number	(%)
Vehicle Maneuver						
Straight-following road	12,657	59.6	17,222	59.5	29,879	59.6
Turn or changing lanes	2,947	13.9	4,257	14.7	7,204	14.4
Avoiding maneuver	551	2.6	698	2.4	1,249	2.5
Stopped, parking, or backing	4,906	23.1	6,560	22.7	11,466	22.9
Other	165	0.8	192	0.7	357	0.7
Accident Class						
Collision with a vehicle	16,474	77.6	21,821	75.4	38,295	76.4
Collision with pedestrian/animal	2,382	11.2	3,711	12.8	6,093	12.1
Collision with an object	1,847	8.7	2,517	8.7	4,364	8.7
Other non-collision and overturned	523	2.5	880	3.0	1,403	2.8

Table 4.3 presents driver-related attributes for crashes where children were involved. Factors examined include injury severity, gender, license compliance, restraint use, and alcohol involvement. Driver injury-severity distributions indicated that 0.2% of drivers were injured in the crashes where children were involved. Gender distribution showed that females were more likely to be the driver when children were involved in crashes. The proportion of female drivers was slightly higher in crashes where children aged four to seven were involved than that of children aged eight to 13. Also, a considerable number of violations, such as safety belts not being used, alcohol involvement, and driving with invalid licenses, can be observed among drivers who were riding with children involved in crashes.

Child passengers' characteristics were also investigated in order to identify differences among them. According to Table 4.4, by looking at injury severity of the child passengers, there were a considerable number of children injured in crashes. Gender of the child passenger was equally distributed among children involved in crashes. As might be expected, a large percentage of children in both age groups were restrained and not ejected at the time of the crash.

TABLE 4.3
Driver-Related Characteristics for Crashes Involving Children

Driver-Related Characteristics	Children (aged 4-7 years)		Children (aged 8-13 years)		Children (aged 4-13 years)	
	Number	(%)	Number	(%)	Number	(%)
Driver Injury Severity						
Fatal injury	34	0.2	46	0.2	80	0.2
Incapacitating injury	146	0.7	220	0.8	366	0.8
Non incapacitating injury	1,074	5.3	1,544	5.6	2,618	5.5
Possible injury	1,547	7.7	1,980	7.2	3,527	7.4
Not injured	17,334	86.1	23,621	86.2	40,955	86.1
Driver Gender						
Female	14,226	67.0	18,147	66.2	32,373	64.6
Male	6,997	33.0	10,777	39.3	17,774	35.4
Driver License Compliance						
Valid license	19,759	93.9	27,224	94.8	46,983	94.4
Not licensed or invalid licensed	1,278	6.1	1,484	5.2	2,762	5.6
Driver Safety Belt Use	19,923	93.9	27,102	93.7	47,025	93.8
Alcohol Involvement	140	0.7	183	0.6	323	0.6
Driver Ejection						
Ejected	36	0.2	58	0.2	94	0.2
Not ejected	19,893	99.4	27,092	99.3	46,985	99.3
Trapped	79	0.4	136	0.5	215	0.5

A considerable percentage of children aged four to seven, who were supposed to be restrained in booster seats, were restrained by seatbelt only when they were involved in crashes. Also, it was interesting to note that nearly 4.0% of child passengers were not restrained at the time of the crash, leading to significant safety risks.

Table 4.5 shows environment- and road-related characteristics of crashes where children were involved. A majority of these crashes occurred during daytime, perhaps because children mostly travel during daytime. A large number of children-involved crashes seemed to occur in the afternoon and evening this might happen due to a high frequency of children’s travel during those hours. A majority of the crashes took place under no adverse weather conditions. Also, many crashes occurred on weekdays reflecting that children frequently traveled on weekdays.

TABLE 4.4
Child Passenger-Related Characteristics for Crashes Involving Children

Child Passenger-Related Characteristics	Children (aged 4-7 years)		Children (aged 8-13 years)		Children (aged 4-13 years)	
	Number	(%)	Number	(%)	Number	(%)
Child Injury Severity						
Fatal injury	22	0.1	28	0.1	50	0.1
Disabled (incapacitating)	91	0.5	184	0.7	275	0.6
Injury, not incapacitating	784	3.9	1,331	4.8	2,115	4.4
Possible injury	1,200	5.9	1,743	6.3	2,943	6.2
Not injured	18,087	89.6	24,197	88.0	42,284	88.7
Child Gender						
Female	10,330	48.8	14,570	50.4	24,900	49.7
Male	10,845	51.2	14,316	49.6	25,161	50.3
Child Safety Restraint						
Child/booster seat used	10,955	53.1	661	2.4	11,616	24.0
Seat belt used	8,965	43.5	25,938	93.2	34,903	72.0
None	709	3.4	1,246	4.5	1,955	4.0
Child Ejection						
Ejected	59	0.3	114	0.4	173	0.4
Not ejected	19,977	99.5	27,158	99.3	47,135	99.4
Trapped	48	0.2	74	0.3	122	0.3

TABLE 4.5
Environment-Related Characteristics for Crashes Involving Children

Environment-Related Characteristics	Children (aged 4-7 years)		Children (aged 8-13 years)		Children (aged 4-13 years)	
	Number	(%)	Number	(%)	Number	(%)
Light Condition						
Daylight	15,916	75.1	20,751	71.9	36,667	73.3
Not daylight	5,278	24.9	8,105	28.1	13,383	26.7
Weather Condition						
No adverse conditions	18,008	85.1	24,538	85.1	42,546	85.1
Rain	1,904	9.0	2,652	9.2	4,556	9.1
Adverse conditions	1,255	5.9	1,638	5.7	2,893	5.8
Time of Crash						
5.00 - 9.00	2,343	11.0	3,209	11.1	5,552	11.1
9.00 - 13.00	4,015	18.9	4,492	15.5	8,507	17.0
13.00 - 17.00	6,759	31.9	9,120	31.5	15,879	31.7
17.00 - 21.00	6,417	30.2	9,188	31.8	15,605	31.1
21.00 - 5.00	1,685	7.9	2,912	10.1	4,597	9.2
Day of Week						
Weekdays	15,402	72.6	19,858	68.7	35,260	70.3
Weekend	5,824	27.4	9,066	31.3	14,890	29.7

As indicated in Table 4.6, most of the crashes that involved four- to13-year-old children occurred on urban arterials and urban local streets. A higher proportion of children-involved crashes occurred on non-intersection roadways. A majority of the crashes took place when driving in dry road surfaces. It was important to note that road surface conditions and weather conditions at the time of the crash have a relationship. Crashes on dry roads, and straight and level surface characteristics were the most prevalent crash conditions for both age categories. The reason for having many crashes under these conditions was perhaps related to the exposure, as children more frequently travel in these conditions. About 2.8% of crashes that involved children occurred in work zones.

TABLE 4.6
Road-Related Characteristics for Crashes Involving Children

Road-Related Characteristics	Children (aged 4-7 years)		Children (aged 8-13 years)		Children (aged 4-13 years)	
	Number	(%)	Number	(%)	Number	(%)
Functional Class						
Rural interstate	669	3.2	938	3.2	1,607	3.2
Rural arterial	2,360	11.1	3,378	11.7	5,738	11.4
Rural collector	1,513	7.1	2,486	8.6	3,999	8.0
Rural local street	1,263	6.0	1,939	6.7	3,202	6.4
Urban interstate	2,065	9.7	2,538	8.8	4,603	9.2
Urban arterial	9,503	44.8	12,290	42.5	21,793	43.5
Urban collector	1,328	6.3	1,879	6.5	3,207	6.4
Urban local street	2,524	11.9	3,481	12.0	6,005	12.0
Crash Location						
Non-intersection-on roadway	10,822	51.0	14,911	51.5	25,733	51.3
Intersection-on roadway	9,718	45.8	13,032	45.0	22,750	45.4
Off roadway	684	3.2	985	3.4	1,669	3.3
Road Surface Condition						
Dry	17,147	81.0	23,360	81.0	40,507	81.0
Wet	2,527	11.9	3,476	12.1	6,003	12.0
Debris	1,491	7.0	1,998	6.9	3,489	7.0
Work Zone	604	2.8	777	2.7	1,381	2.8
Road Surface Character						
Straight and level	15,916	75.4	21,636	75.2	37,552	75.3
Straight not level	4,008	19.0	5,540	19.3	9,548	19.1
Curved	1,184	5.6	1,592	5.5	2,776	5.6

Frequencies and percentages of vehicle-related characteristics of children-involved crashes are listed in Table 4.7. In most cases the vehicle was function able after the crash, which might match the fact that many children-involved crashes belong to the "not injured" injury-severity category. A majority of crashes involved automobiles, most likely because this was the most common vehicle type in the vehicle population and also carrying children.

TABLE 4.7
Vehicle-Related Characteristics for Crashes Involving Children

Vehicle-Related Characteristics	Children (aged 4-7 years)		Children (aged 8-13 years)		Children (aged 4-13 years)	
	Number	(%)	Number	(%)	Number	(%)
Vehicle Damage						
None	537	2.5	718	2.5	1,255	2.5
Damaged	6,019	28.5	8,206	28.5	14,225	28.5
Functional	8,065	38.2	10,961	38.1	19,026	38.1
Disabling	5,583	26.4	7,560	26.3	13,143	26.3
Destroyed	916	4.3	1,346	4.7	2,262	4.5
Vehicle Body type						
Automobile	9,076	42.8	12,375	42.8	21,451	42.8
Van	5,010	23.6	6,142	21.2	11,152	22.2
Pickup-truck, camper-rv	2,221	10.5	3,701	12.8	5,922	11.8
Sport utility vehicle	4,883	23.0	6,641	23.0	11,524	23.0
Other	36	0.2	70	0.2	106	0.2

An occupant was categorized as seat belt restrained if a lap and/or shoulder belt was used at the time of the crash. According to Table 4.8, among four- to seven-year-old child passengers involved in crashes, only 29% used booster seats, while 22% still used child seats, and 1% used infant restraints. Even though the law required use of booster seats in this age group, the majority (42%) of children used only seat belts and 3% of children were not restrained. Almost 90% of children in age group eight to 13 were reported to be using seat belts, while 4% were not restrained at the time of crash. Restraint categories of lap belt only, air bag deployed and lap belt only, and shoulder belt only, where the seat belt restraint requirements have not been fully satisfied, were also investigated and percentages are presented in Table 4.9.

TABLE 4.8
Children in Crashes Based on Type of Safety Restraint Used (2004–2008)

Child Passenger Age		Safety Restraint Use						
Group	Years	Infant seat	Child seat	Booster seat	Seat belt	Non used	unknown	Total
4 - 7	4	81	3,259	773	1,556	176	134	5,979
	5	42	1,228	1,647	2,153	172	148	5,390
	6	17	67	2,122	2,470	173	162	5,011
	7	10	27	1,682	2,786	188	153	4,846
Sub Total		150	4,581	6,224	8,965	709	597	21,226
		1%	22%	29%	42%	3%	3%	100%
8- 13	8	7	12	632	3,705	160	161	4,677
	9	0	1	5	4,368	189	200	4,763
	10	0	0	1	4,292	188	168	4,649
	11	1	0	1	4,311	198	142	4,653
	12	0	0	1	4,528	225	177	4,931
	13	0	0	0	4,734	286	236	5,256
Sub Total		8	13	640	25,938	1,246	1,084	28,929
		0%	0%	2%	90%	4%	4%	100%
Total		158	4,594	6,864	34,903	1,955	1,681	50,155
		0%	9%	14%	70%	4%	3%	100%

TABLE 4.9
Proper Use of Seat Belt Restraint among Children Involved in Crashes

Child Passenger Age		Total Passengers Involved in Crashes	Restrained		Lap or Should Belt Only	
Group	Years		Passengers	% out of total	Passengers	% out of restraint
4 - 7	4	5,979	5,669	95%	185	3%
	5	5,390	5,070	94%	277	5%
	6	5,011	4,676	93%	237	5%
	7	4,846	4,505	93%	251	6%
8- 13	8	4,677	4,356	93%	292	7%
	9	4,763	4,374	92%	267	6%
	10	4,649	4,293	92%	256	6%
	11	4,653	4,313	93%	250	6%
	12	4,931	4,529	92%	246	5%
	13	5,256	4,734	90%	220	5%
Total		50,155	46,519	93%	2,481	5%

Percent restraint use of children by age is presented in Figure 4.1. Restraint use among children involved in crashes was lower among older children compared to younger children.

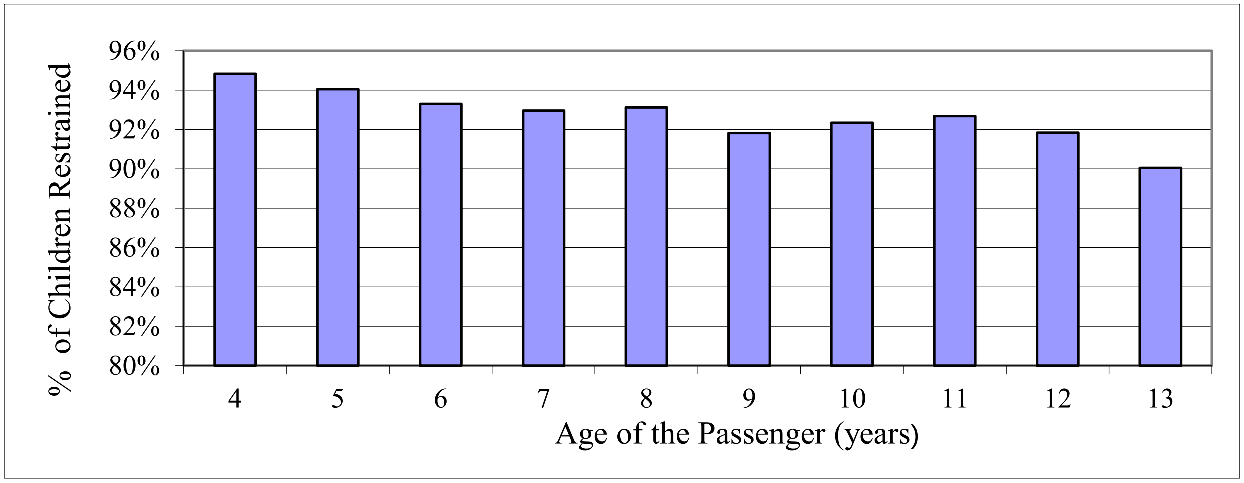


FIGURE 4.1
Percent Restraint Use of Children in Crashes by Age

Restraint use among children involved in crashes decreased with an increased number of other occupants in the vehicle as shown in Figure 4.2. This trend towards failure to restrain children in the presence of other occupants was disconcerting as one might expect that the influence of others in the vehicle would have a positive influence on restraining children. On the other hand, it could be that limited space and number of seat belts needing to be utilized became a problem with an increasing number of occupants.

