FINAL REPORT

Determinants of Motor Vehicle Fatalities and Fatality Rates in Illinois

Project VA-H1, FY 99

Report No. ITRC FR 99-3

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August 2002

Illinois Transportation Research Center
Illinois Department of Transportation

ILLINOIS TRANSPORTATION RESEARCH CENTER

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
ITRC FR 99-3		

4. Title and Subtitle Determinants of Motor Vehicle Fatalities and Fatality Rates In Illinois	5. Report Date August 2002 6. Performing Organization Code
7. Author(s) Jamshid Mohammadi, C. Jotin Khisty, Cemal Ayvalik and Samir Patil	8. Performing Organization Report No. 10. Work Unit No. (TRAIS)
9. Performing Organization Name and Address Illinois Institute of Technology Department of Civil and Architectural Engineering 3201 S. Dearborn Street Chicago, IL 60616	12. Contract or Grant No. VA-H1, FY 99 13. Type of Report and Period Covered Final Report November 1999 through April 2002
11. Sponsoring Agency Name and Address Illinois Transportation Research Center Southern Illinois University Edwardsville Engineering Building, Room 3026 Edwardsville, IL 62026-1803	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

In this study, four groups of factors were identified as those that influence fatalities in Illinois. These were divided into driver-related, vehicle-related, highway/environment, and demographics factors. Based on a descriptive analysis of fatality data, alcohol involvement, speeding, age, rural versus urban highways, divided versus undivided highways, snowy and icy days, location of crashes in relation to the intersection, and railroad crossing were identified as factors that affect fatalities. Correlation and regression analyses were conducted at the local level to identify regional differences in fatality data. Among factors related to the driver, crashes involving alcohol was perhaps the only factor that indicated a significant regional difference and some degree of correlation with higher fatalities. The correlation and regression analyses were also conducted at the State level to investigate the dependence of fatalities on the four factor groups from year to year. The results indicated that the proportion of drivers in the 16-19-year age involved in crashes contributes significantly to the fatality rate. Also, crashes involving drivers with any blood alcohol concentration level in their systems in general contribute significantly to traffic fatalities. The significance of weekday/weekend, night/day, urban/rural driving and snowy/rainy day conditions was also investigated through the correlation and regression analyses. The analyses revealed comparable results for weekday versus weekend driving. On vehicle-related factors, crashes involving passenger cars showed a strong correlation with the fatality rate. Finally, the results of a time series analysis indicated that motor vehicle fatalities are be on the decline in Illinois.

17. Key Words	18. Distribution Statement
Crashes, Fatalities, Fatality causes, Fatality data Fatality trends	No restrictions. This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	133	

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Final Technical Report

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Foreword

This final report is prepared by Illinois Institute of Technology (IIT) and contains all the findings, methods developed and data analyses conducted as part of the requirements of the project VA-H1, FY99 entitled: " Determinants of motor vehicle fatalities and fatality rates in Illinois." The project was sponsored by the Illinois Department of Transportation (IDOT) and administered by the Illinois Transportation Research Center (ITRC). The authors wish to express their sincere appreciation to the entire members of the Technical Review Panel (TRP) for their guidance throughout the course of study. The authors especially would like to thank Dr. Mehdi Nassirpour of IDOT for his valuable input to the direction of the study, and Steven Hanna and Dianne Kay of ITRC for their administrative direction of the program.

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Executive Summary

This report summarizes the results of a study conducted by Illinois Institute of Technology (IIT) on the identification of the determinants of motor vehicle fatalities and fatality trends in Illinois. The study was based on available data and a series of descriptive and statistical analyses.

The sources of data and the type of data compiled from these sources used in the study included: (1) Illinois Department of Transportation (IDOT), Division of Traffic Safety (type of data: fatalities); (2) Fatality Analysis Reporting System (FARS), National Highway Traffic Safety Administration (type of data: fatalities); (3) IDOT Division of Highways (type of data: vehicle miles of travel); (4) Illinois State Water Survey (type of data: weather records in Illinois including the number of rainy and snowy days for the period 1975-2000); (5) IDOT Office of Planning and Programming (types of data: the average annual daily traffic data was obtained through IDOT Division of Traffic Safety; and data on the length of highways and streets for 1975-1999); (6) Illinois Department of Revenue (type of data: liquor taxes); (7) Bureau of Census (types of data: population distribution in Illinois for 1990 and estimates of population by county and age for 1991-1999; and data on the number of employees working for alcohol vendors for the years 1992 and 1998); (8) National Personal Transportation Survey (type of data: vehicle miles of travel (VMT) by age group for the years 1977, 1983, 1990 and 1995); and (9) Illinois Secretary of State (type of data: the number of licensed drivers in Illinois was obtained through IDOT Division of Traffic Safety).

Through a review of literature, four groups of factors were identified as those that influence fatalities. These included: (1) Driver factors -- In this group, blood alcohol concentration (BAC) level, speed, seatbelt use and fatigue were listed as those factors that can directly be controlled to reduce fatalities; whereas, age, gender, driving hours, day/night driving and weekend/weekday driving are those that may not be directly controlled. (2) Vehicle factors -- Vehicle factors that can be controlled include safety equipment, car defects and airbag deployment. Those that cannot be directly controlled are vehicle type and size. (3) Highway/Environment factors -- In this category, factors that can be controlled are posted speed, roadside safety devices, geometric design of highway, median and feeder ramps. Those that cannot be directly controlled are weather and urban/rural highway use. (4) Demographics -- Under this group, the level of law enforcement and emergency medical service (EMS) availability are those factors that can be controlled; whereas, type of area (rural vs. urban), change in travel patterns, VMT and socioeconomic composition are factors that may not be directly controlled.

Several types of analysis were conducted to identify trends in fatalities, investigate the significance and effect of various factors on fatalities, and provide an estimate of future trends in fatalities in Illinois. These analyses included: (1) a comprehensive descriptive evaluation of the four groups of data that were believed to influence fatalities; (2) multi-variable correlation and regression analyses of fatality rates and factors related to the driver, vehicle, environment, and demographics; (3) hypotheses development and testing on the influence of various factors on fatalities; and (4) a time series analysis for forecasting future trends in fatalities. In all these analyses the fatality rate was computed as the ratio of the number of fatalities to the VMT.

In conducting the descriptive analyses, nearly all factors identified as those that influence fatalities were used along with the fatality data to evaluate the trends observed in these factors over 1975-1999. The results are presented in the form of graphs and tables. Correlation analyses were also conducted to determine whether trends in individual factors followed the trends in fatality rates. Among various factors studied, several had significant prevalence in fatal crashes and fatalities. These were alcohol involvement, speeding, age, rural versus urban highways, divided versus undivided highways, snowy and icy days, location of crashes in relation to the intersection; and railroad crossing.

To conduct a county-level regression analysis, the State was divided into 29 regions each consisting of one or more counties. Among factors related to the driver, crashes involving alcohol was perhaps the only factor that indicated a rather significant regional difference and some degree of correlation with higher fatalities. It is emphasized that this finding is not conclusive. The prevalence of other factors such as the level of traffic law enforcement, better education and awareness on adverse effects of alcohol consumption, and social/economical status may influence fatality rates in certain regions where per capita alcohol consumption is higher than other areas. The analysis indicated a significant correlation between fatalities and crashes involving alcohol in less populated areas, regions with lower per capita income and especially in southern Illinois counties where there is a rather large concentration of recreational areas. More populated areas such as Cook County and counties in the Chicago area have lower per capita traffic fatalities. Also, in Champaign County, there is a lower fatality rate with a high concentration of younger age groups. On other driver-related factors such as speeding and use of seatbelt, age and driving hours, the analysis did not support any significant variations across the State. Considering the vehicle factors, the analysis of data did not reveal any evidence that these factors had any regional variations across the State. However in the highway/environmental group, the weather showed significant regional differences in affecting fatalities. Specifically, the numbers of snowy and icy days contribute significantly to fatality rates.

At the State-level, the correlation and regression analyses were conducted for 22 years of data. The analysis was intended to investigate the dependence of fatalities on the four factor groups from year to year. Among the driver factors, the results indicated that the proportion of drivers in the 16-19-year age involved in crashes to the total driving population contributes significantly to the fatality rate. On the significance of other driver-related factors, crashes involving drivers with any BAC level in their systems in general contribute significantly to traffic fatalities. The same is true for crashes involving speeding drivers. The significance of weekday/weekend, night/day, urban/rural driving and snowy/rainy day conditions was investigated through correlation and regression analyses. The analyses revealed comparable results for weekday versus weekend driving. When night versus daytime driving was considered, the analysis revealed a strong correlation between fatality rate and crashes occurring during dark hours. Furthermore, the average number of snowy days showed a strong correlation with fatality rates. On vehicle-related factors, three types of vehicles were considered namely passenger cars, trucks and buses. Crashes involving passenger cars showed a strong correlation with the fatality rate.

To identify how fatalities may change in future years, a time series analysis was conducted. The results indicated that in general motor vehicle fatalities are on decline in Illinois. The average reported fatalities in Illinois are about 1600 per year. This average has been reduced in more recent years. The time series analysis was conducted for the year 2002 to 2009. The level of uncertainties in the results increases as estimates in long-term futures are sought. Considering a short-term future, the estimates for fatalities in years 2002 and 2003 will be about 1240 per year. This estimate is an upper bound value based on 99% confidence level and about ±30% variation. Considering longer term estimates, the analysis resulted in 1230 fatalities in 2008 and 2009. Again, this is an upper bound value based on a 99% confidence level and ±55% variation. At the regional levels, decline of fatalities is not consistent. Since detailed information on fatalities and factors causing fatalities were not widely available at regional and county level, a more rigorous analysis of future trends at the regional level could not be conducted. Areas with large population concentrations in Illinois seem to be the major contributors to the decline in fatality rates in Illinois. The descriptive analysis and correlation and regression analyses were consistent in providing an insight into how various factors contribute to fatalities.

1.0 INTRODUCTION, OBJECTIVES AND SCOPE

1.1 General

This final report is prepared by Illinois Institute of Technology (IIT) and contains all the findings, methods developed and data analyses conducted as part of the requirements of the project VA-H1, FY99 entitled: " Determinants of motor vehicle fatalities and fatality rates in Illinois." The project was sponsored by the Illinois Department of Transportation (IDOT) and administered by the Illinois Transportation Research Center (ITRC).

1.2 Objectives of the Study

The Objectives of the study were:

(1) to describe fatalities and fatal crash patterns both at the state and county levels,

(2) to identify and describe possible factors that may affect fatalities and fatality rates in Illinois, and,

(3) to build both county and state level databases based on the available data sources.

1.3 Scope of the Study

The project consisted of a program of study to: (1) compile data on fatalities and fatal crashes in Illinois to identify factors that affect the rate of fatal crashes both at the county and State level, (2) develop a comprehensive database for the data gathered on fatal crashes at the state and county level by using the fatal crash data from several sources as identified in the study, (3) conduct relevant statistical analyses to determine the significant variables that affect fatalities and fatality rates in Illinois, and (4) develop a model that can describe the time-varying fluctuation in fatality rates in terms of factors that are identified as those influencing fatalities, fatal crashes and fatality rates in Illinois.