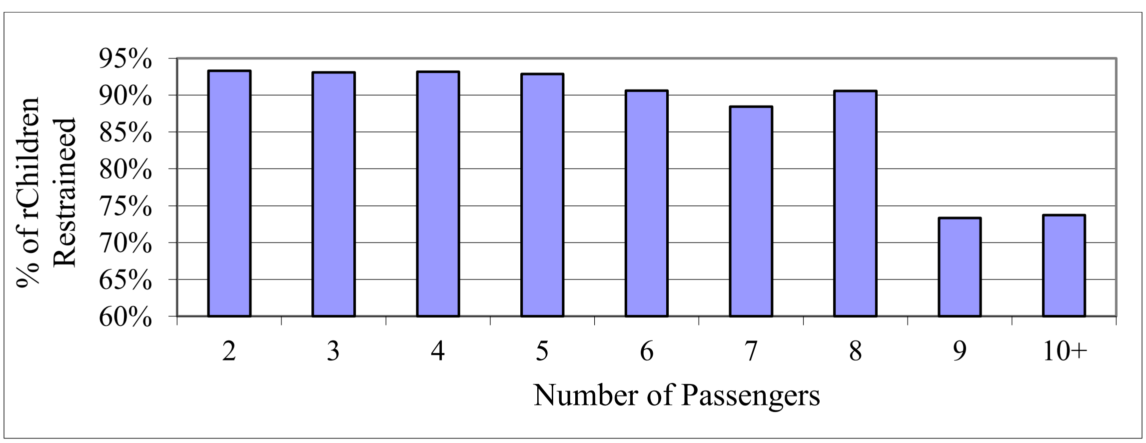


FIGURE 4.2
Percent Restraint Use of Children in Crashes by Number of Passengers

Use of restraints was substantially lower in older vehicle models as shown in Figure 4.3. Perhaps this was in part reflecting the lack of availability of seat belts, discomfort, or poor fit of restraint in older vehicle designs. Restraint use was lower among children in camper-RVs and farm equipment, as shown in Figure 4.4. This may reflect the lack of availability of restraints or characteristics of drivers of these vehicles.

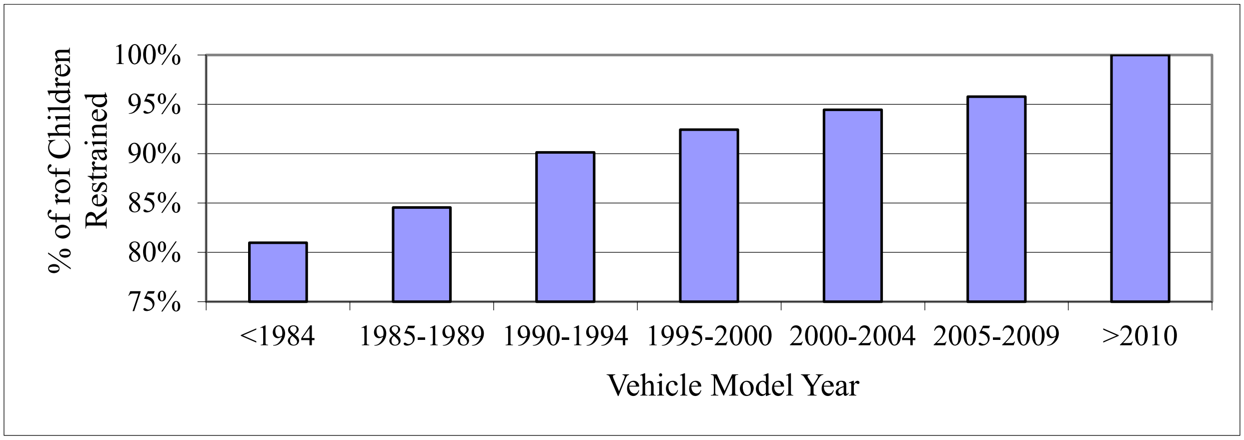


FIGURE 4.3
Percent Restraint Use of Children in Crashes by Vehicle Model Year

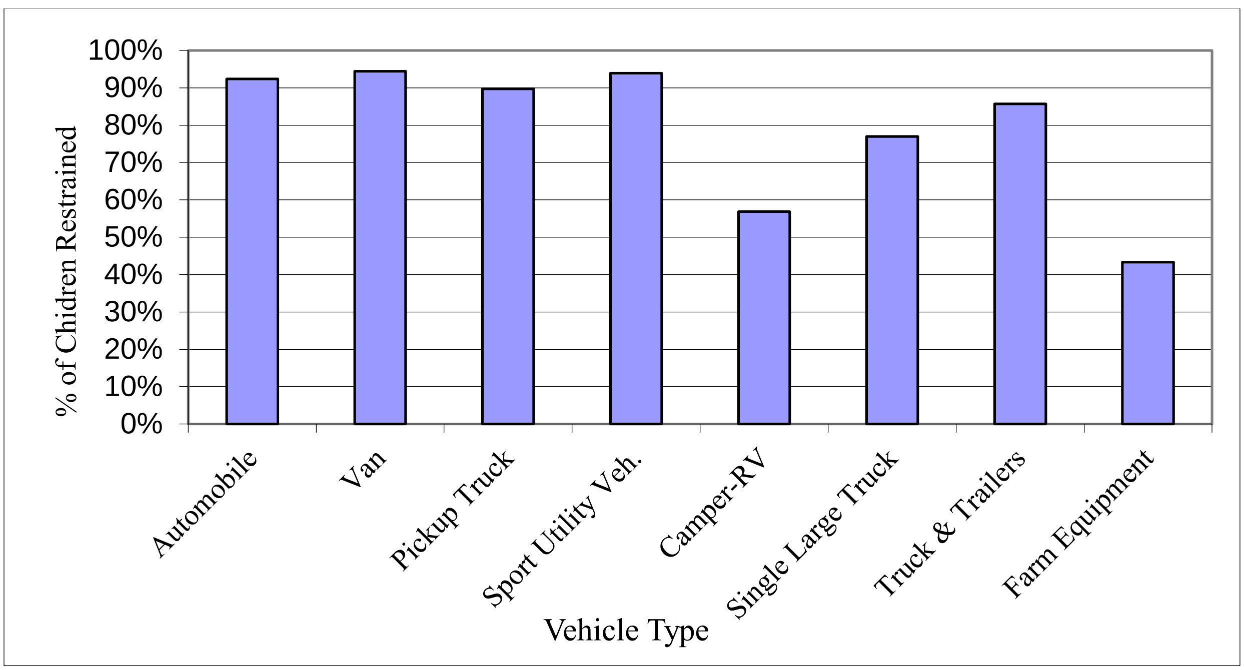


FIGURE 4.4
Percent Restraint Use of Children in Crashes by Vehicle Type

Restraint use was lower for crashes that occurred during late night and early morning hours as shown in Figure 4.5. Night travel might involve longer trips on different types of roadways than daylight travel, and children might be allowed to ride unrestrained so they can lay down or sleep during the late hours, possibly leading to the situation. Restraint use by children was also related to driver characteristics. More children were restrained in vehicles with drivers 25 years or older than in vehicles with younger drivers as shown in Figure 4.6.

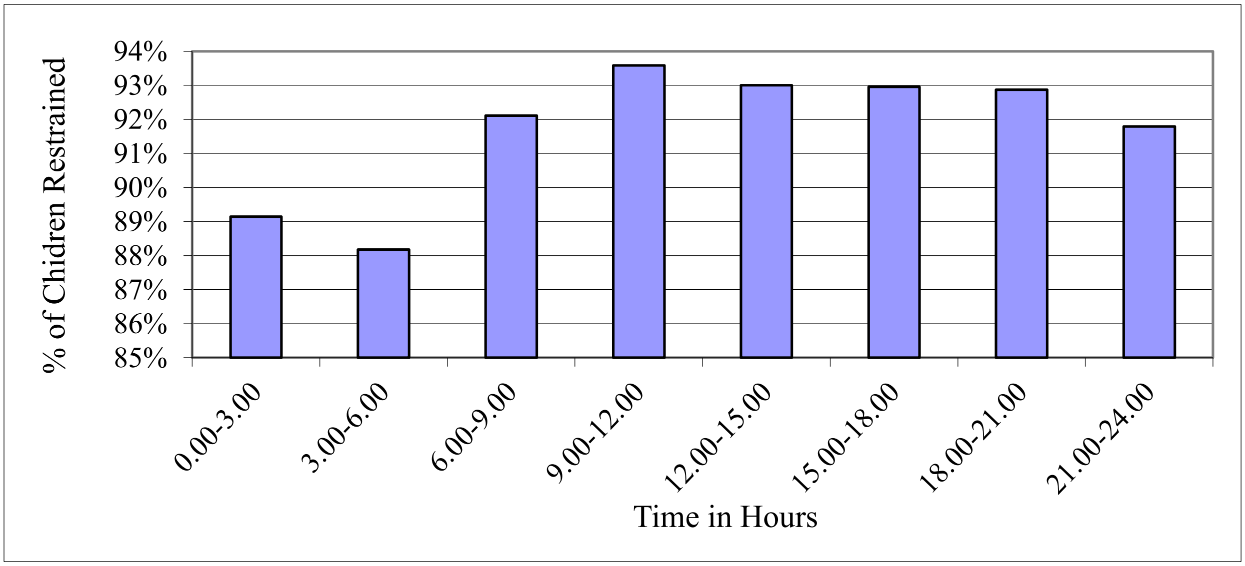


FIGURE 4.5
Percent Restraint Use of Children in Crashes by Time of Day

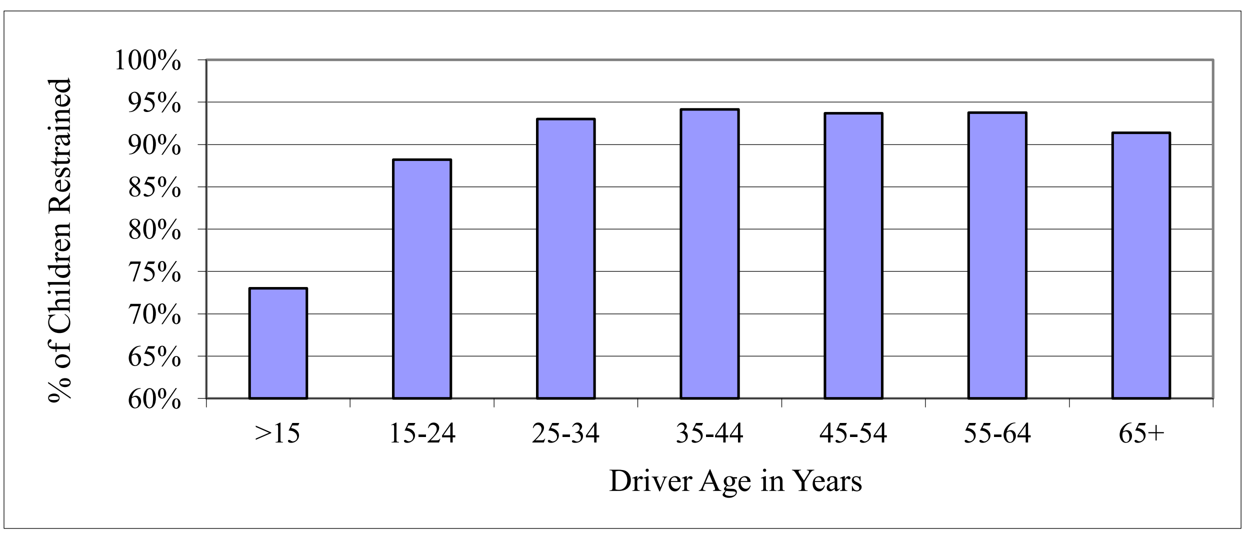


FIGURE 4.6
Percent Restraint Use of Children in Crashes by Driver Age

Driver restraint use strongly influenced restraint use by children as shown in Figure 4.7. Children were more likely to be restrained in vehicles with restrained drivers. About 96% of children involved in crashes were restrained when the driver was also restrained. However, when the driver was not restrained the percentage of children who were restrained reduced considerably to 55%.

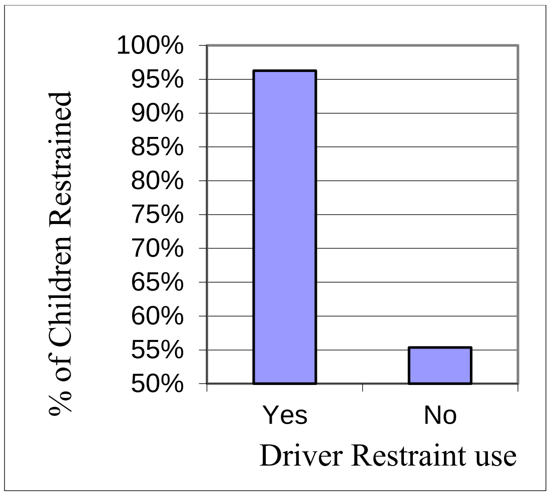


FIGURE 4.7
Percent Restraint Use of Children in Crashes by Driver Restraint Use

Figure 4.8 illustrates restraint use by children by age group when they were traveling with restrained drivers. When the driver was restrained, 53% of children ages four to seven were restrained in booster seats or child seats. Even though the law required use of booster seats in this age group, a considerable percentage (44%) of children used only seat belts and 2% of children were not restrained while riding with a restrained driver. When the driver was restrained, 94 % of children ages eight to 13 were restrained in seat belts as required. However, 2% of children were still in child seats and 2% of children were not restrained.

Figure 4.9 shows restraint use in crashes involving children traveling in a vehicle where the driver was unrestrained. Only 27% of children ages four to seven, who were riding with an unrestrained driver, were restrained by booster seat or child seat at the time of the crash. Another 28% of these children were restrained by seat belts and 42% were unrestrained. In the older age group, the percentage of unrestrained child passengers who were riding with unrestrained drivers was higher than with the younger age group. This can be observed among children traveling with restrained drivers as well.