2.0 REVIEW OF RELATED WORK

2.1 Introductory Remarks

The statistics of fatalities and injuries involving motor vehicles reveal that some 40,000 deaths and more than 3.5 million injuries occur annually on the nation's highways. The statistics for Illinois show an average of 1400 fatalities and 150,000 injuries per year over the last 25 years. In the year 2000, 1,274 fatal crashes had occurred in which 1,977 vehicles have been involved and 1,418 individuals have been killed. These are alarming statistics in the sense that they surpass nearly all other incidence of fatalities and injuries due to various other causes (e. g., airplane crashes, gas explosions, fire, etc., Wiggins, 1985). The United States traffic fatalities dropped dramatically from 49,301 in 1981 to about 43,700 in 1982. This corresponded to a 20-year low per mile of travel. In years prior to that a similar decrease occurred only in 1974 (Hedlund, et al, 1984). This decrease was only two years after the year 1972 when over 50,000 fatalities occurred. In fact the 1972 statistics indicated a peak in the number of fatalities in U.S. (National Safety Council data, 1995 and Cerrelli, 1994 and 1995). In the period between 1982-1992, several consecutive years of substantial decreases in motor vehicle fatalities occurred. However, slight increase in 1993 and 1994 occurred at 39,250 and 40,150 fatalities, respectively. These statistics are according to the National Highway Traffic Safety Administration (NHTSA) data. Since 1994, a slight decrease in motor vehicle fatalities has been observed both at the national and state level.

The 1974 decline in motor vehicle fatalities is primarily attributed to the oil crisis, the implementation of the 55-mph speed level and depressed economic conditions, which disrupted the nation's driving habits. The 1982 decline however is attributed to such factors as alcohol programs, occupant restraint use, demographic shifts, travel patterns and economic conditions (Hedlund, et al, 1984).

Motor vehicle fatalities are believed to be affected by many factors including some type of human error, lack of attention or misjudgment of road or traffic conditions and by several socioeconomic factors. Generally, a fatality is caused by a host of factors. However, often a dominant factor can be identified as the main cause of fatality. Factors influencing overall crash risk and potential fatalities may be grouped into four broad categories. These are: (1) drivers; (2) vehicle; (3) highway/ environmental; and (4) demographic factor groups. The prevalence of a factor in a fatality can often be identified with other factors, not necessarily from the same group. However, it is difficult to ascertain whether the lack of a specific factor would have prevented the fatality. Numerous studies have looked into the significance of different factors on fatalities. Among these, Malliaris, et al (1997) discussed the relationship between crash casualties and crash attributes. This and similar studies are helpful in identifying the determinants of motor vehicle fatalities and fatality rates.

A major objective of this study focuses on identifying the determinants of motor vehicle fatalities and fatality rates. By studying these determinants in a given region, the study aims at providing an insight into how future fatalities and fatality rates may change in the region. Due to the diversity and variety of potential factors contributing to traffic crashes, it is difficult to precisely assess the nature and quantity of motor vehicle fatalities for a given region; and estimate future trends in fatality rates. However, within each region, certain factor groups can be studied and identified as major players in shifting the future fatalities and fatality rate trends. The estimate for future fatality rates in the region can then be made using statistical time series analysis based on past data and within a statistical confidence level.

Factors such as the blood alcohol concentration (BAC) level, age, fatigue, failure to use seatbelt, speed, driving hours, and driver's violation records are within the factor group describing the driver's behavior and habits. Vehicle factor group includes vehicle type, safety equipment (such as the antilock brake system), and car defects. Highway and environmental factor group includes posted speed limit, highway geometric design, pedestrian and bicycle traffic, animal crossing, and the regional number of wet versus dry days per year. Demographic factors can be attributed to county location, rural versus urban regions and driver's residence location.

In this section, previous studies that have evaluated various factors on the motor vehicle fatalities are reported. Most such studies examined specific factors and often did not offer a year-by-year variation in fatalities, and changes in fatality trends, that may have been influenced by the prevalence of one or more of these factors. A more comprehensive analysis of trends in fatalities in terms of various factors is conducted based on published data and reported in Section 6 of this report.

2.2 Factors Related to Driver's Behavior and Habits

Numerous studies have investigated the prevalence of BAC level in crashes leading to fatalities. Other driver-related factors studied are speed violations, driver's habits, age and gender. A review of studies dealing with these issues is presented next.

2.2.1 Blood Alcohol Concentration (BAC) Level

Hall (1996) investigated the role of alcohol in traffic crashes. Out of about 42,400 traffic fatalities in 1983, about 50% are believed to have been caused by alcohol and drivers under influence of alcohol. Several other studies have also looked at the significance of alcohol in traffic crashes. Among these is the study by Owens and Sivak (1996) and Pendleton, et al (1985). The latter study addressed alcohol involvement in fatalities by motor vehicles in Texas; whereas the former study examined the significance of alcohol in traffic fatalities at night. Wells and McDonald (1999) studied the relationship between alcohol consumption patterns and cars and work habits, sports and home accidents for various age groups. The study suggested that younger drivers are more frequently involved in alcohol related motor fatalities than are older drivers. Voas, et al (1998) reported that the total number of drinking drivers fell by about one third between 1986 and 1996. However, there was no significant change in the number of drivers with BAC levels above 0.05. BAC level is measured in terms of weight per volume. BAC levels are typically reported in grams of alcohol per deciliter of whole blood (g/dl). The symbol "%" is frequently used to denote (g/dl) in percentages (Moskowitz & Fiorentino, 2000). Although, reporting BAC levels in percentages is not technically true, since it is describing a measure of weight in a measure of volume, it can be accepted for practical purposes. In that sense, having a BAC level of 0.05% means 0.5 parts of alcohol to 1000 part blood in the body. A BAC level of 0.05 is the level above which impairments are reported (NIAAA, 1997). The

Illinois legal BAC limit is 0.08. Furthermore, Voas (1998) reported that the proportion of female drivers involving alcohol had increased over the last decade. Roger and Schoenig (1993) studied the impact of 1982 legislative reform, including penalties, greater sentencing and introduction of laws on California regarding driving under the influence (DUI) countermeasures, on crashes. These factors were measured at both the state and countrywide events to quantify alcohol related crash rates. Due to implementation of these laws in California, there was a reduction in the subsequent alcohol related fatalities.

2.2.2 Speed

The significance of speed in causing fatalities can be considered in two different groups of factors; namely, the driver's behavior group, and the highway group. This section discusses the speed from the viewpoint of the driver's behavior. The significance of speed (as it appears in the form of posted limits) is further discussed in Section 4.3 under the highway and environmental factor group.

Statistics of National Highway Traffic Administration (US Department of Transportation, 1999) for 1998 show that about 599,000 people received minor injuries in speeding related crashes. About 72,000 additional people received moderate injuries and about 40,000 received critical injuries in speeding related crashes. This is about 30% of all fatal crashes. However, it is emphasized that speeding related crashes are from crash reports. And as such, the information on the driver's speed in a crash report is a subjective determination by police.

2.2.3 Driver's Habits and Fatigue

Fatigue and trip time (driving hours) are among other determinants of fatal crashes. Summala and Mikkola (1994) studied the significance of such factors as fatigue and age on fatal crashes among car and truck drivers using Finnish crash data. Fell and Black (1997) investigated the features of driver fatigue incidents (crash, near crash and unintentional drifting out of lane). These factors were primarily present in fatal crashes occurred in cities. Furthermore, the study indicated that crashes resulting from driver's fatigue occurred more in work-related trips. In particular, "shift-workers" were prominent in crashes resulting from driver's fatigue.

Arnold, et al(1997) surveyed drivers' hours of work and perception of the causes and magnitude of fatigue as a problem in the heavy-transport industry. The study found that 51% of drivers had longer than 14 hours of driving per day. This rather long driving time was believed to be the main cause of fatigue.

In regard to a driver's general habits, several studies have supported the notion that the number of fines received by a driver is correlated with the number of his/her crashes. Sagberg (1999) studied road crashes by drivers falling asleep or being drowsy. The study found that 3.9% of all crashes involve drivers being sleep or drowsy. On the study of the driver's habit by gender, crash data reveal that more male drivers are involved in sleep-related crashes than are female drivers. It is noted that evidently male drivers operate vehicles at higher speeds. This may further increase the risk of crashes when sleep or drowsiness is also involved. Kuge, et al (1995) reported on the causes of rear-end collision based on the analysis of driver's behavior. However, this study did not include any fatality data.

Lack of sleep contributes to fatigue and imposes as a serious hazard to drivers. Feyer (2001), in her editorial article in the April 2001 issue of the British Medical Journal, reports this as being a problem especially for night workers. According to Feyer, about 29% of drivers in the UK and 25% in New York have reported to fall asleep at the wheel at some time. She further reports that about 10% of 70,000 serious crashes that involved only one vehicle were fatigue-related. Fatigue is also reported to be a major problem in about one-third of Australian truck drivers.

Stutts, Wilkins and Vaughn (1999) present a comprehensive report on a study dealing with the role of drowsiness in motor vehicle crashes and the characteristics of drivers involved in such crashes. Approaches used in the study included the analysis of police-reported crash data, in-depth on-site crash investigations immediately following a crash, and surveys of general driving population. According to this study, work and sleep schedules were both strongly associated with involvement in sleep-related crashes. Compared to drivers in no-sleep crashes, drivers in sleep crashes were nearly twice as likely to work at home at more than one job and their primary job was much more likely to involve non-standard hours. The study further reported that working the night shift increased the odds of a sleep-related (versus non-sleep-related) crash by nearly six times. The report also indicated that time spent asleep per night is also a strong risk factor; the fewer the hours slept, the greater the odds for involvement in a sleep-related crash. Johnson (1998) reports that about 23% of drivers have said that they had actually fallen asleep at the wheels.

2.2.4 Age and Gender

Many studies and statistical data have shown that certain age groups are more likely to be involved in motor vehicle fatalities. When the fatality rate is calculated on estimated annual travel, the highest rate is found among the youngest and oldest drivers.

The 1998 statistics from the National Highway Traffic Safety Administration (US Department of Transportation, 1999) reveal that elderly drivers constitute about 9% of the resident population but account for 14% of all traffic fatalities. Garber and Srinivasan (1991) report that crash risk for elderly drivers is higher than it is for the average person, especially at intersections outside cities. It was found that providing a longer amber signal time and protecting left-turn pockets would help the older drivers by reducing the risk of crashes. Evans (1991) reported that elderly drivers are less likely to be involved in rollover crashes or crashes involving alcohol.

Chandler (1998) investigated the relation between fatality rates, driver age and gender. The study showed that the fatality rate for teenage drivers is about four times higher than the rate for drivers in 25 to 65 year age group. Libertiny (1997) also examined available crash data to determine how age can affect the frequency and severity of traffic crashes. Massie, et al (1995, 1997) looked into the role of age and gender in crashes. In their 1995 study, Massie, et all (1995) examined passenger vehicle travel data from the 1990 nationwide transportation survey, combined with crash data from the 1990 Fatality Analysis Reporting System (FARS) and the 1990 General Estimate System (GES), to produce crash rate per vehicle mile of travel. The observed elevated rates were reported to be for drivers in the age group comprising of drivers with 16 to 19 years of age; and again in the age group comprising of drivers with 75 years of age and older. Youngest drivers had highest rate of involvement in all police reported crashes. Doherty, Andery, MacGergor (1999) studied situational risks of young drivers, especially in terms of the passenger effect, and found young drivers 16-19 years had higher involvement in such type of fatalities.

2.2.5 Use of Safety Equipment

Another factor that can be attributed to the driver's behavior is the proper use of occupant restraints and safety equipment such as the seatbelts and proper installation and use of car child seats. Information on whether the driver and/or passengers properly wore seatbelts in a crash can often be obtained from crash reports. However, the information is not often complete or it may be subjective based on circumstances and evidences observed by police. Furthermore, the vehicle fatality data bases, which were reviewed as part of the literature search, did not provide complete information as to whether drivers and passengers involved in fatal crashes have properly worn seatbelts. It is obvious that understanding whether seatbelts and child car seats are properly used is an important factor in fatal crash investigations. However, in most cases, where other factors (such as speeding, and blood alcohol level) are the major causes of fatal crashes, the lack of proper seatbelt use is often considered a secondary cause. The review of literature does not provide any comprehensive and widely-published studies to address the significance of seatbelt and car child seat use, as a driver-related and/or passenger-related factor, on fatalities and fatality trends. Studies available on safety equipment are mainly based on the trends in fatalities and fatality rates following the implementation of seatbelt laws and installation of airbags as standard equipment on passenger cars and light trucks. For example, Thomas (1998) conducted a study to investigate the effect of seatbelt laws and their enforcement status. Evans (1988) conducted a study on the effectiveness of rear seat restraint systems for passengers of 16 years of age and older. FARS data for 1975-1985 was used for this purpose. The study reports that an average restraint system effectiveness for the two outboard rear seating positions is estimated s $(18\pm9)\%$. The error limit is reported to indicate one standard deviation. The study suggested that there is a 39-40% chance that the rear lap belts reduce fatality likelihood, with less than 1 in 10 chance that the reduction exceeds 30%.

The next section covers more information on the significance of occupant restraints from the viewpoint of vehicle-related factors.

2.3 Factors Related to the Vehicle

2.3.1 Availability of Safety Equipment

In early 1990's, gradually motor vehicle manufacturers offered the antilock brake system (ABS) as standard equipment on new vehicles. The significance of ABS on traffic fatalities has also been a controversial issue. Farmer, et al (1997) examined the fatal crash rates of passenger cars and vans for two groups of vehicles. Those with and without ABS with all other designs being nearly identical. The results showed that drivers in vehicles with ABS were significantly more likely to be involved in crashes fatal to their own occupants especially in single vehicle crashes. In contrast, the ABS vehicles were less likely to be involved in crashes fatal to occupants of other vehicles or non-occupants (i.e., pedestrian and bicycle riders). Farmer, et al (1997) further indicated that overall the ABS appears to have had little effect on fatal crash involvement. It is emphasized that in early years of ABS introduction to vehicles, many drivers were not fully familiar with how to take the full advantage of the ABS capabilities. With several years of use and education, drivers became more familiar with ABS operation. Thus the ineffectiveness of ABS or its adverse effect on traffic safety may be attributed to drivers' unfamiliarity with correct operation of ABS especially in early years it became standard equipment in vehicles.

Other components studied in highway fatality statistics are seatbelts and airbags. The mandatory use of seat belts was intended as a means to reduce fatalities and major injuries in rollovers. Airbags were intended as an extra protection in head collisions. Numerous studies have addressed the effectiveness of airbags in reducing fatal injuries. Airbags are now considered as standard equipment in vehicles and may have been the reason for a decline in fatality rates since 1994. Using the crash data from New York, North Carolina, and Florida States, Padmanaban et al (1993) studied the non-fatal injury risk of airbags and airbag deployment. The safety performance of airbags was then measured in terms of major and minor injury reduction for drivers. The standard use of airbags has brought up another controversial issue in vehicle safety in recent years. Injuries resulting from airbag deployments have been reported in media in conjunction with the driver's position with respect to the steering wheel, improper use of the seat belts and child car seats. The argument over the injuries initiated from airbag deployments has caused the car manufacturers to re-design new generation of airbags that impose a lesser amount of pressure on the drivers and passengers during head-collision impacts. No formal studies have looked into recent crash data to comment on the performance of the new generation of airbags in crashes involving injuries and/or fatalities. However, a recent article (Garvey, 2001) indicates that the deaths resulting from airbag deployment is on decline since 1996. The article quotes data from the National Safety Council and reports that fatalities caused by air bags have declined dramatically since 1996, when 35 people (19 of them children) died mostly in slow-speed crashes. Traffic fatalities attributed to air bags were cut in half by 2000; although the number of automobiles equipped with the front-seat devices increased by more than three times. According to the article, the National Highway Traffic Safety Administration estimates that air bags have saved the lives of 8,645 people since 1987 and 7,224 of them since 1996. Although no specific reason for decline in airbag fatalities is mentioned, indications are pointing to the "Air Bag & Seat Belt Safety Campaign" as being an effective educational tool.

2.3.2 Vehicle Type and Size

In 1988, large trucks accounted for 3% of all registered vehicles, 7% of total vehicle miles traveled and 9% of all vehicles involved in fatal crashes. Sparrow (1985) studied crash involvement and injury rate for small cars. The results showed that small car drivers cause a significantly lower percent of the crashes they are involved in than do drivers of larger cars. Wood (1996) examined the passive safety of cars in the context of the influence of the car size and mass on the relative safety of cars. The results of the study showed fatalities and injuries proportionally increase with the vehicle size.

The increase in the use of sport utility vehicles (SUVs) has led insurance companies to study the significance of this type of vehicle in crashes. The studies on their size and stability and rollover incidences in causing fatalities (either to their own or other vehicle occupants) are being continued at this time.

Donelson, et al (1999) conducted a study to examine the importance of selected fatality-risk factors for the magnitude and meaning of fatality rates. The objectives were to quantify the influence of fatality-risk factors, to adjust fatality-based rates for that influence, and to assess how well adjusted rates measured differences for various groups of vehicles. The study concentrated on rollover incidences in single-vehicle crashes involving light-duty trucks. Statistical models of fatality risk were developed with multivariate logistic regression applied to data on single-vehicle rollovers.

2.4 Highway and Environmental Factors

2.4.1 Highway Design and Roadside Safety Devices

Several studies are noted here to highlight the importance of highway design factors in fatalities. Viner, et al (1994) addressed the issue of roadside safety devices and guidance for the acceptability. They further discussed the frequency and severity of crashes involving roadside safety hardware by vehicle type (pickup trucks, passenger cars, etc.). Miaou and Lum (1993) conducted a statistical evaluation of the effects of highway geometric design on crashes involving trucks. The data from the Highway Safety Information System of the FHWA was used along with a probabilistic prediction model known as the Poisson process to evaluate the effects of highway geometric design on crash rates. Furthermore, uncertainties in reductions in crashes expected from implementation of improvements in highway geometric design were discussed. This study was based on a five-year truck crash data compiled from rural highways in the State of Utah.

McGinnis and Swindler (1997) studied roadside crashes involving single vehicle running off the road. The study addressed the significance of roadway and roadside hardware design and traffic characteristics in future roadside safety. The study suggested that if the roadside safety funding does not grow adequately, future crashes and fatalities may increase significantly. Ratthenbury and Gloyns (1992) reported on the crash patterns in rural areas and measures that can be used to reduce fatalities. The importance of proper roadside safety devices in reducing crashes involving fatalities was discussed.

Several other factors can also be attributed to the roadway design and geometry. Included in these factors are: (1) number of lanes; (2) highway divided/media barrier; (3) access and feeder ramps; (4) traffic light and signal coordination; (5) length of left-turn pockets at intersections; and (6) use of traffic signs at construction zones. Several studies address the significance of median on highway crashes. Squire and Parsonson (1989) present a statistical study of crash rates for highways with raised medians and continuous two-way left-turn lanes used as median treatments on four- and six-lane roads. Regression equations to model expected crash experience were developed. Four- and six-lane roadway study sections in Georgia were analyzed separately. The crash rate of raised medians was found to be lower than the rate of two-way left-turn lanes for both four-and six-lane roadway sections. Bowman and Vecellio (1994) studied the effect of both urban and suburban median types on safety of vehicles and pedestrians. The study was supported by the Federal Highway Administration and included an investigation on the impact of median types on the safety of vehicles and pedestrians. The study included the analysis of some 32,894 vehicular and 1,012 pedestrian crashes occurring in three cities on arterials with such median types as: (1) raised, (2) flush or two-way left-turn; and (3) no existing median (undivided roadways).

In another study, data for two states were extracted from the Highway Safety Information System and used by Knuiman, Council and Reinfurt (1993) to examine the effect of median width on the frequency and severity of crashes. Logarithmic-linear models for crash rates were used to describe the effect of median width after adjusting for other variables. These effects were estimated by the quasi-likelihood technique assuming a negative-binomial variance for the crash count per roadway section. Results indicated that total crashes and severity decline rapidly when median width exceeds about 25 ft.

The University of Western Ontario Accident Research Team (Lane, et al, 1995) investigated every fatal crashes, and approximately one out of every 50 personal-injury crash, within a defined geographic area of three counties. Over a seven-year period, the team investigated 107 collisions (62 fatal and 45 personal injury) that occurred on median-divided highways. These crashes were representative of over 2,300 collisions on the highways involving 81 fatalities and injury to over 3,200 vehicle occupants. Vehicle loss of directional control prior to any impact occurred in 55 of the 62 fatal cases and in 36 of the 45 personal-injury cases. In 36 fatal cases and 17 personal-injury cases loss of control was initiated after a vehicle traveled from the roadway onto the gravel shoulder. Rollover crashes were the most frequent collision type investigated and comprised 25 fatal and 25 personal-injury cases. Unrestrained occupants made up 24 of the 29 rollover fatalities with 96% of these unrestrained occupants being ejected from the vehicle. Collision with an oncoming vehicle after median-crossover occurred in 26 fatal cases. These crashes were usually frontal or side impacts characterized by extensive vehicle damage and massive intrusion into the occupant compartment.

2.4.2 Weather Factor

Studies by Shanker, Mannering and Barfield (1994) explored the frequency of occurrence of highway crashes based on a multivariate analysis of roadway geometric and weather and other seasonal effects. The results uncovered important determinants of crash frequency, by studying the relationship between weather and geometric elements. The study offers an insight into potential measures, that can be taken, to counter the adverse effect of weather conditions that compromise highway safety. Bjornstig, Bjornstig and Dahlgren (1996) studied snow as the cause of crashes. The study showed that elderly female drivers and younger male drivers were mostly involved in these types of fatalities. Weather conditions in winter months can be considered as a significant factor in causing crashes. Crash reports always include weather and road pavement conditions. However, usually crashes occurred in bad weather conditions are due to driver or vehicle-related factors. And as such, the bad weather condition is often a secondary cause. A metric to use as a factor investigating the significance of bad weather conditions in fatalities is the annual number of wet days in an area.

2.4.3 Highway Speed Limits

The change in speed limit (that occurred in the late 80's) has been a subject of research on crashes causing fatalities. The significance of the speed change on fatalities has been a controversial issue. In April 1987, the United States Congress passed the Surface Transportation and Uniform Relocation Assistance (STURA) Act. The act permitted the states to increase the speed limit on rural Interstate highways to up to 65 mph. Following the act of Congress, most states raised the speed limit from 55 to 65 mph on portions of their rural Interstate highways. In the State of Illinois, the speed limit was increased to 65 mph (at the end of April 1987) on rural interstates and limited-access highways. The debate over these changes has focused on whether the increase in the speed limit increases the motor vehicle fatalities. Studies conducted to investigate this factor have shown conflicting results.

Lave and Elias (1994) conducted a comprehensive evaluation of the effect of the 65-mph speed limit on fatalities on a "system-wide" basis rather than concentrating on local effects. The results showed that the implementation of the 65 mph speed limit has actually reduced the fatality rates by 3.4 to 5.1% on a state-wide basis, assuming the effects of other factors such as long-term trends, driving exposure, seat belt laws and economics to be constant. A study conducted by Rock (1995) for the State of Illinois provided opposite results than those by Lave and Elias (1994). In Rock's study, two types of rural highways were examined. These were roads with 55 mph and roads with 65-mph speed limits. The results indicated that the higher speed limit led to additional 300 crashes per months in rural Illinois, with associated increases in deaths and injuries. Chang and Paniati (1990) studied the effect of the 65 mph speed limit on traffic safety for 32 states that raised their speed limit to 65 mph by June 30, 1987. Their model to predict the number of fatalities was based on the 1975 - 1988 long-term patterns in rural interstate fatalities and limited data after the implementation of the 65-mph speed limit. The predicted fatalities were larger than actual fatalities in 14 of the 15 months after the speed-limit change. However, no conclusive results were presented as to whether the 65-mph speed limits will result in significantly more number of fatalities. Garber and Gramham (1989) studied the effect of 65 mph speed limits on rural highway fatalities for 40 states that had adopted speed limit by mid 1988 utilizing the monthly Fatality Analysis Reporting System (FARS) data. The results suggested that the new law had increased fatalities on rural interstates by 15% and rural non-interstates by 5%. Wilmot and Khanal (1998) examined results of studies conducted around the world on the effect of speed limits on safety. Their research showed that speed couldn't be linked statistically to crashes, although it was statistically significant as a major factor in crash severity. If speed limits are increased only on controlled access facilities, while retaining lower speed limits on other facilities, system-wide safety may not be adversely affected.