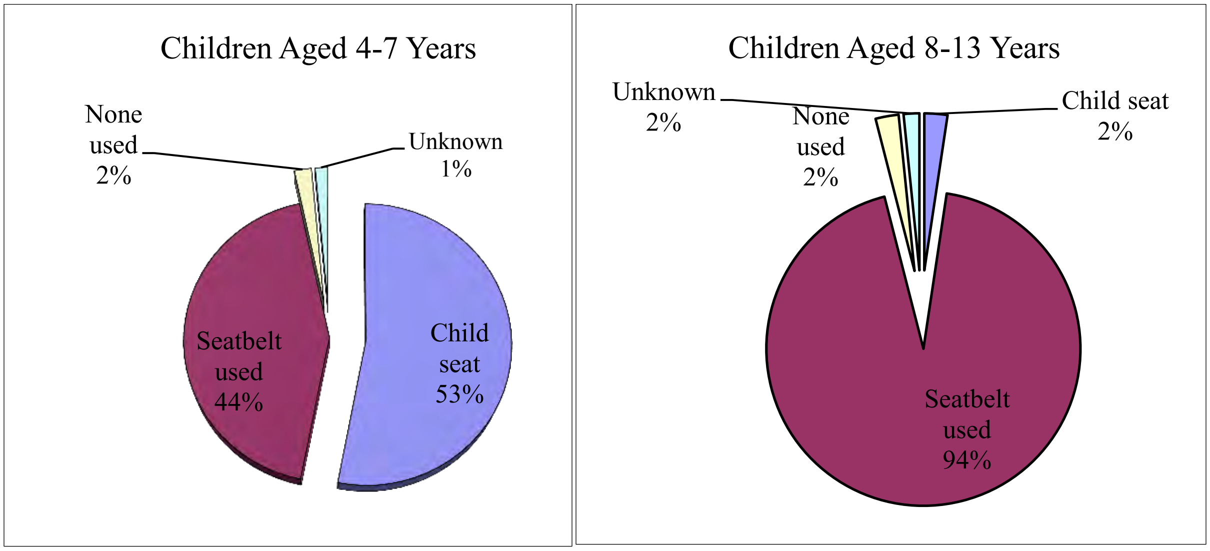


FIGURE 4.8
Child Passengers' Restraint Use when Traveling with Restrained Drivers

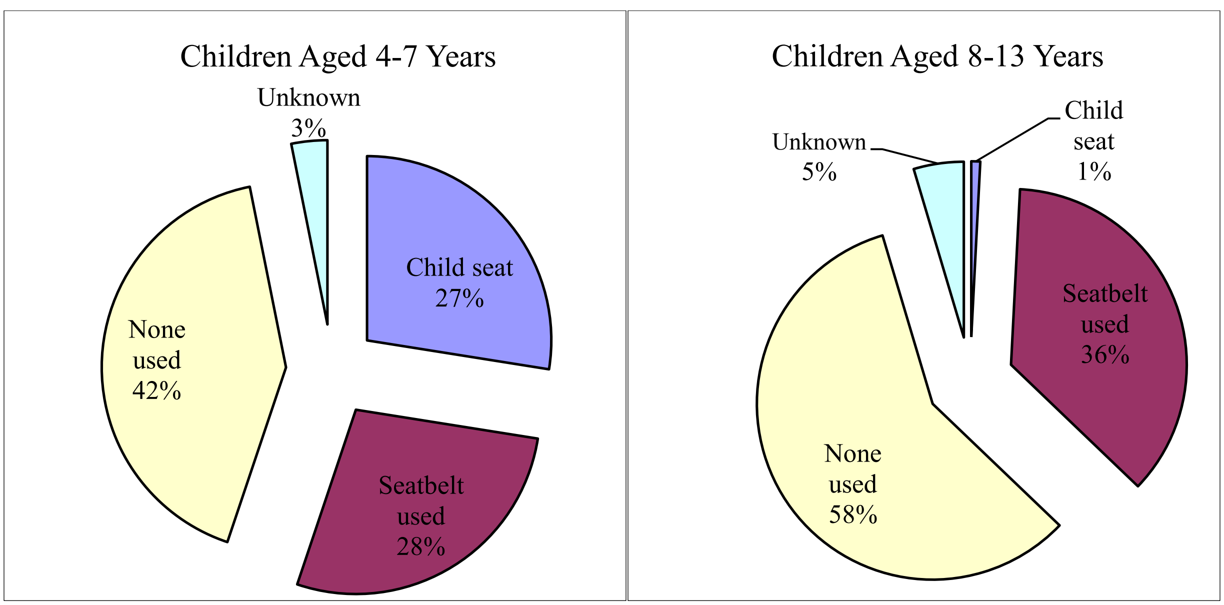


FIGURE 4.9
Child Passengers' Restraint Use when Traveling with Unrestrained Drivers

When looking at combined crash data from 2004-2008, child restraint use was lower in rural areas as compared to that of urban areas as shown Figure 4.10. The level of enforcement in rural areas might be lower than in urban areas, which might have contributed to the situation. Also, rural travel might also involve longer trips, and children might be allowed to ride unrestrained so they can lie down and sleep during trips, possibly leading to the situation.

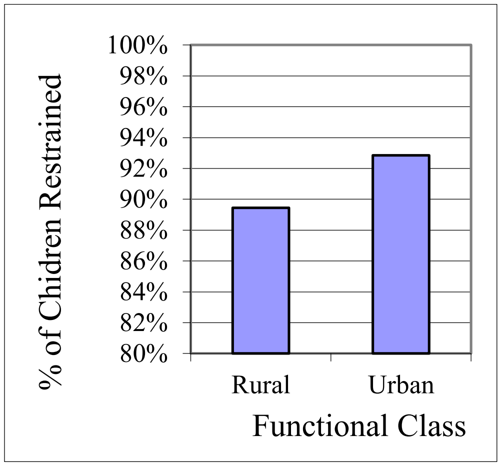


FIGURE 4.10
Percent Restraint Use of Children in Crashes by Roadway Functional Class

Child restraint use by children involved in crashes was also slightly lower on Sundays as shown in Figure 4.11. An increase in recreational social activities on Sundays and different characteristics of these trips might have played a role in this.

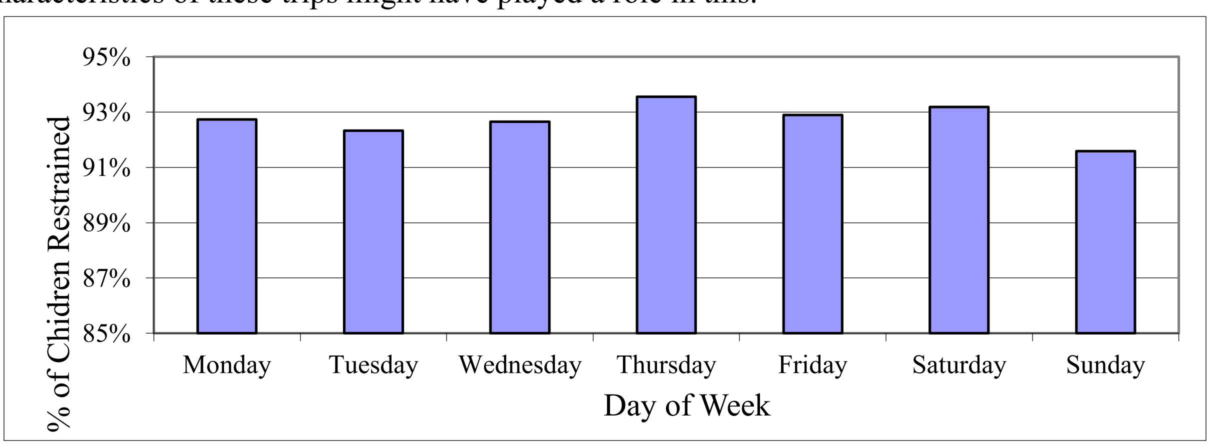


FIGURE 4.11
Percent Restraint Use of Children Involved in Crashes by Day of Week

Driver alcohol use was associated with lower restraint use by children as shown in Figure 4.12(a). Only 68% of children who were riding with a drunken driver were restrained, but about 93% of children were restrained when they were riding with a sober driver. This is indicative of high-risk drivers who were less likely to restrain children traveling with them as well. According to Table 4.3, in 65% of cases where children were involved in crashes, the driver was a female. However, as shown in Figure 4.12(b), both female and male drivers equally restrained their child passengers.

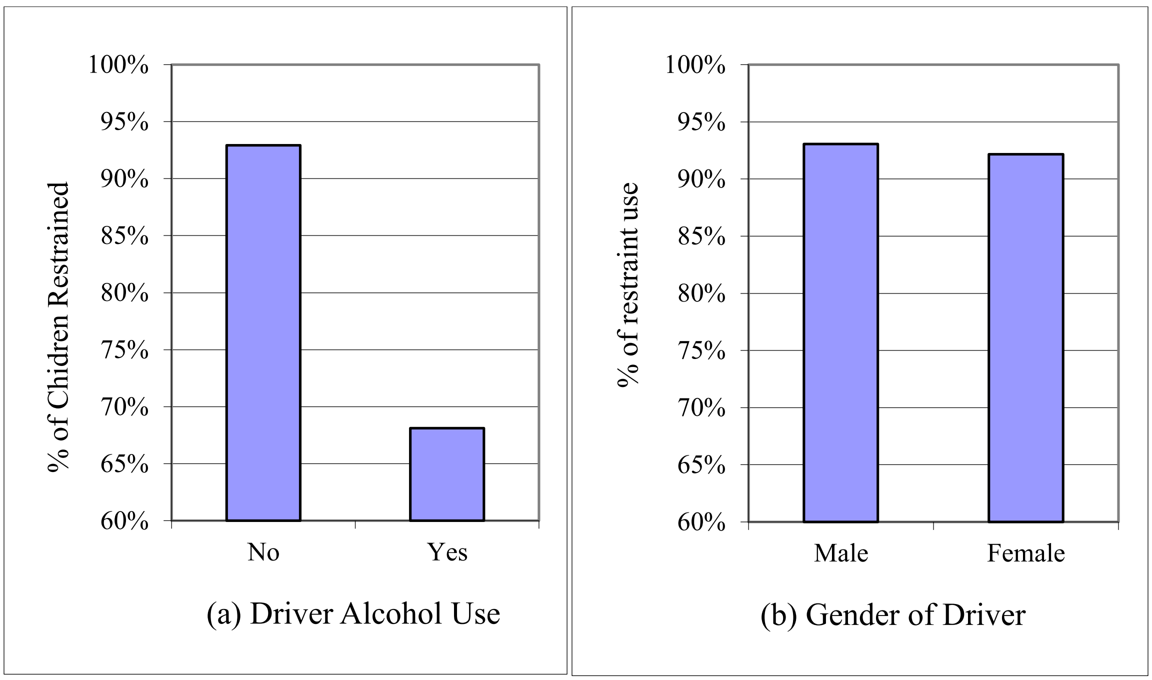


FIGURE 4.12
Percent Restraint Use of Children in Crashes by Driver Alcohol Involvement and Gender

Restraint use by children involved in crashes by driver license compliance level is presented in Figure 4.13(a). About 94% of children were restrained by valid driver license holders, but only 83% of children were restrained by invalid license holders or drivers that were not licensed. As shown in Figure 4.13(b), restraint percentages among children who were involved in crashes did not vary with driver license restrictions.

Injury severity level of the driver of the vehicle transporting child passengers involved in crashes was also examined in order to identify the variation of injury outcomes between drivers and child passengers.

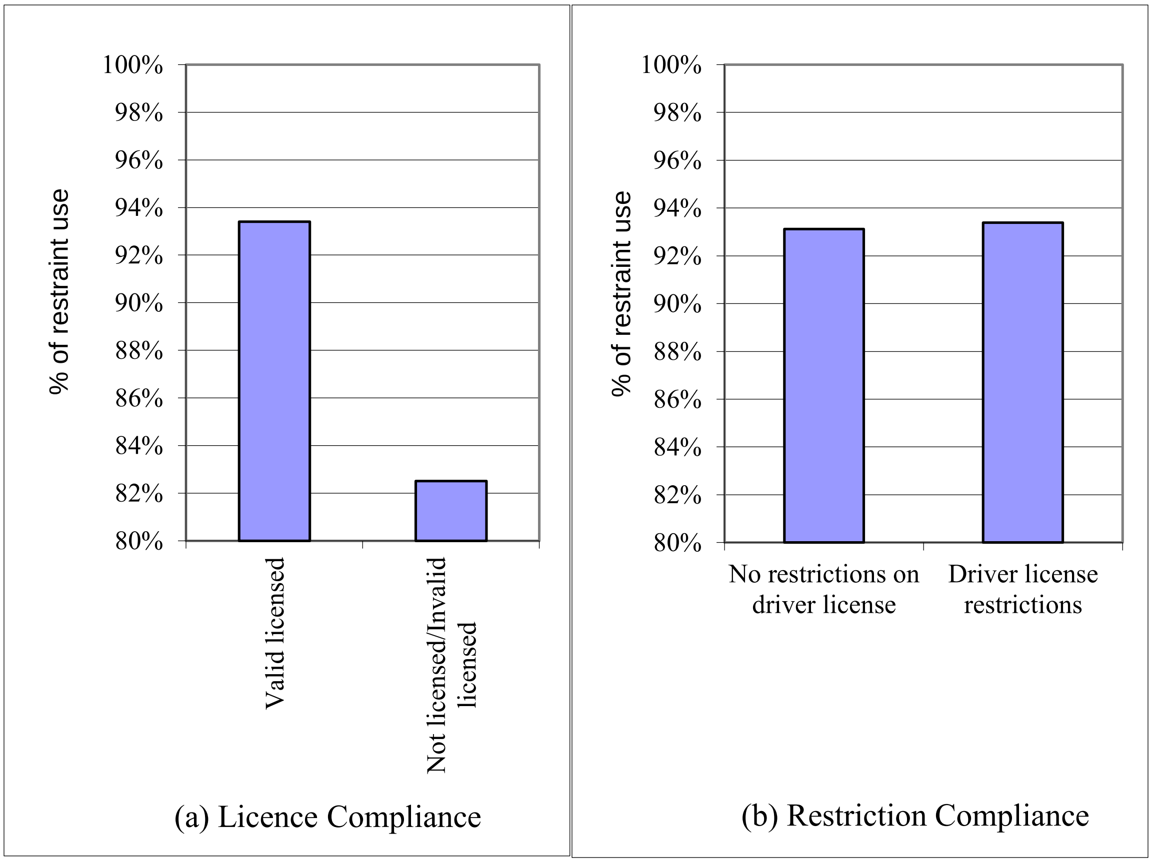


FIGURE 4.13
Percent Restraint Use of Children in Crashes by License and Restriction Compliance

Table 4.10 shows driver injury severity based on age of the children involved in crashes. Severe injuries among drivers were a relatively low percentage of overall injuries, and the injury severity distribution did not vary with the age of the child passenger. As of the date of this report, no law exists about the seating position of Kansas children (Kansas Legislature 2011). However, it was suggested that the safest position is always in the center of the rear seat. Figure 4.14 shows the distribution of seating positions for children four to13 years old involved in crashes in Kansas. Only 10% of children were in the middle of the rear seat, but almost 64% of children travelled in the rear seat.