2.5 Demographics

Crash location and driver's residence location (urban versus rural), and socioeconomic compositions are important demographic factors discussed in this section.

2.5.1 Driver's Residence Location

Blatt and Furman (1998) studied the residence location of drivers involved in fatal motor crashes. The aim of the study was to investigate whether rural traffic fatalities involve people who actually live in rural residential areas. The data from the 1988 - 1992 files of the Fatality Analysis Reporting System (FARS) maintained by the National Highway Traffic Safety Administration (NHTSA) were used for this purpose. The study revealed that the majority of fatal crashes occurred on rural highways and that the majority of people involved in rural fatal crashes had rural residence addresses.

2.5.2 Travel Patterns

Massie, Green and Campbell (1997) studied the effect of such predictors as driver gender, time of day, and average annual mileage traveled on crashes. Crash rates were estimated through the use of a multivariate modeling technique. The results showed that male drivers had a consistently higher risk of crash involvement per mile driven than did female drivers. The study further showed that female drivers had a higher rate in being involved in non-fatal crashes that did male drivers.

Chu (1999) estimated the number of deaths that might have been avoided, because of a potential change in travel patterns, from 1969 to1995 in the US. Four travel patterns were considered including distribution of: (1) travel between urban and rural areas; (2) travel between interstate and other roadways; (3) travel taken at night versus those taken during daytime hours; and (4) travel taken by female drivers versus those taken by male drivers. It was concluded that the change in travel patterns had a significant effect on highway fatalities. Although no detailed discussion on this result was presented, one may conclude that the change in travel pattern may have caused a shift in the driver's perception and habits causing an increase in crashes leading to fatalities.

2.5.3 Socioeconomic Factors

Hoxie, et al (1984) presented an empirical investigation on socioeconomic impacts on highway fatalities. Abdallla (1997) studied the relationship between social characteristics of community and road crash casualties. They report that the casualty rates among residents from communities classified as relatively deprived were significantly higher compared with those from relatively affluent communities. No further discussions on the findings were presented. Sainz and Saito (1996) conducted a study that looked into motor vehicle crashes that involve Hispanic drivers. The study reports that nationwide, motor vehicle crashes are the third leading cause of death for Hispanics (after heart disease and cancer). In spite of this trend, no comprehensive summary of traffic crashes involving Hispanics and their attitude toward traffic safety has been compiled. The lack of traffic injury and fatality data for Hispanics and a lack of uniformity in reporting such data are also mentioned in the study by Sainz and Saito.

2.5.4 Other Factors

Among other factors related to the demographics are (1) the level of area traffic law enforcement; and (2) emergency medical service (EMS) care availability. In Illinois, the level of law enforcement can be obtained from the Illinois State Police records. In regard to the EMS care, the information on crash reports may be helpful to determine whether an EMS Run Number or Agency has been recorded.

The level of law enforcement and its effectiveness is reported in a study by Swadling (1997) in Western Australia. The study also looked into how the law enforcement can change fatalities and injuries from crashes. The study reports on police resources and enforcement methods. The effectiveness of the law enforcement methods was analyzed based on commonly used performance indicators, including percentage changes in number of fatal and serious injury crashes, number of road deaths per 100,000 population, and number and proportion of motorists detected exceeding the speed limit. The appropriateness of these performance indicators was also discussed. Statistics for the five-year period 1992-1996 were examined to determine the effects on the speeding behavior of drivers in Western Australia of recent increases in police speeding enforcement equipment and activities. Results showed that there have been significant reductions in the incidence of speeding behavior and in speed-related crashes during this period.

2.6 Summary of Findings from Previous Studies

Motor vehicle fatalities are primarily initiated by some type of human error, lack of attention or misjudgment of situational conditions or the driver's habits. These are superimposed by many other secondary factors such those related to the socioeconomic composition of the community, vehicle condition, road and weather conditions. From the studies noted above, it is concluded that major factors affecting motor vehicle fatal crashes can be categorized in four groups. These are: (1) drivers related; (2) vehicle related; (3) highway/environment related; and (4) demographic related factors. Within each group, several factors are identified and summarized in Table 2.1. These factors are divided into two parts; namely, those that can be controlled, and those that are unlikely to be controlled. It is certain that a specific crash leading to fatalities is caused by more than a single factor.

A thorough evaluation of factors listed in Table 2.1 is helpful in identifying: (1) the determinants of motor vehicle fatalities and fatality rates in Illinois; and (2) how changes in certain factors can be effective in reducing the future fatality rates. Specifically, the information on the dependence of the fatality rate on certain key factors may be used in developing strategies that can be considered for reducing the future fatality rate in those areas where the rates are rather high. To achieve this objective, one may look into factors in Table 2.1 as two types; namely, those that cannot be directly controlled; and those that can be directly controlled to reduce future fatality rates. The control of a specific factor can be achieved by implementing new regulations, and increase in fines and enhancement of educational activities and awareness.

From the review of related studies, it is evident that most such studies offer specific information on the significance of one or more factors in causing fatalities. Usually, no information on the long-term effect of these factors on fatalities and fatality control is provided. Based on the review of literature, a series of hypotheses were compiled on the significance of various factors (reported in the literature) on fatalities. These hypotheses are listed in Section 5. To further provide an insight into the trend in fatalities in terms of factors listed in Table 2.1, fatality data were examined over an extended period of time from various sources such as FARS and IDOT. The results of this investigation are provided in Section 6 and complement the findings from the review of related studies.

Table 2.1 Factors Causing Fatalities.

Group	Factors that can be controlled	Factors unlikely to be controlled
Driver	BAC, speed, seatbelt use, fatigue	Age, gender, driving hours day/night driving, weekend/weekday driving
Vehicle	Safety equipment, car defect, Airbag deployment	Vehicle type and size
Highway/ Environment	Posted speed, roadside safety devices, geometric design, median, feeder ramps.	Weather, urban/rural highways
Demo-graphics	Level of area traffic law enforcement, emergency medical service (EMS) care availability.	Type of area (rural versus urban), change in travel patterns, vehicle miles of travel (VMT), socioeconomic composition

3.0 METHODS OF ANALYSIS

This section presents an overview of various methods used in the analysis of fatality rates in Illinois. The results from these analyses are provided in Sections 5 and 6.

3.1 Descriptive Analyses

Descriptive analyses are used to examine the variations in fatality rates over the study period (1975-1999). The examination of fatality data is primarily based on plot of fatality rates with considerations for the prevalence of specific factors in the four factor groups (identified and described in Section 2). As part of this analysis, data on total fatalities, driver fatalities, motorist fatalities, non-motorist fatalities, and driver, crash, and vehicle attributes were obtained and analyzed. In addition, a correlation matrix and a series of cross-correlation functions between fatalities and relevant factors were developed. A correlation matrix simply identifies whether any two factors have a similar effect on fatalities. The cross-correlation functions (CCF) show the correlation between two sets of fatality series (plotted as a function of time). The CCF is especially helpful in identifying whether any given two factors have consistent effect on fatalities over an extended period of time. An important consideration in investigating fatality rates is information on specific dates when new laws and regulations in traffic safety were implemented. Using this information, the entire duration of the study was divided into several periods. The change in fatality rates within each period was studied by examining trends in fatality data; and comparing this trend with changes in factors that affect fatalities. Conclusions from the descriptive analyses are primarily by observations within these period as described further in Section 6.

3.2 Box-Jenkins Time Series Analysis

The time series analysis is an effective method for identifying the future trends in fatalities in Illinois. The analysis is based on previous fatality data gathered over a sufficiently long period of time. In most applications, time is divided into equal intervals. The prevalence of any autocorrelation in the quantity of concern at various time intervals is then analyzed and identified. The autocorrelation is then used to determine the correlation of residuals. The future estimates for the quantity is obtained based on the model parameters. Smaller residuals usually indicate better forecasts for the quantity (see Appendix B). The results are of course subject to uncertainties. Usually, the forecast results are given with a ± variation. The time-series analysis method varies widely in the level of complexity and applications. Generally, two basic approaches are used in a time series analysis. These are:

1. The self projecting approach; and,
2. The cause and effect approach.

The self-projecting approach is generally referred to as the "univariate method." Several methods fall under this approach. They range from simple methods that are based on trend projection and moving averages to a more sophisticated method such as the Box-Jenkins (1994) method. These methods require a minimum amount of data and often provide for a reasonable accuracy for short to medium term forecasting.

The cause and effect approach in cases where the quantity of concern is affected predominantly by one or two factors only. Methods that fall under this approach include those ranging from the simple to more complicated multi-variable regression analyses.

Software available for conducting time series analyses varies to a great extent on the capabilities and levels of applicability. Software for the uni-variable analyses are simpler to use and often offers the maximum user's interaction. Whereas, software available for multi-variable analyses offers little options for user's interaction.

In this research, the uni-variable Box-Jenkins method was used for forecasting future fatality trends. In order to investigate the significance of various factors on fatalities, a multi-variable correlation and regression analysis was used and applied at the county and State level in Illinois. The details of the time series analysis are provided in Appendix B.

3.3 Multivariable Correlation and Regression Analyses

To further investigate the significance of the combined effect of various factors on fatalities, two possible methods can be used. These are:

- A multi-variable time series analysis.
- A comprehensive multi-variable correlation and regression analysis between fatalities and various factors (identified and reported in Section 2).

After a review of options available for using a multi--variable time series analysis, it was decided to proceed with the correlation and regression analysis. This decision was based on the fact that the available software for a multi-variable time series analysis did not offer the flexibility for user interaction. Furthermore, the level of uncertainties in the final estimates increases when a host of variables is introduced into the time series analysis; thereby diminishing the reliability of the forecast estimates. Programs for multi-variable correlation and regression analyses offer a maximum level of visibility to the user. Furthermore, the analysis method is more flexible in offering the possibility to divide the fatality into various time segments or regions in the State.

The main objective of the multi-variable analysis is to identify whether there are regions within the State in which fatality rates are significantly affected by a particular factor or group of factors. This information will be useful in developing any plan that can be implemented to further reduce fatalities across the State. The correlation and regression analyses were conducted both at the county level and the State level based on data over the 1990-1999 period (for county-level analysis) and 1975-1996 period (for State-level analysis). The county level analysis looked into regional effect of various factors on fatality; whereas the State level analysis focused on the trends in fatality rates and its dependence on different factors for the entire State over the investigation period.

In general, the regression equation is written as follows:

$$Y = a + b_1X_1 + b_2X_2 + ... \qquad (3.1)$$

in which Y is the dependent variable (the fatality rate) and X_i are independent variables. Constants a and b_1, b_2, ... are computed based on the available data. In addition to these constants, several statistics are also computed as a result of a regression analysis. These are: (1) a matrix of correlation coefficients between the dependent variable and all the independent variables; (2) the square of correlation coefficient (R^2 value); and (3) the slope factors (B value). The R^2 value provides information on the proportion of explained variance of a dependent variable based on selected independent variables. The B values are related to the correlation. A positive B value is an indication that the correlation is positive. The correlation matrix identifies those factors that have a strong correlation with the fatality rate. The matrix is then used to select factors that can be included in the multivariable regression analysis. These factors are then identified as indicators of fatalities and fatality trends.

3.4 Methods Used for Hypothesis Tests

This section presents hypothesis development, and methods used for hypothesis testing. The inferences were made for factors involved in fatal motorway crashes with some comparisons between the characteristics of drivers, vehicles and environmental factors. This required collection of some data outside FARS, particularly, about the highway infrastructure and driver characteristics in Illinois. Furthermore, in some instances certain assumptions had to be made due to the lack of a comprehensive set of relevant data.

The dependence of fatalities on a relatively large number of factors resulted in an intractable number of possible hypotheses. Following the literature survey, the descriptive statistics and the fatality trends, the number of hypotheses was reduced to cover those factors that are identified as the main determinants of motor vehicle fatalities. Furthermore, the availability of historical data allowed examining the changes in different factors, and subsequently, providing an explanation for the possible causes of variation in the fatality and fatality trends through the study period.

The null hypothesis is that the fatal crash attributes reported within FARS and those in normal traffic conditions are equal. Expected frequencies of a condition is calculated for FARS data based on the distribution of that condition in general traffic. Chi-square statistic was computed to identify whether the conditions in FARS and those in general traffic are identical. The chi-square statistic is given in Eq. 3.2. Larger chi-square values are contradictory to null hypothesis and the p-value.

$$X^2 = \sum \frac{(n_{ij} - \mu_{ij})^2}{\mu_{ij}} \tag{3.2}$$

where:

n_{ij} = observed frequencies; and μ_{ij} = expected frequencies.

This type of testing required additional data to reflect the conditions of the environment, and general driver attributes. In some instances some assumptions had to be made to estimate the expected frequencies for FARS when data specific to Illinois was not available.

Each hypothesis test was defined with a null hypothesis H_0 and an alternate (or research) hypothesis H_1. For example, H_0 can be defined as follows:

> H_0: "Crashes involving drivers with any BAC level have equal fatalities per crash than those with drivers involving no BAC levels."
>
> Whereas H_1 is defined as follows:
>
> H_1: "Crashes involving drivers with any BAC level have larger fatalities per crash than those with drivers involving no BAC levels."

Several other statistical analyses are also performed along with hypothesis test analyses. These include: (1) chi-square analysis; (2) contingency table and odds ratio analysis; and (3) relative risk (propensity index) analysis.

The chi-square test is conducted to test the equality of proportions in two population groups. For example, one wishes to test the null hypothesis that the proportion of drivers involved in fatalities on urban roadways is identical to the proportion of drivers with fatalities in the general driving population. This test is helpful in providing statistical evidence on the relationship between fatality rates and a specific factor. The chi-square values, computed from this analysis, are used to arrive at significance levels identifying whether differences between any two groups of data are statistically significant. The result is often specified with a probability value (p-value). Conducting a hypothesis test at a 0.001 significance, when p-values are larger than 0.001, the results indicate that the hypothesis cannot be rejected.

The 2x2 contingency table is used to test the association between categorical variables. Categorical variables describe frequency counts of observations occurring in a given set of data. For example, we wish to test that the association between the speeding and fatalities involving drivers with any BAC level. The null hypothesis states that there is no association between the two variables (i.e., speeding drivers and fatalities involving drivers with any BAC level). The number of such statements can be very large. Accordingly, we used this analysis only for those factors that were determined to appear jointly in crashes involving fatalities. An outcome of the contingency table analysis is the "odds ratio." The "odds ratio" quantifies indicate the difference between two specific factors involved traffic fatalities. Mathematically-speaking, odds of success of a factor within the data are defined as

$$Odds_1 = p_1 /(1-p_1)$$

Similarly, the odds for a second factor are defined as

$$Odds_2 = p_2 /(1-p_2)$$

In which p_1 and p_2 are the probabilities associated with the prevalence of factors 1 and 2 in the fatality data, respectively. The odds-ratio is then written as

$$\theta = Odds_1/ Odds_2$$

The odds ratio can be equal to any non-negative number. When the two factors are independent, the respective odds ratio is equal to 1.0. The value 1.0 serves as a baseline for comparison. Values that are different from 1.0 in a given direction represent stronger levels of association between the two factors being involved in fatalities. In the analysis of fatality data the odds ratio was used to determined whether a particular factor was statistically more prevalent in fatalities than others. For example, the odds ratio is used to compare the odds of male drivers versus female drivers being involved in fatal crashes.

The relative risk is used to measure the likelihood of change in fatality rates given a unit percentage change in a specific factor. The relative risk value is obtained by dividing the percentage of fatalities by the percentage of a specific factor in a group of data. For example, in studying the significance of age in fatalities, the relative risk determines the likely percentage change in fatality rate given a merely one percent change in VMT by a specific age group of drivers. A value smaller than one indicates less likelihood that a particular factor has an effect on fatalities; whereas, a relative risk larger than one indicates that there is a larger likelihood that the factor has an effect on fatalities.

4.0 REVIEW OF AVAILABLE DATA

4.1 Sources of Fatality Data

Throughout the course of this research, Several sources were consulted to compile information on the statistics and causes of fatalities in Illinois. Major sources of data included the following:

- Illinois Department of Transportation, Division of Traffic Safety.
- Fatality Analysis Reporting System (FARS), National Highway Traffic Safety Administration.

To complement the data obtained from these sources, numerous other organizations were contacted. Data obtained through these sources was specifically used for further analysis on the dependency of fatalities on various factors, identification of trends in these factors and the distribution of these factors at the county and State level. The following provides a summary of the sources of additional data and the type of data compiled from these sources.

- IDOT Division of Highways (type of data: vehicle miles of travel).
- Illinois State Water Survey (type of data: weather records in Illinois including the number of rainy and snowy days for the period 1975-2000).
- IDOT Office of Planning and Programming (two types of data were acquired: 1. the average annual daily traffic data was obtained through IDOT division of Highway Safety; and 2. data on the length of highways and streets for 1975-1999).
- Illinois Department of Revenue (type of data: liquor taxes).
- Bureau of Census (Two types of data were acquired: 1. data on population distribution in Illinois for 1990 and estimates of population by county and age for 1991-1999; and 2. data on the number of employees working for alcohol vendors for the years 1992 and 1998).
- National Personal Transportation Survey (type of data: VMT data by age group for the years 1977, 1983, 1990 and 1995).
- Illinois Secretary of State (type of data: data on the number of licensed drivers in Illinois was obtained through IDOT Division of Traffic Safety).

Data from these sources indicates that among those factors listed in Tables 2.1 and Table 4.1, BAC level, age, urban vs. rural driving, VMT and weather are among those that highly influence fatalities. These along with the other factors listed in Table 4.1 are the major determinants of motor vehicle fatalities and fatality rates in Illinois.

4.2 Identification of Determinants of Motor Vehicle Fatalities

The review of literature (Sections 2) revealed four groups of factors identified as those that may influence fatalities and fatality rates. The study on the significance of these factors required a detailed analysis based on the available data and distribution of data within the State. Specifically, this analysis can be used to determine whether a given factor correlates with the fatality rates; and if such a correlation exists, how the correlation changes by regions. Table 4.1 lists factors for which information is provided in various data sources and used in the final selection of the determinants of motor vehicle fatalities.

Table 4.1 Factors used in Selection of Determinants of Fatalities.*

Group	Factor	Level of Control**
Driver	Age	Partial
	BAC	Partial
	Gender	None
	Speeding	Partial
	DUI history	Partial
	Crash history	Partial
	Speeding history	Partial
	Night/day	None
	Weekday/weekend	None
Vehicle	Type	None
	Weight	Partial
	Airbag deployment	Partial
Highway/ Environment	Weather	None
	Surface condition	Partial
	Undivided/divided	Partial
	Road function	None
	Intersection	Partial
	Posted speed limit	Full
	Work zone	Partial
Demographics	Urban/rural	None
	VMT	None
	Law enforcement	Full
	EMS access	Full

* Some of these factors appear in FARS

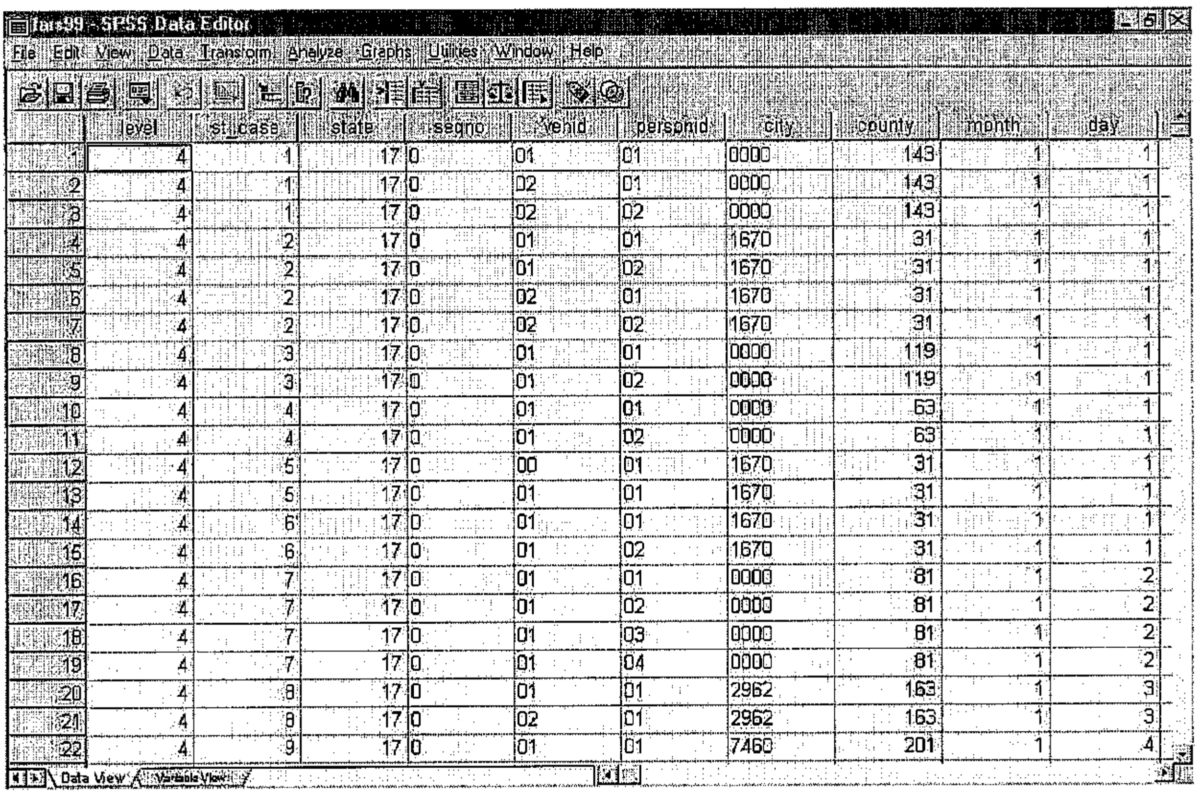
** Refers to the degree to which one can control the factor to change fatalities

It is emphasized that not all of the factors identified in Section 2 are reported in FARS and other databses. Furthermore, factors reported in Table 4.1 are more specific; whereas, those in Table

2.1 are more in general sense. For example, a factor in FARS data under "highway/environment" group is listed as "surface condition," and another as "undivided/divided" highway. These factors both belong to "geometric design" which was identified and listed in Table 2.1.