TABLE 4.10
Children Involved in Crashes Based on Drivers' Injury Severity

Child Age		Fatal Injuries	Incapacitating Injuries	Non-Incapacitating Injuries	Possible Injuries	No Injuries	Unknown	Total
Group	Years							
4 - 7	4	6	39	310	420	4,905	299	5,979
	5	13	38	272	387	4,387	293	5,390
	6	5	31	266	383	4,070	256	5,011
	7	10	38	226	357	3,972	243	4,846
	Total	34	146	1,074	1,547	17,334	1,091	21,226
		0.2%	0.7%	5.1%	7.3%	81.7%	5.1%	100.0%
8- 13	8	9	31	247	305	3,834	251	4,677
	9	9	37	250	334	3,900	233	4,763
	10	7	35	242	301	3,834	230	4,649
	11	7	32	230	332	3,809	243	4,653
	12	5	34	264	348	4,016	264	4,931
	13	9	51	311	360	4,228	297	5,256
	Total	46	220	1,544	1,980	23,621	1,518	28,929
		0.2%	0.8%	5.3%	6.8%	81.7%	5.2%	100.0%
Total		80	366	2,618	3,527	40,955	2,609	50,155
		0.2%	0.7%	5.2%	7.0%	81.7%	5.2%	100.0%

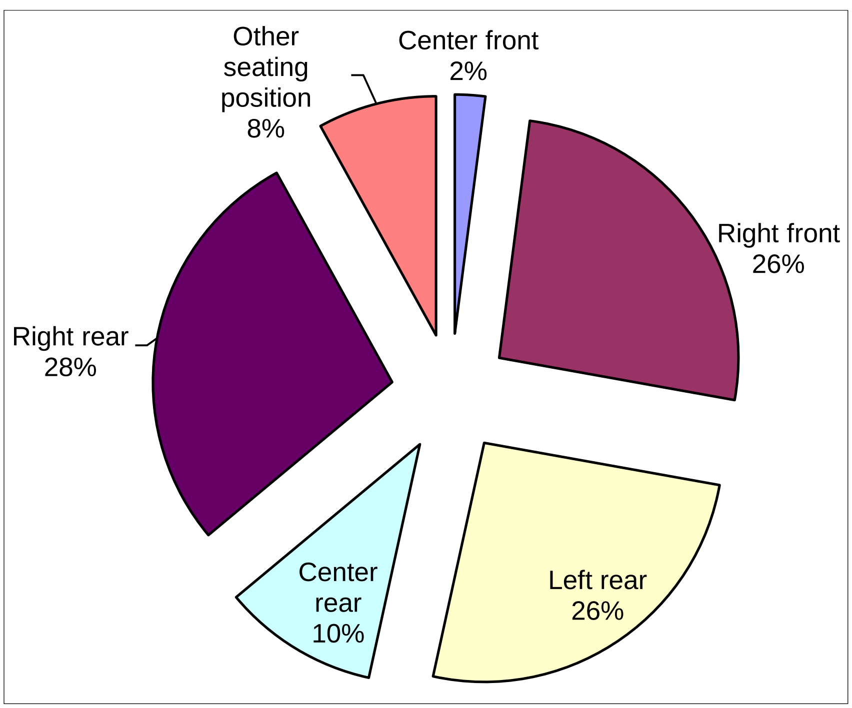


FIGURE 4.14
Seating Position of Children Involved in Crashes

Percentages of restrained children by seating position are shown in Figure 4.15. Children traveling in the front seat were less likely to be restrained than children who travelled in the rear seats. Children who travel in left and right rear seating positions indicated high restraint usage as compared to the center rear seating position.

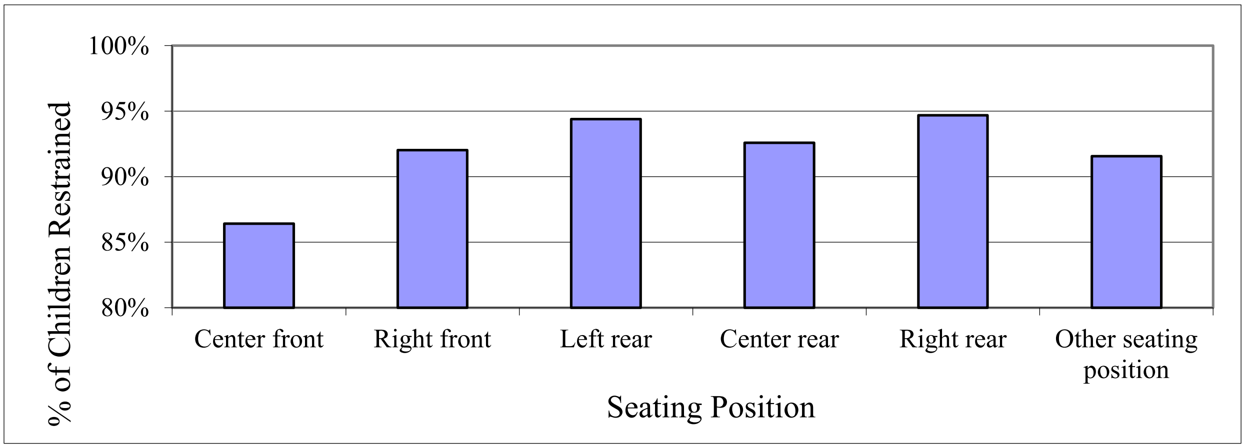


FIGURE 4.15
Percent Restraint Use of Children Involved in Crashes by Seating Position

4.2 Contingency Table Analysis

Data were then analyzed with the Chi-Square test of independence to check whether there was a relationship between restraint use and other variables. An example calculation is given below.

H_o : There is no relationship between restraint use by children involved in crashes and driver restraint use.

H_a : H_o is not true.

Observed frequencies for this case are shown in Table 4.11. Expected frequencies were calculated as the multiple of row total and column, divided by the total number of crashes using Equation 3.1. The Chi-Square values calculated using Equation 3.2. are also shown in Table 4.11. The calculated Chi-Square value was 10,741. With three rows and two columns in the contingency table, the test statistic has a Chi-Square distribution with two (2×1) degrees of freedom. Once the Chi-Square values were calculated, they were compared with the tabular values at the considered confidence level. In this case, at a 95% confidence level, the value shown in the table for two degrees of freedom is 5.99. Since the calculated Chi-Square value was greater than the table value, or the *p*-value was less than 0.05, the null hypothesis was rejected and it could be concluded that restraint use by children was not independent from driver restraint use.

TABLE 4.11
Contingency Table for Restraint Use of Driver by Restraint Use of Children

	Restraint use	Driver restrained	Driver not restrained	Total
Observed Frequency	Child seat restrained	11,186	200	11,386
	Child seatbelt restrained	33,942	548	34,490
	Child not restrained	1,030	860	1,890
	Total	46,158	1,608	47,766
Expected Frequency	Child seat restrained	11,003	383	11,386
	Child seatbelt restrained	33,329	1,161	34,490
	Child not restrained	1,826	64	1,890
	Total	46,158	1,608	47,766
Chi-Square values	Child seat restrained	3	88	91
	Child seatbelt restrained	11	324	335
	Child not restrained	347	9,968	10,315
	Total	362	10,379	10,741

The results, at a 95% confidence level, for all other variables are presented in Table 4.12. According to the *p*-values, it can be concluded that child restraint use is not independent of most other variables. Hence, the relationship between those variables and child restraint use was further investigated.

The literature suggests that seating position has an effect on injury severity of child passengers. Therefore, seating positions were investigated using the Chi-Square test. Table 4.13 shows observed and expected frequencies for children four to seven years old involved in crashes. After calculating the Chi-Square, it was compared with the tabular values at the considered confidence level. At 95% confident level, Chi-Square values were significant. Comparing observed and expected frequencies for seating position versus injury severity for four to seven year olds, it can be noted there is over-involvement in crashes by front-seating child passengers. Observed numbers of not-injured, rear-seating child passengers in crashes were more than expected. In this age category, child passengers appeared to have the greatest benefit from rear seating.

TABLE 4.12
Chi-Square Test Results for Child Restraint Use

Variable	*p*-value at 95% confidence interval
Driver seat belt use	<0.0001
Driver gender	<0.0001
Child gender	<0.0001
Child seat position in the vehicle	<0.0001
Valid driver license	<0.0001
Restricted driver license	<0.0001
Driver alcohol use	<0.0001
Light condition	0.0005
Weather condition	<0.0001
Time of day	<0.0001
Day of week	<0.0001
Road functional class (rural/urban)	<0.0001
Road condition (dry, wet, …)	<0.0001
Road character (following straight, curved…)	<0.0001
Number of passengers	<0.0001
Vehicle body type	<0.0001
Vehicle model year (new/old)	<0.0001
Work zone	0.0052
Speed	<0.0001

TABLE 4.13
Expected and Observed Frequencies for Seating Position versus Injury Severity for 4–7 Year Olds Involved in Crashes

Seating position	Expected		Observed	
	Injured	Not injured	Injured	Not injured
Center front	37	319	63*	293
Right front	237	2,043	367*	1,913
Left rear	644	5,559	631	5,572*
Center rear	274	2,365	257	2,382*
Right rear	659	5,692	572	5,779*
Other seating positions	249	2,149	209	2,189*
Total	2,099	18,128	2,099	18,128

* Observed frequency is more than expected.

Observed and expected frequencies for children eight to13 years old involved in crashes are shown in Table 4.14. It can be noted that observed number of injured front-seating, older-age group, child passengers in crashes were slightly more than expected. Also, the numbers of injured rear-seating child passengers were less than expected.

TABLE 4.14
Expected and Observed Frequencies for Seating Position versus Injury Severity for 8–13 Year Olds Involved in Crashes

Seating position	Expected		Observed	
	Injured	Not injured	Injured	Not injured
Center front	70	506	71*	505
Right front	1,168	8,501	1,277*	8,392
Left rear	697	5,076	638	5,135*
Center rear	272	1,978	271	1,979*
Right rear	821	5,977	751	6,047*
Other seating positions	319	2,325	339*	2,305
Total	3,347	24,363	3,347	24,363

* Observed frequency is more than expected.

Chi-Square values for other variables by injury severity were also investigated and resulting *p*-values at a 95% confidence level are tabulated in Table 4.15.

TABLE 4.15
Chi-Square Tests Results for Child Injury Severity

Variable	*p*-value at 95% confidence interval
Driver seat belt used	<0.0001
Driver gender	0.0012
Driver injury severity	<0.0001
Child gender	<0.0001
Child seat position in the vehicle	<0.0001
Valid driver license	<0.0001
Restricted driver license	<0.0001
Driver alcohol use	<0.0001
Light condition	<0.0001
Weather condition	0.0072
Time of the day	<0.0001
Day of the week	0.0028
Road functional class (rural/urban)	<0.0001
Off roadway	<0.0001
Intersection	<0.0001
Accident class (collision, overturn,…)	<0.0001
Road condition (dry, wet,…)	0.054
Road character (following straint, curved…)	<0.0001
Damage	<0.0001
Number of passengers	<0.0001
Vehicle body type	<0.0001
Vehicle maneuver	<0.0001
Occupant ejected	<0.0001
Driver ejected	<0.0001
Vehicle model year (new/old)	<0.0001
Work zone	0.2442
Speed	<0.0001

These results further proved results of the univariate and multivariate analysis of predicting odds of child injury as described in the following section.

4.3 Odds Ratio Analysis

The dependent variable in these analyses was "Injured", which was binary-variable based on whether the child was injured or not in the crash. Table 4.16 shows the odds of the univariate and multivariate analysis. Univariate analysis is based on the assumption that the dependent variable is influenced by only one independent variable, while keeping all other variables constant. Multivariate analysis is based on the assumption that the dependent variable is influenced by many independent variables. Independent variables included driver-, child-, environment-, road-, and vehicle-related characteristics. Some of those variables were re-classified as a binary variable by combining some categories of the attribute in order to investigate the combined effect. For example, all rural interstate, rural arterial, rural collector, and rural local roads were considered as rural roads and compared with all categories of urban roads.

An odds ratio greater than 1.000 indicates the concerned characteristic leads to a higher injury risk, and vise versa. For example, child passengers traveling with drivers with valid licenses and restrained drivers had a lower injury risk as both the univariate and multivariate odds ratios are less than 1.000. When investigating odds of child passenger-related variables, restrained children showed a significantly lower risk than unrestrained children. The odds ratio of rear seating was less than 1.000, which indicated rear seating had reduced injury risk for child passengers. An important risk factor was ejection, which may be caused due to failure to use the restraint. The odds ratios of environment-related variables were not statistically significant at the 95% confidence interval. Injury risk on rural roads was higher than that of urban roads for children involved in crashes. Off roadways also showed higher injury risk for children. As one can expect, injury risk under dry road conditions was lower than wet roads for child passengers involved in crashes. The odds ratio also indicated that riding on straight, level roads was at significantly lower injury risk for children than curved or sloping roads.