4.3 Description of Data Matrix

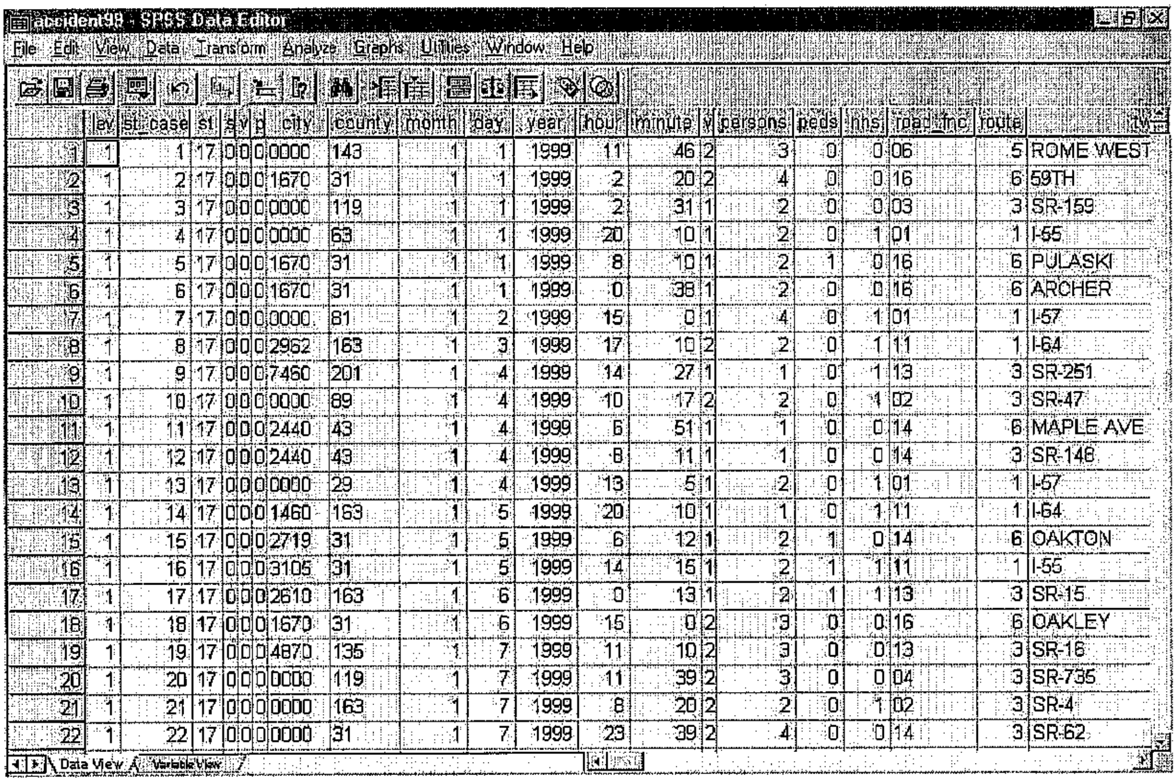
The fatality data compiled as part of this study is stored in a compact disc (CD) with the read-only-memory (ROM) format. FARS is the major data component used in the study. FARS contains data on a census of fatal motorway crashes occurred in the U.S. It is compiled annually and has a comprehensive coverage of information pertaining to fatal crashes. FARS incorporates information from police crash reports, death certificates, state vehicle registration files, coroner/medical examiner reports, state driver licensing files, hospital medical reports, state highway department data, emergency medical service reports, vital statistics, and other state records. FARS is sponsored and maintained by NHTSA. FARS data for 1975 to the most current year can be found in NHTSA's web site and also can be ordered from NHTSA in a CD along with relevant documentation. The finalized FARS file contains data at four different levels. These are crash, driver, vehicle, and personal. However, there exists a single data file for each year. FARS files are stored in ASCII sequential format in which several lines contain information on the same incident at different levels. The number of lines for a single crash is dictated by the number of vehicles, and persons involved, see Fig. 4.1.



	level	st_case	state	segno	vehid	personid	city	county	month	day
1	4	1	17	0	01	01	0000	143	1	1
2	4	1	17	0	02	01	0000	143	1	1
3	4	1	17	0	02	02	0000	143	1	1
4	4	2	17	0	01	01	1670	31	1	1
5	4	2	17	0	01	02	1670	31	1	1
6	4	2	17	0	02	01	1670	31	1	1
7	4	2	17	0	02	02	1670	31	1	1
8	4	3	17	0	01	01	0000	119	1	1
9	4	3	17	0	01	02	0000	119	1	1
10	4	4	17	0	01	01	0000	63	1	1
11	4	4	17	0	01	02	0000	63	1	1
12	4	5	17	0	00	01	1670	31	1	1
13	4	5	17	0	01	01	1670	31	1	1
14	4	6	17	0	01	01	1670	31	1	1
15	4	6	17	0	01	02	1670	31	1	1
16	4	7	17	0	01	01	0000	81	1	2
17	4	7	17	0	01	02	0000	81	1	2
18	4	7	17	0	01	03	0000	81	1	2
19	4	7	17	0	01	04	0000	81	1	2
20	4	8	17	0	01	01	2962	163	1	3
21	4	8	17	0	02	01	2962	163	1	3
22	4	9	17	0	01	01	7460	201	1	4

Figure 4.1 View of Multi Level FARS Data

Therefore, caution and strict adherence to the documentation is needed when extracting information from FARS. For the purpose of this study, records from Illinois were extracted for 26 years and four different SPSS data files were created. The SPSS data files are in a format that can be recognized by the Statistical Package for Social Sciences (SPSS) software. The record layouts and programs written to create those files are provided in the CD. A view from the crash level data is provided in Figure 4.2; and list of variables included in crash level data is given in Table 4.2.



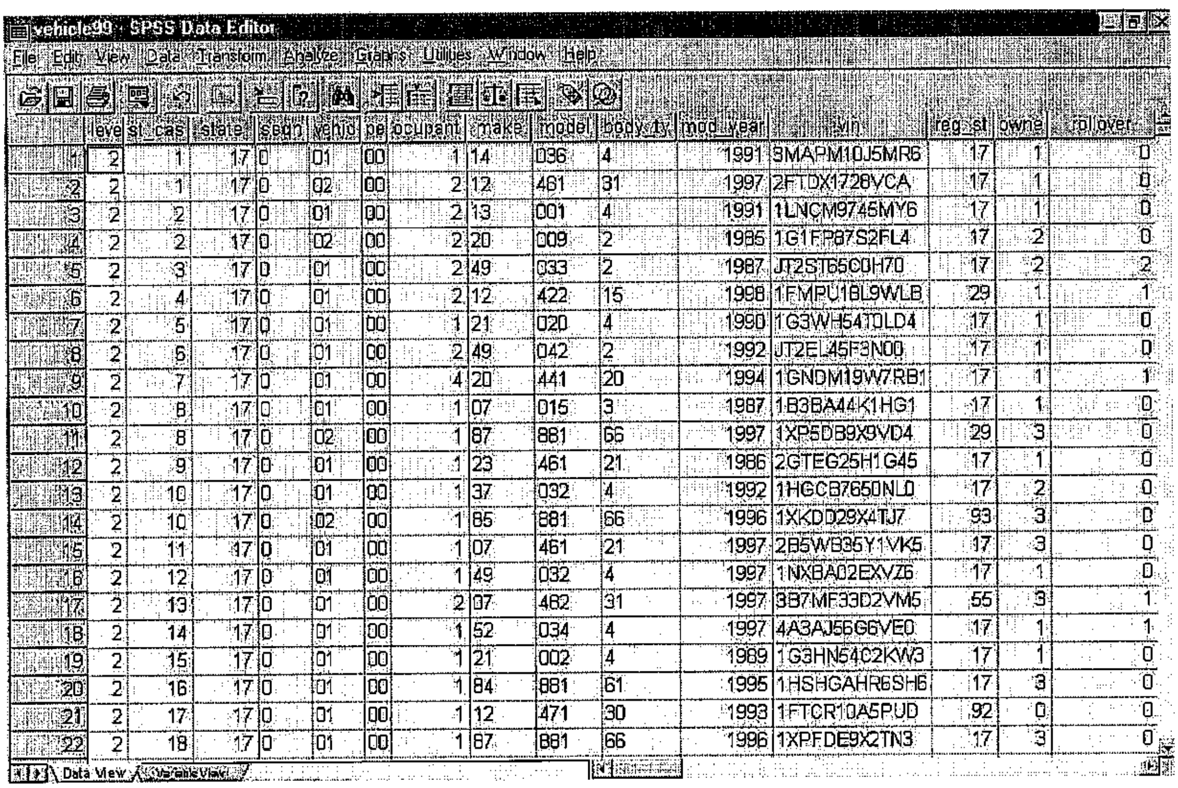
	lev	st_case	st	s	v	p	city	county	month	day	year	hour	minute	v	persons	peds	nhs	road_fnc	route	tw
1	1	1	17	0	0	0	0000	143	1	1	1999	11	46	2	3	0	0	06	5	ROME WEST
2	1	2	17	0	0	0	1670	31	1	1	1999	2	20	2	4	0	0	16	6	59TH
3	1	3	17	0	0	0	0000	119	1	1	1999	2	31	1	2	0	0	03	3	SR-159
4	1	4	17	0	0	0	0000	63	1	1	1999	20	10	1	2	0	1	01	1	I-55
5	1	5	17	0	0	0	1670	31	1	1	1999	8	10	1	2	1	0	16	6	PULASKI
6	1	6	17	0	0	0	1670	31	1	1	1999	0	38	1	2	0	0	16	6	ARCHER
7	1	7	17	0	0	0	0000	81	1	2	1999	15	0	1	4	0	1	01	1	I-57
8	1	8	17	0	0	0	2962	163	1	3	1999	17	10	2	2	0	1	11	1	I-64
9	1	9	17	0	0	0	7460	201	1	4	1999	14	27	1	1	0	1	13	3	SR-251
10	1	10	17	0	0	0	0000	89	1	4	1999	10	17	2	2	0	1	02	3	SR-47
11	1	11	17	0	0	0	2440	43	1	4	1999	6	51	1	1	0	0	14	6	MAPLE AVE
12	1	12	17	0	0	0	2440	43	1	4	1999	8	11	1	1	0	0	14	3	SR-148
13	1	13	17	0	0	0	0000	29	1	4	1999	13	5	1	2	0	1	01	1	I-57
14	1	14	17	0	0	0	1460	163	1	5	1999	20	10	1	1	0	1	11	1	I-64
15	1	15	17	0	0	0	2719	31	1	5	1999	6	12	1	2	1	0	14	6	OAKTON
16	1	16	17	0	0	0	3105	31	1	5	1999	14	15	1	2	1	1	11	1	I-55
17	1	17	17	0	0	0	2610	163	1	6	1999	0	13	1	2	1	1	13	3	SR-15
18	1	18	17	0	0	0	1670	31	1	6	1999	15	0	2	3	0	0	16	6	OAKLEY
19	1	19	17	0	0	0	4870	135	1	7	1999	11	10	2	3	0	0	13	3	SR-16
20	1	20	17	0	0	0	0000	119	1	7	1999	11	39	2	3	0	0	04	3	SR-735
21	1	21	17	0	0	0	0000	163	1	7	1999	8	20	2	2	0	1	02	3	SR-4
22	1	22	17	0	0	0	0000	31	1	7	1999	23	39	2	4	0	0	14	3	SR-62

Figure 4.2 A Sample View of Crash Level Data

Similarly, Figs. 4.3 to 4.5 provide sample views and Tables 4.3-4.5 provide lists of variables in each of the vehicle, driver and person level FARS data files.

Table 4.2. Crash Level Variables.

FARS Variables		
Crash Date Atmospheric Condition City Construction/Maintenance Zone County Day of Week Emergency Medical Services (EMS) Notification Time EMS Arrival Time at Hospital EMS Arrival Time at Scene First Harmful Event Hit and Run Light Condition Manner of Collision Milepoint	National Highway System Number of Drinking Drivers in Crash Number of Fatalities in Crash Number of Nonmotorist Forms Submitted Number of Person Forms Submitted Number of Travel Lanes Number of Vehicle Forms Submitted Rail Grade Crossing Identifier Related Factors—Crash Level Relation to Junction Relation to Roadway Roadway Alignment Roadway Function Class Roadway Profile	Roadway Surface Condition Roadway Surface Type Route Signing School Bus Related Special Jurisdiction Speed Limit State Time Traffic Control Device Traffic Control Device Functioning Traffic way Flow Traffic way Identifier

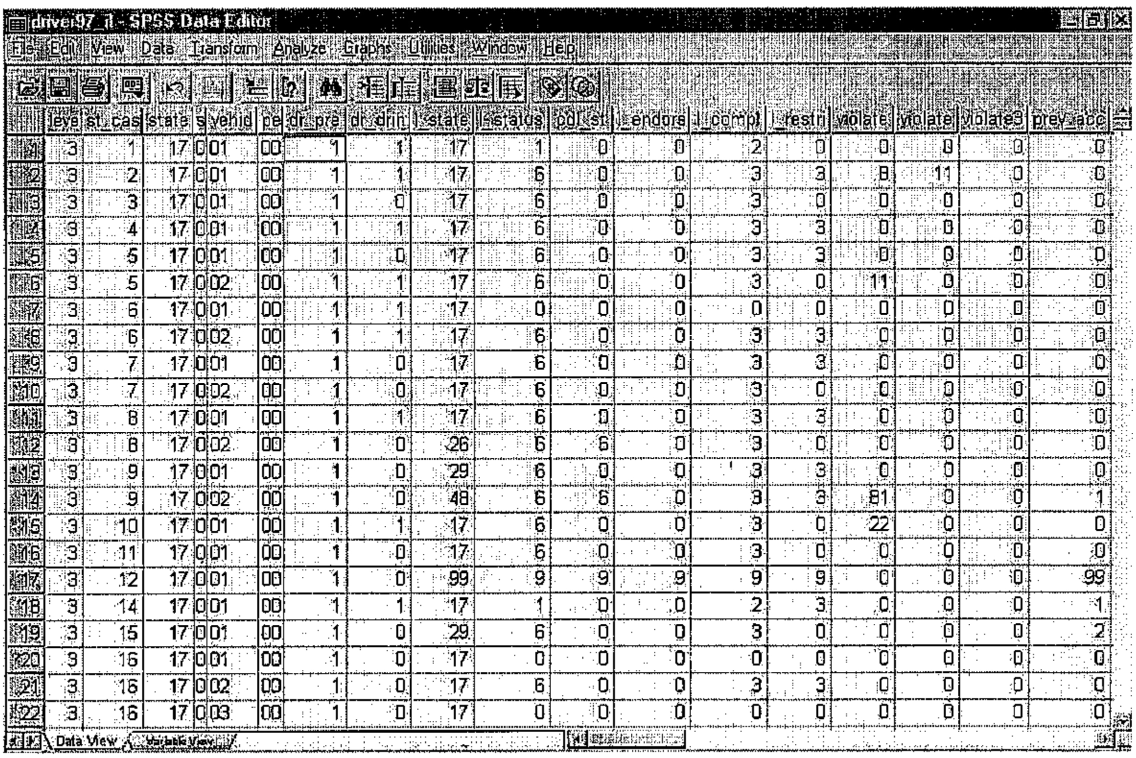


	leve	st_cas	state	segn	vehic	pe	ocupant	make	model	body_ty	mod_year	vin	reg_st	owne	rollover
1	2	1	17	0	01	00	1	14	036	4	1991	3MAPM10J5MR6	17	1	0
2	2	1	17	0	02	00	2	12	461	31	1997	2FTDX1728VCA	17	1	0
3	2	2	17	0	01	00	2	13	001	4	1991	1LNCM9746MY6	17	1	0
4	2	2	17	0	02	00	2	20	009	2	1985	1G1FP87S2FL4	17	2	0
5	2	3	17	0	01	00	2	49	033	2	1987	JT2ST65C0H70	17	2	2
6	2	4	17	0	01	00	2	12	422	15	1998	1FMPU18L9WLB	29	1	1
7	2	5	17	0	01	00	1	21	020	4	1990	1G3WH54T0LD4	17	1	0
8	2	6	17	0	01	00	2	49	042	2	1992	JT2EL45F3N00	17	1	0
9	2	7	17	0	01	00	4	20	441	20	1994	1GNDM19W7RB1	17	1	1
10	2	8	17	0	01	00	1	07	015	3	1987	1B3BA44K1HG1	17	1	0
11	2	8	17	0	02	00	1	87	881	66	1997	1XP5DB9X9VD4	29	3	0
12	2	9	17	0	01	00	1	23	461	21	1986	2GTEG25H1G45	17	1	0
13	2	10	17	0	01	00	1	37	032	4	1992	1HGCB7650NL0	17	2	0
14	2	10	17	0	02	00	1	85	881	66	1996	1XKDD29X4TJ7	93	3	0
15	2	11	17	0	01	00	1	07	461	21	1997	2B5WB35Y1VK5	17	3	0
16	2	12	17	0	01	00	1	49	032	4	1997	1NXBA02EXVZ6	17	1	0
17	2	13	17	0	01	00	2	07	482	31	1997	3B7MF33D2VM5	55	3	1
18	2	14	17	0	01	00	1	52	034	4	1997	4A3AJ56G6VE0	17	1	1
19	2	15	17	0	01	00	1	21	002	4	1989	1G3HN54C2KW3	17	1	0
20	2	16	17	0	01	00	1	84	881	61	1995	1HSHGAHR6SH6	17	3	0
21	2	17	17	0	01	00	1	12	471	30	1993	1FTCR10A5PUD	92	0	0
22	2	18	17	0	01	00	1	87	881	66	1996	1XPFDE9X2TN3	17	3	0

Figure 4.3 A Sample View of Vehicle Level Data

Table 4.3 Vehicle Level Variables.

FARS Variables	
Body Type	
Cargo Body Type	Registered Vehicle Owner
Crash Avoidance Maneuver	Registration State
Emergency Use	Related Factors—Vehicle
Extent of Deformation	Level
Fire Occurrence	Rollover
Truck Gross Vehicle Weight Rating	Special Use
Hazardous Cargo	State Information
Impact Point—Initial	Travel Speed
Impact Point—Principal	Truck Fuel Type
Jackknife	Underride/Override
Manner of Leaving Scene	Vehicle Configuration
Most Harmful Event	Vehicle Identification
Motor Carrier Identification Number	Number
Motorcycle Displacement	Vehicle Make
Number of Axles	Vehicle Maneuver
Number of Deaths in Vehicle	Vehicle Model
Number of Occupants in Vehicle	Vehicle Model Year
Number of Vehicle Forms Submitted	Vehicle Number
Passenger Car Weight	Vehicle Role
Passenger Car Wheelbase	Vehicle Trailering

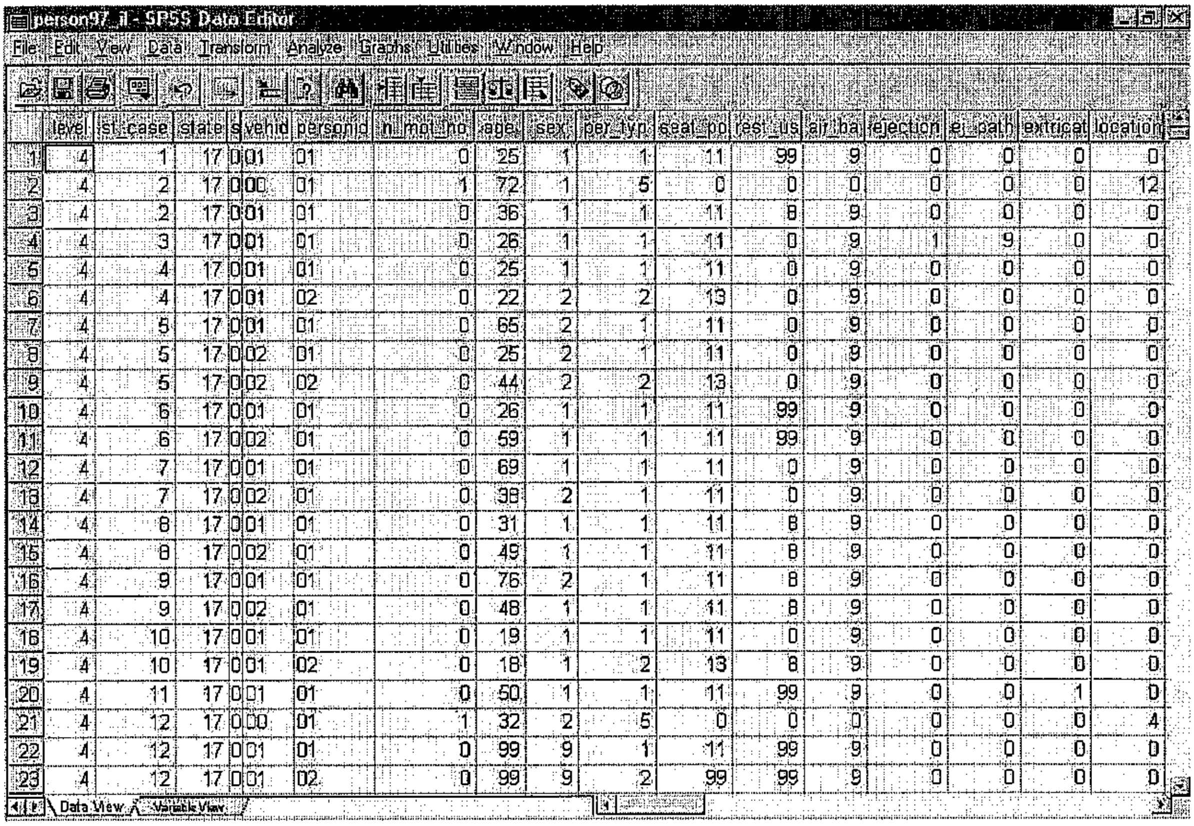


	leve	st_cas	state	s	vehid	pe	dr_pre	dr_drin	l_state	l_status	cdl_st	l_endors	l_compl	l_restri	violate	violate	violate3	prev_acc
1	3	1	17	0	01	00	1	1	17	1	0	0	2	0	0	0	0	0
2	3	2	17	0	01	00	1	1	17	6	0	0	3	3	8	11	0	0
3	3	3	17	0	01	00	1	0	17	6	0	0	3	0	0	0	0	0
4	3	4	17	0	01	00	1	1	17	6	0	0	3	3	0	0	0	0
5	3	5	17	0	01	00	1	0	17	6	0	0	3	3	0	0	0	0
6	3	5	17	0	02	00	1	1	17	6	0	0	3	0	11	0	0	0
7	3	6	17	0	01	00	1	1	17	0	0	0	0	0	0	0	0	0
8	3	6	17	0	02	00	1	1	17	6	0	0	3	3	0	0	0	0
9	3	7	17	0	01	00	1	0	17	6	0	0	3	3	0	0	0	0
10	3	7	17	0	02	00	1	0	17	6	0	0	3	0	0	0	0	0
11	3	8	17	0	01	00	1	1	17	6	0	0	3	3	0	0	0	0
12	3	8	17	0	02	00	1	0	26	6	6	0	3	0	0	0	0	0
13	3	9	17	0	01	00	1	0	29	6	0	0	3	3	0	0	0	0
14	3	9	17	0	02	00	1	0	48	6	6	0	3	3	81	0	0	1
15	3	10	17	0	01	00	1	1	17	6	0	0	3	0	22	0	0	0
16	3	11	17	0	01	00	1	0	17	6	0	0	3	0	0	0	0	0
17	3	12	17	0	01	00	1	0	99	9	9	9	9	9	0	0	0	99
18	3	14	17	0	01	00	1	1	17	1	0	0	2	3	0	0	0	1
19	3	15	17	0	01	00	1	0	29	6	0	0	3	0	0	0	0	2
20	3	16	17	0	01	00	1	0	17	0	0	0	0	0	0	0	0	0
21	3	16	17	0	02	00	1	0	17	6	0	0	3	3	0	0	0	0
22	3	16	17	0	03	00	1	0	17	0	0	0	0	0	0	0	0	0

Figure 4.4 A Sample View of Driver Level Data

Table 4.4 Driver Level Variables.