TABLE 4.16
Odds Ratios for Injury of Children Involved in Crashes

Characteristics	*Univariate*	*Multivariate Analysis*		
			95 % Confidence Interval	
	Odds Ratio	*Odds Ratio*	*Lower Bound*	*Upper Bound*
Driver-Related Characteristics				
Male	0.994	0.993	0.904	1.091
Valid licensed	0.538	0.851	0.734	0.987
Safety belt used	0.174	0.621	0.541	0.712
Alcohol related	5.035	1.932	1.292	2.889
Ejected	17.245	0.829	0.285	2.398
Child-Related Characteristics				
4- 7 years old	0.872	0.993	0.893	1.103
Male	0.886	0.827	0.796	0.944
Child seat	0.682	0.293	0.243	0.354
Seat belt	0.640	0.334	0.286	0.390
Ejected	60.684	24.968	11.760	53.013
Rear seat	0.789	0.917	0.832	1.011
Environment-Related Characteristics				
Not daylight	0.939	0.861	0.736	1.007
Weather: No adverse conditions	1.063	0.686	0.330	1.426
Rain	0.998	0.792	0.368	1.629
Adverse conditions	0.812	1.000	-	-
Time: 5.00 - 9.00	1.006	0.946	0.824	1.086
9.00 - 17.00	1.000	1.000	-	-
17.00 - 21.00	0.971	0.993	0.888	1.109
21.00 - 5.00	1.200	1.194	0.951	1.499
Week days	0.973	1.042	0.944	1.151
Road-Related Characteristics				
Rural roads	1.472	1.082	0.967	1.211
Location: Non-intersection-related	1.230	0.888	0.796	0.991
Intersection-related	1.000	1.000	-	-
Off roadway	3.339	1.012	0.807	1.268
Road surface condition: Dry	0.604	0.736	0.371	1.461
Wet	0.608	0.865	0.426	1.755
Debris	1.000	1.000	-	-
Surface character: Straight and level	0.875	0.888	0.796	0.991
Straight not level	1.150	1.012	0.807	1.268
Curved	1.000	1.000	-	-
Vehicle-Related Characteristics				
Vehicle Damage: None	1.000	1.000	-	-
Minor damage	0.709	0.775	0.310	1.934
Function	1.107	1.152	0.463	2.865
Disabling	5.347	4.720	1.902	11.717
Destroyed	22.383	16.072	6.422	40.223
Vehicle: Automobile	0.489	0.821	0.232	2.902
Van	0.262	0.546	0.154	1.937
Pickup-truck, camper-rv	0.299	0.555	0.157	1.961
Sport utility vehicles	1.000	1.000	-	-

When the vehicle is disabled or destroyed in a crash, the child would be at higher injury risk than there is no damage.

4.4 Logistic Analysis

Logistic analysis provides measures for independent variables, while identifying effects of interactions among terms in relation to the dependent variable. Hence, a logistic model was developed to further investigate child passenger injury risk using coefficient estimates. The dependent variable, injury severity, was defined as a binary variable where the child is injured or not injured. All other crash-, vehicle-, roadway-, environment-, driver-, and passenger-related characteristics were considered as independent variables. The highly correlated independent variables were excluded once the correlation coefficient matrix had been developed. The cut-off value of 0.65 was used for identifying highly correlated variables. Based on a developed correlation coefficient matrix, weather and road conditions were identified as the only two highly correlated variables. Two models were then developed by including one of the correlated variables at a time, while keeping everything else the same and a better model was selected.

4.4.1 Injury Severity Model for Crashes Involving Children Aged 4–13

The developed injury severity model for crashes involving children aged four to 13, including model fit statistics, is shown in Table 4.17. The statistical significance of individual coefficients was tested using the Wald Chi-Square statistic. Variables such as gender of the child, validity of the driver license, driver seat belt use, alcohol involvement, travel on urban roads, vehicle damage, automobile use, pickup/truck use, vehicle maneuver, child ejection, vehicle model year, and speed were all significant at the 0.05 level. The test of the intercept merely suggests whether an intercept should be included in the model. Interpretation of the intercept in a logistic regression model depends on how the independent variables were defined. The intercept represents the logit of the probability of injury, if all of the characteristics are set to zero; consequently, the value of the intercept cannot be meaningfully interpreted. Negative coefficient estimates show the reduced probability of potential injury severity, while positive coefficient estimates show the increased probability of potential injury severity.

TABLE 4.17
Injury Severity Model for Crashes Involving Children Aged 4–13 (Model 1)

Label	Parameter Definition	Coef.	P value
intercept	intercept	-3.454	<.0001*
AGE	if age is from 4-7 years=1, from 8-13= 0	-0.004	0.937
DRMALE	if driver is male=1, otherwise 0	0.009	0.857
CHIMALE	if child is male=1, otherwise 0	-0.163	<.0001*
SEAT	if child rear seating=1, otherwise 0	-0.059	0.265
VALID	if valid license=1, otherwise 0	-0.1745	0.035*
RESTRIC	If restricted driver license=1, otherwise 0	0.027	0.585
SEATB	if seat belt used=1, otherwise 0	-1.260	<.001*
CSEAT	if child seat used=1, otherwise 0	-1.306	<.001*
AIRB	if airbag deployed=1, otherwise 0	0.310	0.041*
ALCO	if driver alcohol involved=1, otherwise 0	0.063	0.005*
DARK	if dark or night =1, otherwise 0	0.086	0.183
RAIN	if rain=1, otherwise 0	0.044	0.581
ADVER	if weather is adverse=1, otherwise 0	-0.297	0.015*
WEEK	if weekday=1, otherwise 0	-0.045	0.345
RDFUNC	if rural roads=1, otherwise 0	0.096	0.208
OFF	if off roadway=1, otherwise 0	0.108	0.422
INTER	if intersection on roadway=1, otherwise 0	0.255	<.001*
OVER	if non-collision or overturned=1, otherwise 0	2.453	<.001*
VEHI	if collision with a vehicle=1, otherwise 0	2.095	<.001*
FIXED	if collision with fixed object=1, otherwise 0	2.369	<.001*
SLEVEL	if road is straight and level =1, otherwise 0	-0.563	0.049*
SNLEVEL	if road is straight but not level=1, otherwise 0	0.457	0.103
NSLEVEL	if road is curved =1, otherwise 0	-0.419	0.165
MINOR	if vehicle has minor damage=1, otherwise 0	-0.419	0.025*
FUNC	if vehicle is functional=1, otherwise 0	0.015	0.936
DISAB	if vehicle is disabled=1, otherwise 0	1.387	<0.001*
DESTR	if vehicle is destroyed=1, otherwise 0	2.464	<0.001*
PASS	if other passenger present=1, otherwise 0	0.149	0.008*
AUTO	if automobile =1, otherwise 0	-0.472	0.473
VAN	if van =1, otherwise 0	-0.836	0.205
PICK	if pickup truck, camper rv =1, otherwise 0	-0.858	0.192
STRAIT	if straight-following road =1, otherwise 0	-0.128	0.067
TURN	if turn or changing lanes =1, otherwise 0	-0.343	<0.001*
EJECT	if child eject =1, otherwise 0	2.961	<0.001*
TRAP	If child trapped =1, otherwise 0	1.770	0.001*
DREJECT	if driver eject =1, otherwise 0	-0.226	0.684
DRTRAP	If driver trapped =1, otherwise 0	1.029	0.004*
NEW	if vehicle made > 2000 =1, otherwise 0	-0.191	<0.001*
WZONE	if work zone=1, otherwise 0	-0.006	0.039*
SPEED	on road speed limit	0.004	0.188
Likelihood Ratio		3,400	<.001*
Score		4,333	<.001*
AIC		13,164	
SC		13,496	
-2logL		13,082	

* Significant at 95% confidence level

According to the estimated coefficient, male children were less likely to have an injury when involved in crashes than female children. Variable child seat use has a *p*-value less than 0.000 and a likelihood ratio of -1.306. That means, if the child is in a child seat, the injury severity is less. Variable seat belt use is one of the significant variables that, having a likelihood ratio of -1.260, shows children were less likely to suffer injuries when involved in crashes. As the model coefficient showed, when an air bag was deployed, the chance for the child to be injured was higher. Previous research pointed out that air bags, when used with seat belts, work very well to protect teenagers and adults. However, airbags can be dangerous to children, and it was recommended that children be seated in rear seats. If the front seat was needed for a child passenger, it was recommended to turn off the air bags, if the facility was available. If the driver has a valid driving license, the child has less chance of being injured. The variable coefficient of alcohol involvement was positive 0.063, and hence, riding with a drunken driver increases the probability of a crash occurring with higher potential injury severity. The significant positive coefficient for intersection-related crashes showed that the children were more likely to suffer injuries in intersection-related crashes. Also, they were vulnerable for injuries in collision with a vehicle, collision with fixed objects, and non-collision overturn crashes. If the vehicle was destroyed or disabled injury severity was higher. If the vehicle had minor damage or was functional at the time of the crash, child passengers involved were less likely to suffer injuries. Children were at high-injury risk when riding with passengers. If the child passenger was ejected or trapped when involved in a crash, the child was at a high risk for injury. Also, if the driver was trapped in the crash, the child was at a high risk for injury. When the vehicle was newer, the child was less likely to suffer injuries at the time of a crash.

As characteristics of older children differ from those of a younger group, separate logistic regression models were developed for four to seven year olds and eight to 13 year olds who were involved in crashes. Parameter estimates and *p*-values of those models are given in Table 4.18. According to the two developed models, restraint use and child passenger seat, and child ejection are significant coefficients for both models. At intersection crashes, collisions with a fixed object, collision with a vehicle, non-collisions, or overturns were significant factors for increasing child injury severity.

TABLE 4.18
Injury Severity Models for Each Age Group of Children Involved in Crashes

Label	Parameter Definition	Age 4-7 years (Model 2)		Age 8-13 years (Model 3)	
		Coef.	p-value	Coef.	p-value
intercept	intercept	-5.476	<.01*	-3.246	<.01*
DRMALE	if driver is male=1, otherwise 0	-0.006	0.94	0.016	0.79
CHIMALE	if child is male=1, otherwise 0	-0.031	0.65	-0.226	<.01*
SEAT	if child rear seating=1, otherwise 0	-0.144	0.08	-0.020	0.76
VALID	if valid license=1, otherwise 0	-0.095	0.43	-0.178	0.08
RESTRIC	If restricted driver license=1, otherwise 0	-0.091	0.22	-0.107	0.07
SEATB	if seat belt used=1, otherwise 0	-1.416	<.01*	-1.210	<.01*
CSEAT	if child seat used=1, otherwise 0	-1.466	<.01*	-1.356	<.01*
AIRB	if airbag deployed=1, otherwise 0	0.509	0.18	0.300	0.08
ALCO	if driver alcohol involved=1, otherwise 0	0.165	0.61	0.763	<0.01*
DARK	if dark or night =1, otherwise 0	0.119	0.23	0.085	0.28
RAIN	if rain=1, otherwise 0	0.124	0.28	-0.038	0.70
ADVER	if weather is adverse =1, otherwise 0	-0.580	<0.01*	-0.147	0.30
WEEK	if weekday=1, otherwise 0	-0.051	0.53	0.097	0.13
RDFUNC	if rural roads=1, otherwise 0	0.221	0.05*	0.106	0.25
OFF	if off roadway=1, otherwise 0	0.090	0.68	0.173	0.27
INTER	if intersection on roadway=1, otherwise 0	0.219	<0.01*	0.255	<.01*
OVER	if non-collision or overturned=1, otherwise 0	0.215	<0.01*	2.671	<.01*
VEHI	if collision with a vehicle=1, otherwise 0	2.205	<0.01*	2.341	<.01*
FIXED	if collision with fixed object=1, otherwise 0	0.215	<0.01*	2.636	<.01*
SLEVEL	if road is straight and level =1, otherwise 0	-0.799	0.04*	-0.475	0.18
SNLEVEL	if road is straight but not level=1, otherwise 0	0.591	0.12	0.442	0.22
NSLEVEL	if road is curved =1, otherwise 0	-0.923	0.02*	-0.218	0.56
MINOR	if vehicle has minor damage=1, otherwise 0	-0.298	0.30	-0.485	0.03*
FUNC	if vehicle is functional=1, otherwise 0	0.132	0.64	-0.066	0.77
DISAB	if vehicle is disabled=1, otherwise 0	1.487	<0.01*	1.336	<0.01*
DESTR	if vehicle is destroyed=1, otherwise 0	2.475	<0.01*	2.413	<0.01*
PASS	if other passenger present=1, otherwise 0	0.187	0.02*	0.132	0.05*
AUTO	if automobile =1, otherwise 0	1.490	0.19	-0.863	0.25
VAN	if van =1, otherwise 0	0.924	0.42	-1.149	0.12
PICK	if pickup truck, camper =1, otherwise 0	1.004	0.38	-1.205	0.11
STRAIT	if straight-following road =1, otherwise 0	-0.043	0.68	-0.108	0.03*
TURN	if turn or changing lanes =1, otherwise 0	-0.077	0.53	-0.431	<0.01*
EJECT	if child eject =1, otherwise 0	3.249	<0.01*	2.919	<0.01*
TRAP	If child trapped =1, otherwise 0	1.598	<0.01*	1.843	<0.01*
DREJECT	if driver eject =1, otherwise 0	0.045	0.96	-0.301	0.65
DRTRAP	If driver trapped =1, otherwise 0	1.282	0.02*	0.740	0.07
NEW	if vehicle made > 2000 =1, otherwise 0	-0.145	0.06	-0.190	<0.01*
WZONE	if work zone=1, otherwise 0	0.250	0.32	-0.119	0.46
SPEED	on road speed limit	0.010	0.04*	0.006	0.11
Likelihood Ratio		1,429	<0.01*	2,358	<.01*
Score		1,839	<0.01*	2,984	<.01*
AIC		6,082		8,711	
SC		6,376		9,018	
-2logL		6,002		8,631	

* Significant at 95% confidence level

4.4.2 Injury Severity Model for Crashes Involving Children Aged 4–7

According to parameter estimates for children aged four to seven, as shown in Table 4.18, children were less likely to be injured when involved in crashes with adverse weather conditions. If the child was in a child seat, injury severity was less. If the child was in a booster/child seat, the injury severity was less. Children using seat belts were less likely to suffer injuries when involved in crashes. Also, they were at high risk for injuries in intersection-related crashes, in a collision with a vehicle, a collision with fix objects, and non-collision overturn crashes. A lower injury risk to children showed when they were involved in crashes at straight-level roadways and curved roadways. If the child passenger was ejected or trapped, the driver was trapped, or the vehicle was destroyed or disabled, the child had a high chance of injury. If the vehicle was newer, child passengers were less likely to suffer injuries. Traveling on rural roads or traveling at high speed showed high injury risk for child passengers.

4.4.3 Injury Severity Model for Crashes Involving Children Aged 8–13

According to parameter estimates for children aged eight to 13, as shown in Table 4.18, male children were less likely to be injured when involved in crashes than female children. Children using seat belts were less likely to suffer injuries when involved in crashes. If the child passenger was ejected or trapped, or the vehicle was destroyed or disabled, the child had a high chance of injury. If the vehicle was newer, or it did not get damaged at the time of the crash, child passengers were less likely to suffer injuries. Alcohol involvement of the driver or traveling at high speeds showed high injury risk for child passengers. Children were likely to suffer severe injuries when involved in crashes where the driver was on straight roads or attempting to turn or change lanes. They were also at high risk for injuries in intersection-related crashes, in a collision with a vehicle, a collision with fix objects, and non-collision overturn crashes.

4.4.3.1 Model Comparison

The three models were compared using the Negelkerke R-Square value, and Cox and Snell R-Square values. The R-Square values of all three models do not show many differences as given in Table 4.19.

TABLE 4.19
Comparison of Injury Severity Models

Indices	Model 1 Age 4-13 yrs	Model 2 Age 4-7 yrs	Model 3 Age 8-13 yrs
Cox and Snell R-Square	0.1311	0.1155	0.1384
Nagelkerke R-Square	0.2654	0.2449	0.2765

Also those models exhibit somewhat similar results. However, the significance values of parameter-estimates provide important differences among two child groups: age four to seven and eight to 13. Male children in the older age group showed less risk for injuries when involved in crashes. Unlike the young age group, children in the older age group were more likely to suffer severe injuries when involved in a crash with a drunken driver. They were less likely to suffer severe injuries when involved in crashes attempting to turn or change lanes, travelling on straight roads, or when the vehicle had minor damage after the crash. Younger children had low injury risk when involved in crashes in adverse weather conditions, travelling on straight and level roads, or on curved roads. Younger children were more likely to suffer severe injuries when drivers were trapped at the time of the crash or travelling at high speeds.

4.5 Contributory Causes

Contributory causes for children involved in crashes were also investigated in this study. Many factors typically combine to produce circumstances that may lead to a traffic crash; there is rarely a single cause of such an event. Mainly these contributory causes can be divided into four categories such as driver-, roadway-, environment-, and vehicle-related contributing causes. Driver contributing causes involve actions taken by or the condition of the driver of the vehicle. Driver contributing causes related to child-involved crashes in Kansas using combined data from 2004 to 2008 are provided in Table 4.20.

Inattention and failure to give enough time and attention were the most frequent driver contributory causes to children involved in crashes. It is interesting to note that when the contributory cause is distraction, reckless, careless, or aggressive driving, under influence of alcohol/drug, or restricted driver license, child restraint use was significantly low. Presence of one or more of these factors does not by itself prove a child is being harmed or is at risk of harm, but it can alert to the possibility that a child may be at risk.

TABLE 4.20
Driver Contributory Causes for Children Involved in Crashes

Driver Contributory Factors	Number of Children-Involved Crashes	Child Restraint Use when Driver Contributory Cause is Reported	
		Frequency	Percentages
Inattention	8,652	8,154	94%
Failed to yield right of way	3,999	3,786	95%
Too fast	2,492	2,268	91%
Improper turn/passing/ backing/signal	2,203	2,113	96%
Followed too closely	2,027	1,939	96%
Disregard traffic signs, signal	1,291	1,204	93%
Distraction	746	663	89%
Avoidance or evasive action	708	651	92%
Reckless / careless/ aggressive driving	332	245	74%
Under influence of alcohol/drugs	315	249	79%
Did not comply with license restriction	249	186	75%
Wrong side or wrong way	196	167	85%
Fell asleep	193	175	91%
Ill or medical condition	107	96	90%
Impeding traffic, too slow	48	44	92%
Improper parking	42	41	98%
Total	23,644	22,010	93%

Roadway and environmental contributory causes for children-involved crashes in Kansas are given in Table 4.21. Roadway factors include wet, debris, or icy roads as main factors. The most predominant environmental cause is the animal hitting the vehicle. Child restraint use is lower in rain, snow, smog, or cloudy environmental contributory crashes. Vehicle contributory causes include any failures in vehicle components or its design. Tires and brakes are the most common vehicle contributory cause in children-involved crashes in Kansas as shown in Table 4.22.

Driver contributory causes are seen as the most prevalent contributing factor of crashes, followed by roadway environment and vehicle factors. All results above show that child seat restraints, seating position of the child, and driver contributory causes are more significant in highway child safety.

TABLE 4.21
Roadway and Environment-Related Contributory Causes for Children Involved in Crashes

Contributory Factors		Number of Children-Involved Crashes	Child Restraint System Used	
			Frequencies	Percentages
Road Factors	Wet	32702	30829	94%
	Debris or obstruction	886	860	97%
	Icy or slushy	534	499	93%
	Ruts, holes, bumps	167	163	98%
	Traffic-control device inoperative	62	60	97%
	Road under construction-maintenance	36	33	92%
Environmental Factors	Animal	4102	4068	99%
	Rain, snow, mist, or drizzle	1047	1010	96%
	Vision obstructed	407	386	95%
	Strong winds	128	117	91%
	Rain, snow, smog, or cloudy	77	65	84%

TABLE 4.22
Vehicle Contributory Factors for Children Involved in Crashes

Vehicle Contributory Factors	Number of Children-Involved Crashes	Child Restraint System Used	
		Frequencies	Percentages
Tires	146	129	88%
Brakes	98	96	98%
Wheel(s)	63	58	92%
Cargo	42	39	93%
Trailer coupling	40	39	98%
Windows-windshield	39	36	92%
Other lights	22	20	91%
Exhaust	19	16	84%
Unattended (not in motion)	6	6	100%
Headlights	5	5	100%
Unattended (in motion)	3	3	100%

4.6 Countermeasures

This section discusses countermeasures for increasing child passenger safety related to both four to seven year olds and eight to 13 year olds, especially focusing on booster seat restraint use for the younger age group and seat belt use for the older age group. Strategies for increasing child passenger protection are quite different from those of adult belt use. The most effective basic strategy for achieving and maintaining high belt use is highly publicized, high-visibility enforcement of strong occupant-restraint-use laws (CDC 1997). Three components in this strategy are laws, enforcement, and publicity, which cannot be separated, and effectiveness decreases if any one is weak or lacking. This section discusses each component's key features. Some communications and outreach and incentive programs directed to well-defined and limited audiences such as schools, businesses, and communities have been moderately successful and also are discussed in this section.

In the child safety literature, many countermeasures to reduce injury risk and increase safety restraint use were suggested. Using a wide range of statistical methods, many studies have reported that restrained child passengers are at lower risk of injuries and fatalities. NHTSA has also listed countermeasures to increase child passenger safety (NHTSA 2010).

4.6.1 Countermeasures Targeting Children in Booster Seats (4-7 Years Old)

Passing legislations and enforcing enhanced booster seat laws are some strategies to promote booster seat use for children four to seven years old. The booster seat law went to effect in 2002 in Washington state. By July 2002, 11 states had enacted booster seat laws and by July 2009, 45 states, including Kansas, had booster seat laws in place (Decina, Hall, and Lococo 2010).

4.6.1.1 Enactment of Child Restraint Use Laws

According to child restraint seat laws, children need to be restrained appropriately for the child's size and age. Law also specifies restraint specifications for children by age, height, weight, or a combination of these factors, as well as the person responsible for restraining the children in the motor vehicle. The effectiveness of child restraint laws in increasing child restraint use and decreasing injury severity has been studied by many researchers and it has been concluded that child restraint laws significantly reduced injury risk among children (NHTSA 2010, Olsen et al. 2010). Also, child restraint laws significantly reduced fatality rates among children. Inactivation of legislation may bring a limited cost, but publicizing and enforceing the law may be expensive. Also, Decina et al. (2009) recommended that child restraint laws be enforced and greater penalties be attached to violations.

4.6.1.2 Coverage: Seating Position, Vehicles, Ages

Various researchers and NHTSA have encouraged states to expand their child restraint laws to include "booster" provisions. This means "to not allow children to be restrained by a seat belt alone until they are big enough for the lap and shoulder belts to fit and continue to do so" (NHTSA 2010). Strong occupant-restraint-use laws should be a combination of child restraint and seat belt laws, covering all seating positions equipped with a seat belt, in all passenger vehicles. Some researchers have been found that transitioning children from child seats to belt-positioning booster seats, instead of directly to vehicle safety belts, provides significant safety benefits for children. Belt-positioning booster seats reduce the injury risk of children in crashes by 45% compared to use of vehicle safety belts alone (NHTSA 2010). A limited cost is needed to expand a restraint-use law covering all seating positions and passenger vehicles. Once the expanded law is enacted and publicized, it can be implemented.

4.6.1.3 Short-Term, High-Visibility Child Restraint/Booster Law Enforcement

In general, increases of child restraint come from enforcing occupant-restraint laws using mobilization efforts by many law enforcement agencies (Decina, Hall, and Lococo 2010). Decina, Hall, and Lococo stated that effective enforcement could include support and cooperation from top management of law enforcement agencies for enforcing child passenger safety laws; training and education of law enforcement officers on child-restraint laws and best practices for children by age, weight, and height; educating judges and prosecutors regarding details of child-restraint laws and risks involved for noncompliance of laws; and frequent publicity surrounding enforcement efforts (Glass, Segui-Gomez, and Graham 2000; Decina, Hall, and Lococo 2010). Parents need to know when their children should be secured in booster seats, how to properly use the seats, and when to graduate to an adult seat belt. They also need to know the child-restraint law in their state, and the differences between the law and best practices for the child's age, weight, and height. Enforcement efforts increased correct use of child restraints at demonstration sites; use of safety belts by older children also increased. Community-wide information plus enhanced enforcement campaigns were effective in increasing child-restraint use. Dedicated checkpoints and roving patrols using stationary spots were also more effective approaches according to a study conducted by Decina, Hall, and Lococo (2010). Vehicles need to be slowed down to effectively spot booster-seat and other child-restraint law violators. High-visibility enforcement campaigns require cost and time. State highway safety offices and law enforcement officers need time to conduct enforcement programs while media staff and consultants require time to develop, produce, and distribute publicity. One to two hours minimal training on best practices for booster-seat and other child-restraint use and laws is sufficient for officers (Decina, Hall, and Lococo 2010). Paid advertising increases a campaign's effectiveness but can be quite expensive. A high-visibility enforcement program requires four to six months to plan and implement (NHTSA 2010).

Officers have reported many obstacles to enforcing booster-seat laws, such as lack of knowledge and experience with booster seats, lack of commitment from management for training and resources for child-restraint law enforcement, and weakness of booster-seat laws (e.g.: age limit, secondary law) Decina, Hall, and Lococo (2010).

4.6.1.4 Communication and Outreach Supporting Enforcement

Outreach strategies such as a combination of news stories and paid advertising are included in high-visibility enforcement and communication programs. Those programs can be conducted as local-, state-, regional-, or national-level programs. Evidence for the effectiveness of education-only programs aimed at healthcare personnel, law enforcement personnel, parents or children, could not be found. Some media campaigns such as paid advertising are expensive. Four to six months are required to plan and implement an effective media campaign (NHTSA 2010). Will (2005) stated that most parents possess a false idea of a reduced perception of risk for motor vehicle injury to their children, and they tune out educational messages. He further states that parents are motivated to pay attention to something they would normally think as unimportant due to injury-prevention messages for maximum behavioral success. Messages such as inform, arouse alarm, persuade, create feeling of vulnerability, and evoke high emotion, and instill in parents/guardian a sense of efficacy for protecting child passengers, are effective. There is a need for understanding the most effective enforcement strategies for the community so that law enforcement agencies can use those to encourage booster-seat use in their communities (Decina, Hall, and Lococo 2010).

4.6.1.6 Communication and Outreach Strategies for Booster-Seat Use

While uncertain, it is believed anywhere from a third to three-quarters of children who should be in booster seats are not (NHTSA 2010). Hence communications and outreach campaigns for booster-seat-age children are quite common. But many booster-seat programs are unsuccessful due to too much information in their nature. Education and messages should be culturally sensitive, bilingual, and within the reading level of the audience (Decina et al. 2009). Educational programs delivered in community-oriented or faith-based centers may be more effective. Depending on the program quality and delivery, cost of enforcement-related communications and outreach programs vary. The time taken to plan and implement a good educational campaign is four to six months.

According to a study conducted by Delaware, New Jersey, Pennsylvania, and Washington, audio visual presentations, enforcement cards identifying child-restraint laws, and providing illustrations and text on child restraint were useful for officers to describe child passenger safety restraint (Decina, Hall, and Lococo 2010). Educational programs about booster seats and the child-restraint law combined with booster-seat giveaways have been successful in increasing booster-seat use at pre-school programs in lower-socioeconomic communities (Apsler 2003; Pierce 2005).

4.6.1.7 Child-Restraint Distribution Programs

Depending on the size of the target audience and the components of the program, costs for program may different. Planning and implementing these programs usually requires several months (NHTSA 2010).

4.6.1.8 Inspection Stations

Misuse of child restraints has also been a concern for several years. Hence, child-restraint inspection stations are important components in improving child-passenger safety. The cost for inspection stations will depend on level of services offered and target audience. To plan and implement these programs usually requires several months (NHTSA 2010). Will and Geller (2004) presented a comprehensive intervention plan for maximum parental participation for safety seat checks and other child seat interventions. Essential components included in this plan are establishing community locations for parents to turn for safety-seat advice, making these locations well known to the public, and increasing caregivers' perceptions of risk of misusing their children's seats. Neighborhood pediatricians, family practices, and obstetrician/gynecologist offices seem to be ideal settings for safety checkups. Also, with proper training of sales personnel, retail stores are good locations for intervention, as safety information could be conveyed to parents when the safety seat is purchased.

Not all countermeasures can be implemented simultaneously, but some are less effective when introduced in isolation. For example, distribution of booster seats increased use of booster seats, but there was evidence that without booster-seat laws, enforcement or education programs had little to mild success (Decina et al. 2009; Decina, Hall, and Lococo 2010).

4.6.2 Countermeasures Targeting Eight to 13 Year Old Occupants

Children in the eight to 13 age group demonstrated a simpler understanding of why they were restrained in seat belts, and were driven by parental influence and a desire to comply with the rules (Kuhn and Lum 2008). When they got older, they were more likely to begin making independent decisions to wear seat belts. Also, they were more likely to observe and report peers who did not restrain by seat belts, but they were less likely to be willing to ask their peers to wear seat belts. Hence, countermeasures to increase seat belt use in this age group are quite different and are listed below and discussed individually in this section.

4.6.2.1 Restraint-Use Laws

A combination of child-restraint and seat belt laws covering all seating positions equipped with a seat belt in all passenger vehicles can be considered as good occupant restraint-use laws (NHSTA 2010). Researchers such as Fell et al. (2005); Guerin and MacKinnon (1985); and Margolis, Bracken, and Stewart (1996) found that restraint-use percentages among children and teens covered by restraint-use laws are higher than those not covered. A limited cost is needed to expand a restraint-use law covering all seating positions in all passenger vehicles. Time taken for expanded restraint-use law coverage is minimal, once the law is enacted and publicized.

4.6.2.2 Communications and Outreach

Communication with parents is important to increase older children's seat belt use on a regular basis (Kuhn and Lam, 2008). According to a study conducted by Kung and Lam, children can be encouraged toward seat belt use by reminding them to wear a seat belt in the car. A message like blinking an eye from parents/guardian is an effective method to encourage seat belt use. Television, radio, and the Internet are good source of safety information for children and parents. Interpersonal doctors' offices/hospitals, friends, family, other parents, and their children's school are also effective sources. Hence, it is important to explore the opportunities to use these sources to convey messages about seat belt use among older children. Wearing a seat belt was a habit for some children and some other children responded to parental reminders and wore the seat belts. Also, children would like to have light or sound reminders to buckle up in the back seat, which is similar to a feature now offered for front seat occupants. Barriers for habitual seat belt use were the absence of conditions to developing the habit such as sporadic reminders or no reminders, lack of modeling by others, and exceptions to the rule (Kuhn and Lam, 2008).

Direct communication to children in this age group could be done at home and school, through child-entertainment channels on television, and video games. Older children were more influenced by their peers, and figures in the media (musicians, athletes, actors), and were engaged in relational technology that connected them to others such as Instant Messenger, e-mail, MySpace.com, cell phones, and iPods (Kuhn and Lam). There was not a good source of information on the factors influencing restraint use for children eight to 15 years old (NHTSA 2010). Hence NHTSA is developing materials and resources for programs for children of the older age group. One of the resources available is the report titled "Increasing Seat Belt Use

Among eight to 15-Year-Olds" (Kuhn and Lam 2008). Depending on the target audience and component of the program, the cost varies. To plan a complete communication programs at least four months is required. It was also proved that school programs increase restraint use substantially among older children. The advantage is the schools and similar institutes provide well-defined audiences for seat-belt-use programs. Some researchers found that school programs increase proper restraint use and slightly increase the percentage of children in rear seats. Program costs will depend on size of the target audience and time may vary from four to 12 months.

4.6.3 Countermeasures in Kansas

Many efforts have been taken to improve child occupant safety in Kansas. One such effort, Safe Kids Kansas, in partnership with community groups and local coalitions, facilitates child safety seat checkup events at inspection stations (Safe Kids 2011). Safe Kids Kansas is a nonprofit coalition of more than 60 statewide and regional organizations and businesses dedicated to preventing accidental injuries to Kansas children ages 0-14. Safe Kids Kansas is affiliated with the Safe Kids Worldwide and is a federally recognized tax-exempt organization. At these events, trained technicians provide education and assistance to parents and caregivers on proper installation and use of child safety seats. The coalition also operates two mobile child safety seat checkup vans to facilitate child safety seat checks in local communities. One van is stationed in Lawrence and one in Wichita to better serve the state. Safe Kids Kansas also works with community groups to distribute child seats and booster seats. More than 27,000 child safety seats and booster seats have been distributed by the coalition to low-income families in the past few years. Safe Kids also works with local communities to develop distribution programs. Intensive hands-on training on child passenger safety seat installation is given to the technicians. In Kansas, 614 child passenger safety technicians are currently trained and certified.

The police department also strives to educate parents on proper use of child safety seats and booster seats (Police Department 2011). A certified child passenger safety technician teaches parents how to install car seats safely and to see if seat has been recalled. The checking takes place the first Wednesday of every month. The Mother and Child Health Coalition was instrumental in obtaining state funding to expand prenatal services for lower income women and in developing a metro-wide database for program planning for each agency and the entire community (Mother and Child Coalition 2011). To help and educate parents and caregivers, local certified child passenger safety technicians are trained to install seats properly. If needed, seats have been provided so that children are riding properly restrained.

The Kansas Traffic Safety Resources Office (KTSRO), which is a program of the KDOT, together with Douglas County Citizens Committee on Alcoholism (DCCCA) promote occupant protection in Kansas (KTSRO 2013). They encourages Kansans to buckle up and travel safely on every trip, with a main focus on saving lives and reducing injuries. Additionally, KTSRO and DCCCA aim to increase awareness about child passenger safety, airbags, and other occupant protection devices through educational classes, seminars, and programming. KDOT, in conjunction with the NHTSA, promotes Child Passenger Safety Week by conducting a week-long law enforcement mobilization (KDOT 2011). The week is designed to bring awareness to the importance of properly restraining children in motor vehicles. Law enforcement agencies participating in the Kansas Clicks Special Traffic Enforcement Program sponsored by KDOT have enforced the Kansas child passenger safety law by stepping up enforcement efforts (Dewey-Kollen 2004). The Kansas Highway Patrol and more than 130 local law enforcement agencies increased patrols, conducted public awareness activities, and held safety seat check lanes during the mobilization (KDOT 2013).

At the time of this report, the Midwest Regional Child Passenger Safety Conference was planned for May 10-12, 2011, in Hutchinson, by the Kansas Traffic Safety Resource Office (KTSRO, 2011). The conference is designed to provide a high-quality learning experience. The Midwest Regional Child Passenger Safety Conference is proud to offer plenary sessions, breakout workshops, hands-on participation, and facility tours. Prestigious speakers will focus on the most current occupant protection resources, technologies, products, and programs. Also, hospitals are conducting child safety seat checkups and certified inspectors will provide guidance on proper child restraint use/installation. For example, a certified child passenger safety technician at Blue Cross Blue Shield of Kansas City gives guidance by appointment (BlueCross 2011). Saint Luke's Health System offers certified child passenger safety technicians who can advise parents on proper use of child-restraint systems and safety belts (Saint Luke's Health System 2011). Additionally, they complete a child safety seat check on the car. If the child is premature, a car seat test will be done with the baby in the car seat. However, community car seat checks are performed by appointment only.

Chapter 5: Conclusions and Recommendations

This chapter presents a summary of the research problem, purpose, data, methodologies, and findings of the study. Conclusions and recommendations are also presented.

5.1 Summary and Conclusions

Crash data were obtained from the Kansas Department of transportation from 2004 to 2008 for this study. Children were divided into two groups, ages four to seven and eight to 13, considering Kansas child-restraint laws. Detailed frequency analysis was carried out. About 3% of children ages four to seven years children group and about 4% of eight to 13 year olds were not restrained. Restraint use among children involved in crashes decreased with increasing age of the child, or number of other occupants in the vehicle. Further, data were analyzed with the Chi-Square test of independence to see whether there was a relationship between restraint use and other variables.

According to the results, restraint use was substantially lower in older vehicles and farm equipment vehicles. Restraint use was significantly less during late night and early morning hours. Child restraint use was also lower in rural areas and on Sundays. Restraint use of child passengers was also related to driver characteristics. More children were restrained in vehicles traveling with a 25 years or older driver. Results also shows that many children were restrained in vehicles with restrained drivers while a considerable percentage of children were not restrained when driving with unrestrained drivers. High-risk drivers, such as drunken drivers, were less likely to restrain children. Driver alcohol use, invalid license, and restrictions on a driver's license were associated with lower restraint use. Children traveling in the front seat were less likely to be restrained than children traveling in the rear seats. Seating positions were also investigated using the Chi-Square test and odds ratios. The odds ratio showed that child-restraint-system use and rear-seating positions were much safer. This result further proved the finding of the univariate and multivariate analysis of predicting odds of child injury. Also, it showed that children traveling on rural roads were less safe.

A logistic model for all children was developed to further investigate child passenger injury risk. The dependent variable was injury severity, defined as a binary variable where a child was injured or not injured. All other crash-, vehicle-, roadway-, environment-, driver-, and passenger-related characteristics were used as independent variables. According to the coefficient, male children were less likely to have an injury when involved in crashes than female children. If the child was in a child seat, the injury severity was less. Children using seat belts were less likely to suffer injuries when involved in crashes. If the driver had a valid driver's license, the child had less chance of injury. Alcohol involvement of the driver showed high possibility of a child passenger being injured in a crash. If the vehicle was destroyed or disabled, injury severity was higher. If a child passenger was ejected or trapped when children were involved in crashes, the child was at a high risk for injury. When a vehicle was newer, the child was less likely to suffer injuries as the result of a crash.

As characteristics of older children differ from those of a younger group, separate logistic regression models were developed for four to seven year olds and eight to 13 year olds who were involved in crashes. These models provided important differences among two child groups. Males in the older age group showed less risk for injuries when involved in crashes. Unlike the younger age group, children in the older age group were more likely to suffer severe injuries when they involved in a crash with a drunken driver. They were less likely to suffer severe injuries when involved in crashes when a driver was attempting to turn or change the lane, travelling on straight roads, or the vehicle had minor damage after the crash. Younger children had low injury risk when they were involved in crashes in adverse weather conditions, or travelling on straight and level roads, or curved roads. Younger children were more likely to suffer severe injuries when drivers were trapped at the time of the crash or travelling at high speeds.

Contributory causes for children involved in crashes were investigated in order to identify the most significant contributory causes. Inattention and failure to give enough time and attention were the most frequent driver contributory causes in child-involved crashes. Roadway-related contributory causes included wet, debris, or icy roads, as main causes in Kansas. The most predominant environment-related contributory cause was an animal hitting the vehicle.

Child seat restraints and rear seating position were identified as main factors which could increase child highway safety. Driver contributory causes such as alcohol involvement and driving without restraint also needed to decrease for child safety to increase on highways.

5.2 Recommendations

Based on the literature review and findings of the study, useful ideas to improve child highway safety are discussed below.

The analysis has shown that children in front seat are more vulnerable for crashes. In Kansas, currently, children are strongly recommended to be restrained in the rear center location. If children whose age is less than eight years old are required to be in the back seats, children will be much safer. Hence, mandating the rear seat for children under eight years old would be recommended. Some other studies also pointed out this requirement in recent past (Huget, 2011). The center rear seat is the safest location in the vehicle. Education programs should be focused on educating parents about the safest seating location.

According to existing law, children between four and eight years of age must be in a federally approved child safety seat/booster seat unless the child weighs more than 80 pounds or is taller than 4'9" in height. Strong, occupant-restraint-use laws should be a combination of child-restraint and seat belt laws covering all seating positions equipped with a seat belt in all passenger vehicles. Transitioning children from child restraints with harnesses to belt-positioning booster seats, instead of vehicle safety belts, provides significant safety benefits for children at least through age eight. However, the booster seat using percentage of this age group in Kansas was 53%. Also, older children using seat belts were less likely to suffer injuries when involved in crashes. Hence, recommendations to increase restraint use among the children include a focus on education, publicity, and enforcement.

Law enforcement agencies should continue to increase enforcement of child passenger protection laws. Effective enforcement could include: support and cooperation from top management of law enforcement agencies for enforcing child passenger safety laws; training and education of law enforcement officers on child-restraint laws and best practices for children by age, weight, and height; educating judges and prosecutors regarding details of child-restraint laws and risks involved in noncompliance of laws; and frequent publicity surrounding enforcement efforts. Obstacles to enforcing booster seat laws such as lack of knowledge and experience with booster seats, lack of commitment from management for training and resources for child-restraint law enforcement, and weakness of booster seat laws should be identified and addressed. Community-wide information plus enhanced enforcement campaigns, media emphasizing enforcement, and random check points are effective in increasing child-restraint use. The child-restraint law could be enforced by increasing penalties for violating the law. Greater enforcement of child-restraint laws would increase child-restraint use.

Education and communication are more important than enforcement. Intervention programs may be effective in increasing parents' knowledge and perceptions about seat-restraint use. Restraint use distribution among children four to eight years olds showed that 53% are in booster seats and 44% are in seat belts only. It may be because parents might not have proper knowledge about children's ages to graduate to adult seat belts. Parents need to know when their children should be secured in booster seats, how to properly use the seats, when to graduate to an adult seat belt, the child-restraint laws in their state, and the differences between the law and best practices for the child's age, weight, and height. Education should also be provided about when it is safe to transport children in adult seat belts. Educational programs about booster seats and the child-restraint laws combined with booster-seat giveaways are successful countermeasures in increasing booster-seat use at pre-school programs in lower socioeconomic communities. State and local agencies should continue to coordinate development and facilitate implementation of educational programs for the community.

As children get older, they were more likely to begin making independent decisions to wear seat belts. Also, they demonstrated a simpler understanding of why they were restrained in seat belts, and were driven by parental influence and a desire to comply with the rules. Hence the communication to increase seat belt use in the older age group is quite different. Communication with parents is important to reinforce their role in demanding that older children consistently use seat belts. Parents can be provided with general safety information from a variety of sources such as television, radio, Internet, doctors' offices/hospitals, friends, family, other parents, and their children's school. Direct communication to children in this age group could be done at home and school through child-entertainment channels on television and video games. Older children were more influenced by their peers; figures in the media such as musicians, athletes, and actors; and when engaged in relational technology that connect them to others such as Instant Messenger, e-mail, MySpace.com, cell phones, and iPods. NHTSA is developing materials and resources for programs interested in targeting this age group, and some pilot programs have been implemented and evaluated that can be used as resources for program development.

Inspection stations are also useful in successfully and positively changing parents' behavior and increasing their knowledge. Neighborhood pediatricians, family practices, and obstetricians/gynecologists may be ideal settings for safety checkups. Also, state licensing agencies can disseminate information about child protection laws through license renewal letters to drivers, displays on counters at licensing centers, and distribution of publications.

It is important to note that restricted measures regarding alcohol-involved driving, mobile phone use, and speeding may reduce the number of children involved in crashes. Effective enforcement may play a key role in preventing alcohol-involved driving and speed-related crashes.

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Appendix A

States' Child-Restraint laws, April 2011

State	*Must be in child restraint*	*Adult safety belt permissible*	*Maximum fine 1st offense*	*Law states preference for rear seat*
Alabama	*younger than 1 or less than 20 pounds in a rear-facing infant seat; 1 through 4 years or 20-40 pounds in a forward-facing child safety seat; 5 but not yet 6 in a booster seat.*	*6 through 14 years*	*$25[1]*	*law states no preference for rear seat*
Alaska	*younger than 1 or less than 20 pounds in a rear-facing infant seat; 1 through 4 years and more than 20 pounds in a child restraint, 4 through 15 years who are either shorter than 57 inches or who weigh more than 20 but less than 65 pounds in a booster*	*4 through 7 years who are at least 57 inches or 65+ pounds; 7 through 15 who are shorter than 57 inches or weigh less than 65 pounds*	*$50[1]*	*law states no preference for rear seat*
Arizona	*4 years and younger*	*not permissible*	*$50*	*law states no preference for rear seat*
Arkansas	*5 years and younger and less than 60 pounds*	*6 through 14 years or 60+ pounds*	*$100*	*law states no preference for rear seat*
California	*5 years and younger or less than 60 pounds[2]*	*6 through 15 years or 60+ pounds*	*$100[1]*	*children 5 years and younger or less than 60 pounds must be in the rear seat[2]*
Colorado	*younger than 1 year and less than 20 pounds in a rear-facing infant seat; 1 through 3 years and 20-40 pounds in a child safety seat; 4 through 7 years in a booster seat*	*8 through 15 years*	*$81*	*1 year and younger and less than 20 pounds must be in the rear seat if available*
Connecticut	*younger than 1 year or less than 20 pounds in a rear-*	*7 through 15 years*	*$60[3]*	*law states no preference for rear*

State	***Must be in child restraint***	***Adult safety belt permissible***	***Maximum fine 1st offense***	***Law states preference for rear seat***
	facing restraint system; 1 through 6 years who is less than 60 pounds in a child restraint system (booster seats may only be used in a seating position with a lap and shoulder belt)	*and 60+ pounds*[3]		*seat*
Delaware	*7 years and younger and less than 66 pounds*[4]	*8 through 15 years or 66+ pounds*[4]	*$25*	*children 11 years and younger and 65 inches or less must be in rear seat if passenger airbag is active*[4]
District of Columbia	*7 years and younger*	*8 through 15 years*	*$75*[1]	*law states no preference for rear seat*
Florida	*3 years and younger*	*4 through 5 years*	*$60*[1]	*law states no preference for rear seat*
Georgia	*5 years and younger and 57 inches or less*[5]	*more than 57 inches*	*$50*[1]	*5 years and younger must be in rear seat if available*[5]
Hawaii	*3 years and younger in a child safety seat; 4 years through 7 years must be in a booster seat or child restraint*	*3 through 7 years who are taller than 4'9"; 4 through 7 years who are at least 40 pounds seated in a rear seat where if there are no available lap/shoulder belts, may be restrained by a lap belt*	*$100*[6]	*law states no preference for rear seat*
Idaho	*6 years and younger*	*not permissible*	*$100*	*law states no preference for rear seat*
Illinois	*7 years and younger*	*8 through 15 years; children who weigh more than 40*	*$75*	*law states no preference for rear seat*

State	***Must be in child restraint***	***Adult safety belt permissible***	***Maximum fine 1st offense***	***Law states preference for rear seat***
		pounds seated in the rear where only a lap belt is available		
Indiana	*7 years and younger*[7]	*8 through 15 years*	*$25*[1]	*law states no preference for rear seat*
Iowa	*younger than 1 year and less than 20 pounds in a rear-facing child seat; 1 through 5 years*	*6 through 17 years*	*$25*	*law states no preference for rear seat*
Kansas	*all children 3 and younger must be in a child restraint; children 4 through 7 who weigh less than 80 pounds and children 4 through 7 who are less than 57 inches tall must be in a child restraint or booster seat*	*all children 8 through 13 years; children 4 through 7 years who weigh more than 80 pounds, and children 4 through 7 years who are taller than 57 inches*	*$60*	*law states no preference for rear seat*
Kentucky	*40 inches or less in a child restraint; 6 and younger who are between 40 and 50 inches tall in a booster seat*	*6 and younger who are taller than 50 inches*	*$50 child restraint; $30 booster seat*	*law states no preference for rear seat*
Louisiana	*younger than 1 year or less than 20 pounds in a child safety seat; 1 through 3 years or 20-39 pounds in a forward-facing child safety seat; 4 through 5 years or 40-60 pounds in a child booster seat*	*6 through 12 years or greater than 60 pounds*	*$100*	*law states no preference for rear seat*
Maine	*less than 40 pounds in a child safety seat; 40-80 pounds and less than 8 years in a safety system that elevates the child so that an adult seat belt fits properly*	*8 through 17 years or less than 18 years and more than 4'9"*	*$50*	*11 years and younger and less than 100 pounds must be in rear seat if available*
Maine	*less than 40 pounds in a child safety seat; 40-80 pounds and less than 8 years in a safety system that*	*8 through 17 years or less than 18 years and more than*	*$50*	*11 years and younger and less than 100 pounds must be in rear seat*

State	***Must be in child restraint***	***Adult safety belt permissible***	***Maximum fine 1st offense***	***Law states preference for rear seat***
	elevates the child so that an adult seat belt fits properly	*4'9"*		*if available*
Maryland	*7 years and younger and either less than 57 inches or 65 pounds or less*	*8 through 15 years; children who are at least 57 inches or 65 pounds*	*$25*	*law states no preference for rear seat*
Massachusetts	*7 years and younger and less than 57 inches*	*8 through 12 years; children who are at least 57 inches tall*	*$25*	*law states no preference for rear seat*
Michigan	*7 years and younger and less than 57 inches*	*8 through 15 years; children who are at least 57 inches tall*	*$10*	*3 years and younger must be in the rear seat if available*
Minnesota	*7 years and younger and less than 57 inches*	*not permissible*	*$50*	*law states no preference for rear seat*
Mississippi	*3 years and younger must be in a child restraint; 4 through 6 years and either less than 57 inches or less than 65 pounds must be in a booster seat*	*6 years and younger who either weigh 65 pounds or more or who are 57 inches or taller*	*$25*	*law states no preference for rear seat*
Missouri	*3 years and younger must be in a child restraint; all children who weigh less than 40 pounds must be in a CR; 4 through 7 years who weigh at least 40 pounds but less than 80 pounds and who are 4'9" or shorter must be in either a CR or booster seat; children 4 years and older who weigh at least 80 pounds or who are at least 4'9" tall must be in either a booster seat or safety belt*	*all children 8 through 16 years; all children 4 years and older who weigh 80 pounds or more or who are taller than 4'9"*	*$50; $10 for violations involving children taller than 4'9" or who weigh 80 pounds or more*	*law states no preference for rear seat*
Montana	*5 years and younger and less than 60 pounds*	*not permissible*	*$100*	*law states no preference for rear seat*

State	Must be in child restraint	Adult safety belt permissible	Maximum fine 1st offense	Law states preference for rear seat
Nebraska	5 years and younger	6 through 17 years[8]	$25[1]	law states no preference for rear seat
Nevada	5 years and younger and 60 pounds or less	not permissible	$500[9]	law states no preference for rear seat
New Hampshire	5 years and younger who are less than 55 inches	6 through 17 years; younger than 6 who are at least 55 inches tall	$50	law states no preference for rear seat
New Jersey	7 years and younger and less than 80 pounds	not permissible	$25	children 7 years and younger and less than 80 pounds must be in the rear seat if available
New Mexico	younger than 1 year in a rear-facing infant seat; 1 through 4 years or less than 40 pounds in a child safety seat; 5 through 6 or less than 60 pounds in a booster seat	7 through 17 years	$25	children younger than 1 year in a rear-facing infant seat must be in the rear seat if available
New York	3 and younger unless they weigh more than 40 pounds and are seated where there is no available lap/shoulder belt; 4 through 7 years unless they are seated where there is no available lap/shoulder belt	8 through 15 years; children who weigh more than 40 pounds or children 4 through 7 years in a seating position where there is no available lap/shoulder belt	$100[1]	law states no preference for rear seat
North Carolina	7 years and younger and less than 80 pounds	8 through 15 years + children 40-80 pounds in seats without shoulder belts	$25[1]	children 4 years and younger who weigh less than 40 pounds must be in the rear

State	Must be in child restraint	Adult safety belt permissible	Maximum fine 1st offense	Law states preference for rear seat
				seat unless the front passenger airbag is deactivated or the restraint is designed for use with airbags
North Dakota	6 years and younger and less than 57 inches or less than 80 pounds	7 through 17 years; 6 years and younger and at least 57 inches tall and at least 80 pounds; 6 years and younger and at least 40 pounds, if there are no available lap/shoulder belts, may be restrained by a lap belt	$25[1]	law states no preference for rear seat
Ohio	3 years and younger or less than 40 pounds in child restraint; 4 through 7 years who weigh 40 pounds or more and who are shorter than 57 inches in booster seat	8 through 14 years[10]	$75[10]	law states no preference for rear seat
Oklahoma	5 years and younger[11]	6 through 12 years	$25	law states no preference for rear seat
Oregon	younger than 1 year or 20 pounds or less must be in a rear-facing child safety seat; 7 or younger: 40 pounds or	taller than 4 feet and 9 inches; 8 through 15	$90	law states no preference for rear seat

State	Must be in child restraint	Adult safety belt permissible	Maximum fine 1st offense	Law states preference for rear seat
	less must be in a child safety seat; more than 40 pounds but 4 feet and 9 inches or less must be in a safety system that elevates the child so that an adult seat belt fits properly			
Pennsylvania	7 years and younger[12]	not permissible	$100	law states no preference for rear seat
Rhode Island	7 years and younger and less than 57 inches and less than 80 pounds	7 years and younger who either weigh 80 pounds or more or who are at least 57 inches tall; 8 through 17	$75	children 7 and younger must be in rear seat if available
South Carolina	younger than 1 year or less than 20 pounds in a rear-facing infant seat; 1 through 5 years and 20-39 pounds in a forward-facing child safety seat; 1 through 5 years and 40-80 pounds in a booster seat secured by lap-shoulder belt (lap belt alone is impermissible)	1 through 5 years and 80+ pounds or any child 5 years and younger if the child's knees bend over the seat edge when sitting up straight with his/her back firmly against the seat back	$150	children 5 years and younger must be in rear seat if available
South Dakota	4 years and younger and less than 40 pounds	5 through 17 years; all children 40+ pounds, regardless of age	$20	law states no preference for rear seat
Tennessee	younger than 1 year or 20 pounds or less in a rear-facing infant seat; 1 through 3 years and 20+ pounds in a forward-facing infant seat; 4 through 8 years and less	9 through 15 years or any child 12 or younger who is 4'9" or taller	$50	children 8 years and younger and less than 4'9" must be in rear seat if available; rear seat recommended for children 9 through

State	***Must be in child restraint***	***Adult safety belt permissible***	***Maximum fine 1st offense***	***Law states preference for rear seat***
	than 4'9" in a booster seat			*12*
Texas	*7 years and younger and less than 57 inches*	*not permissible*	*$25*	*law states no preference for rear seat*
Utah	*7 years and younger and shorter than 57 inches*	*8 through 15 years; all children 57 inches or taller*	*$45*	*law states no preference for rear seat*
Vermont	*younger than 1 year or less than 20 pounds in a rear-facing infant seat; 2 through 7 and more than 20 pounds*	*8 through 17 years and more than 20 pounds*	*$25*	*children 1 year and younger or less than 20 pounds must be in the rear seat unless the front passenger airbag is deactivated*
Virginia	*7 years and younger unless they have a physician exemption*[13]	*8 through 17 years*[13]	*$50*	*children in rear-facing devices must be in a rear seat if available; if not available, they may be placed in front only if front passenger airbag is deactivated*[13]
Washington	*7 years and younger and less than 4'9"*	*8 through 15; 7 years and younger and 4'9" or taller; children who weigh more than 40 pounds in a seating position where there is only a lap belt available*	*$124*	*12 years and younger must be in rear seat if practical*
West Virginia	*7 years and younger and less than 4'9"*	*7 years and younger and 4'9" or taller*	*$20*	*law states no preference for rear seat*
Wisconsin	*children younger than 1 and all children who weigh less than 20 pounds are required to be in a rear-facing infant*	*8 years and younger and more than 80 pounds and 57 inches or taller*	*$75*	*children 3 and younger must be in a rear seat, if available*

State	Must be in child restraint	Adult safety belt permissible	Maximum fine 1st offense	Law states preference for rear seat
	seat; children 1 through 3 years who weigh at least 20 pounds but less than 40 pounds are required to be in a forward-facing child safety seat; children 4 through 7 who both weigh at least 40 pounds but less than 80 pounds and who are less than 57 inches tall are required to be in a booster seat			
Wyoming	*8 years and younger*	*not permissible*	*$50*	*children 8 years and younger must be in the rear seat if available*

[1]*This state assesses points for violations.*

[2]*In California, children weighing more than 40 pounds may be belted without a booster seat if they are seated in the rear seat of a vehicle not equipped with lap/shoulder belts. The California rear seat requirement does not apply if there is no rear seat; the rear seats are side-facing jump seats; the rear seats are rear-facing seats; the child passenger restraint system cannot be installed properly in the rear seat; all rear seats are already occupied by children under 12 years; or medical reasons necessitate that the child not ride in the rear seat. A child may not ride in the front seat of a motor vehicle with an active pasenger airbag if the child is under 1 year of age, or weighs less than 20 pounds or is riding in a rear-facing child restraint system.*

[3]*The fine in Connecticut is $15 if the child is 4-16 years and 40 pounds or more. Connecticut also requires a mandatory child restraint education program for first or second violation.*

[4]*In Delaware, children younger than 12 years/65 inches or less must be restrained in a rear seat if a vehicle has a passenger airbag, unless the airbag has been either deactivated or designed to accommodate smaller people. Exceptions: no rear seat or rear seat occupied by other children younger than 12 years/65 inches or less.*

[5]*In Georgia, children weighing more than 40 pounds are permitted to be restrained in the back seat of a vehicle by a lap belt if the vehicle is not equipped with lap and shoulder belts, or when the lap and shoulder belts are being used by other children who weigh more than 40 pounds.*

[6]*Hawaii drivers are charged $50 for a mandatory child restraint education program and a $10 surcharge deposited into a neurotrauma special fund.*

[7]*In Indiana, children weighing more than 40 pounds are permitted to be restrained by a lap belt if the vehicle is not equipped with lap and shoulder belts, or if all lap and shoulder belts other than those in the front seat are being used to restrain other children who are younger than 16.*

[8]*Nebraska's law is secondary for those children who may be in safety belts and standard for those who must be in a child-restraint device.*

[9]*In Nevada, the minimum fine is $100. An alternative to the fine is at least 10 but not more than 50 hours of community service.*

[10]*In Ohio, the law is secondary for children 4 through 14 years.*

[11]*In Oklahoma, children weighing more than 40 pounds are permitted to be restrained in the back seat of a vehicle by a lap belt if the vehicle is not equipped with lap and shoulder belts, or when the lap and shoulder belts are being used by other children who weigh more than 40 pounds.*

[12]*In Pennsylvania, the law is secondary for children ages 4 through 7 years who must be in booster seats.*

[13]*In Virginia, children at least 4 years but less than 8 years may be belted if any licensed physician determines that use of a child-restraint system by a particular child would be impractical by reason of the child's weight, physical fitness, or other medical reason, provided that any person transporting a child so exempted shall carry on his person or in the vehicle a signed written statement of the physician identifying the child so exempted and stating the grounds for the determination.*

Source: (States' Child-Restraint laws, 2011)

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