FARS Variables	
Commercial Motor Vehicle License Status	Driver License Type
Compliance with License Endorsements	Compliance
Compliance with License Restrictions	Driver Presence
Date of First and Last Crash, Suspension,	Driver Weight
Conviction	Driver Zip Code
Driver Drinking	License State
Driver Height	Non-CDL License Status
Driver Level Counters	Related Factors—Driver
Driver License Status	Level
	Violations Charged



	level	st_case	state	s	vehid	personid	n_mot_no	age	sex	per_typ	seat_po	rest_us	air_ba	ejection	ej_path	extricat	location
1	4	1	17	0	01	01	0	25	1	1	11	99	9	0	0	0	0
2	4	2	17	0	00	01	1	72	1	5	0	0	0	0	0	0	12
3	4	2	17	0	01	01	0	36	1	1	11	8	9	0	0	0	0
4	4	3	17	0	01	01	0	26	1	1	11	0	9	1	9	0	0
5	4	4	17	0	01	01	0	25	1	1	11	0	9	0	0	0	0
6	4	4	17	0	01	02	0	22	2	2	13	0	9	0	0	0	0
7	4	5	17	0	01	01	0	65	2	1	11	0	9	0	0	0	0
8	4	5	17	0	02	01	0	25	2	1	11	0	9	0	0	0	0
9	4	5	17	0	02	02	0	44	2	2	13	0	9	0	0	0	0
10	4	6	17	0	01	01	0	26	1	1	11	99	9	0	0	0	0
11	4	6	17	0	02	01	0	59	1	1	11	99	9	0	0	0	0
12	4	7	17	0	01	01	0	69	1	1	11	0	9	0	0	0	0
13	4	7	17	0	02	01	0	38	2	1	11	0	9	0	0	0	0
14	4	8	17	0	01	01	0	31	1	1	11	8	9	0	0	0	0
15	4	8	17	0	02	01	0	49	1	1	11	8	9	0	0	0	0
16	4	9	17	0	01	01	0	76	2	1	11	8	9	0	0	0	0
17	4	9	17	0	02	01	0	48	1	1	11	8	9	0	0	0	0
18	4	10	17	0	01	01	0	19	1	1	11	0	9	0	0	0	0
19	4	10	17	0	01	02	0	18	1	2	13	8	9	0	0	0	0
20	4	11	17	0	01	01	0	50	1	1	11	99	9	0	0	1	0
21	4	12	17	0	00	01	1	32	2	5	0	0	0	0	0	0	4
22	4	12	17	0	01	01	0	99	9	1	11	99	9	0	0	0	0
23	4	12	17	0	01	02	0	99	9	2	99	99	9	0	0	0	0

Figure 4.5 A Sample View of Person Level Data

Table 4.5 Person Level Variables.

FARS Variables	
Age	Method of Other Drug Determination by Police
Air Bag Availability/Deployment	Nonmotorist Location
Alcohol Test Results	Nonmotorist Striking Vehicle Number
Alcohol Test Type	Person Number
Death Certificate Number	Person Type
Death Date	Police-Reported Alcohol Involvement
Death Time	Police-Reported Other Drug Involvement
Drug Test Results	Race
Drug Test Type	Related Factors—Person Level
Ejection	Restraint System Use
Ejection Path	Seating Position
Extrication	Sex
Fatal Injury at Work	Taken to Hospital or Treatment Facility
Hispanic Origin	Time of Crash to Time of Death
Injury Severity	Vehicle Number
Method of Alcohol Determination	

In addition to the variables listed above, new variables were added in order to extract descriptive statistics and to utilize information in certain hypothesis tests. The programs written for adding those variables in the database are provided in the file called "variable_creator.sps" in the CD. The programs that performs hypothesis tests through the analysis of variance (ANOVA) and Contingency table analysis can be found in the files "anova_hypo_tester.sps" and cta_hypo_tester.sps."

4.4 Limitation of Data

The main source of data used in this study is FARS. All 26 sequential FARS files, starting from 1975 to 1999, were read by SPSS and data was saved with four additional files at different levels: crash, vehicle, driver, and person levels. This data was then supplemented by additional information obtained from IDOT and other sources. The following presents limitation of data from various sources.

Population by county and age -- This information was obtained from the Bureau of Census web-site. Population counts for counties by age are available for 1990. Population by county and age information is provided as estimates for the years 1991-99. For the years prior to 1990, population by county information does not contain age, while population by age is available at the State-level.

Information on the socioeconomic conditions -- These include such information as the Median Income, number of households, number of licensed drivers, employment levels a retrieved from 1990 Census Transportation Planning Package. These variables are at county level for only year

1990. The information from this package was used to test hypotheses for the years close to 1990 assuming that proportions did not changed for 2-3 years around 1990.

Daily vehicle miles traveled -- This is an estimate calculated by multiplying Average Annual Daily Traffic (AADT) by the length of highways and streets. In some instances Annual VMT is given, which is obtained by multiplying daily vehicle miles of travel (DVMT) by 365. County level data was obtained from IDOT Traffic Safety Division covering all the study period.

Proportions of VMT by age groups -- This variable is created from the data extracted from National Personal Transportation Survey (NPTS) of 1995. NPTS is a cross-sectional survey repeated every 5-7 years. Earlier NPTS years that fall into study period are 1990, 1983, 1977. Data pertaining to those years were acquired from Summary of Travel Trends after 1990. The age group breakdowns were also determined by the information in this report. The data provided by NPTS is at national level; and it has been assumed that national proportions of VMT by age groups are comparable to the proportions for the State of Illinois. This item was only used to test hypotheses for those NPTS years.

Number of licensed drivers -- The information for Illinois was acquired from the Secretary of State through the IDOT Traffic Safety Division. The data is at county level and covers the years between 1980-1999. This item was used to calculate certain proportions of drivers for some hypothesis tests for the years within the time interval defined by data availability.

Number of driving under influence arrests -- This was also acquired from the Secretary of State through the IDOT Traffic Safety Division. The data is at county level and covers the last 6 years of the study period. This data was primarily used to establish information on the percentage of drivers with any BAC levels in their systems. No other analysis specific to the number of driving under influence arrests was conducted.

Length of highways and streets -- This information was obtained from Illinois Highway Statistics Reports prepared by IDOT Office of Planning and Programming for 1975-1999. The data is hand coded and is at the State level. The hardcopy of the reports include also county level information which has not been coded. County level data exists for only the period 1996-1998.

Length of highways and streets by road functional classification -- This was obtained from Illinois Highway Statistics Reports. The data is at the State level. The number of Road Functional Class was limited to three since there has been changes in the definition of the classes during the study period. Roadways were divided into three broad categories such as; Interstate Highways, Other Highways and Freeways, and Local Roads. These categories were also expanded by incorporating land-use (urban/rural) information.

Proportions of VMT by vehicle type -- This data information was obtained from Illinois Highway Statistics Reports staring from 1982. The item is at the State level. There are only three categories of vehicles; passenger cars, buses, and trucks. Motorcycle traffic was not included in the reports. Although the reports contain detailed truck type information, these were reduced into a single category since the FARS definitions and categories in the reports did not exactly match.

Numbers of wet and snowy days -- This information was obtained from Illinois State Water Survey for the entire study period. The number of wet days is the count of days when there is a precipitation and/or melted snow. The number of snowy days is the count of says when there is a snow accumulation. The original data is at station level and is converted to county level. Some counties do not have a station while some counties have more than one station. The station readings are averaged within the counties for those with multiple stations. The counties with missing readings were assigned the average of closest station readings.

Annual alcohol consumption per capita -- This information was obtained from the National Institute on Alcohol Abuse and Alcoholism (NIAAA) Surveillance Report #51 (Nephew et al., 1999) which reports data from the Alcohol Epidemiologic Data System (AEDS). The consumption figures are at the State level and based on sales data. There are four categories of alcohol consumption (gl/capita/annum); beer, wine, spirits, and total. The data is hand coded and available starting from 1977. This data was primarily used in identifying those counties that have higher per capita alcohol consumption compared with the rest of the State.

Number of employees working for alcohol vendors -- This data was obtained from Bureau of Census web-site. "Alcohol Vendors" does not appear as a single business or industry type. Instead, Standardized Industry Codes (SIC) are available for eating and drinking places separate and combined, and liquor stores along with the number employees that they employ. The number of employees working for alcohol vendors is the total number of employees working in eating and drinking places and liquor stores. Again, this data was primarily used in identifying those counties that have higher per capita alcohol consumption compared with the rest of the State. The data is at the county level and covers the years between 1992 and 1998. Data for counties with missing information was replaced by using the mean rate of employees per capita from the neighboring counties. This is the primary limitation of this data.

In addition to the itemized limitations listed above, there were several major limitations on the overall data collected. One particular limitation was the lack of coincidental information on all potential factors affecting fatalities. For example, information on the VMT, populations and the average number of wet days were obtained independent of each other (from sources described above). The compilation of data from various sources added to the uncertainty inherent in the statistical analysis outcomes. Furthermore, several data items reported in fatal crash data sources were either based on circumstance, evidence or at best based on the judgment by the officer reporting the crash. Examples are the speed of vehicles involved in the crash, weather conditions at the time of crash, use of seatbelts, etc. This limitation imposes certain levels of uncertainties in identification of causes of fatalities.

A detailed analysis at the regional level requires data on societal, demographics, population distribution and driving habits that may be unique to a particular region. Lack of regional data on these factors imposes limitations on recommending measures that may be taken to reduce fatality risk specific to a region or county in Illinois.

5.0 HYPOTHESES TESING

5.1 General

The review of literature identified several factors as those that are reported in many crashes resulting in fatalities. In this section, several conclusions are drawn from this review and hypotheses established and tested on the factors that affect fatalities. In addition, hypotheses are also formed and tested based on the fatality data compiled from sources mentioned in Section 4.

5.2 Hypotheses Reported in Literature

The review of literature on traffic fatality studies reveals only a handful of factors that have been used in establishing hypotheses and testing. Generally, the null hypothesis states that the prevalence of a factor in driving with a fatal crash involvement is the same as in driving with no fatal crash involvement. Of course, different reports use several variations of this hypothesis statement. Upon establishment of the null hypothesis, available data is used to either reject or support the hypothesis. Among various fatality-causing factors, several have been especially reported in hypothesis development and testing in traffic fatality studies. These are alcohol involvement, speeding, age, gender, and urban versus rural driving. Hypotheses based on the review of literature primarily focus on these factors.

An overwhelming majority of the studies in the traffic safety literature tested several hypotheses either explicitly stating the null and alternative hypothesis, or provided statistics that highlight the significance of a factor in influencing fatal crashes. In this section, a selection of hypotheses reported in the traffic safety literature is provided. The selection is based on the relevance of reported hypotheses to fatal crashes.

In their study of the effectiveness of Illinois 0.08 Law, Voas et al. (2000), explicitly tested the null hypothesis that the percentages of drivers with different BAC levels in fatal crashes remained identical after the enforcement of the law. A time series analysis rejected the null hypothesis at 95% confidence level implying that the law impacted as intended leading to reductions in the percentage of alcohol related fatal crashes.

Perrine, (1989) tested a null hypothesis that single vehicle and multiple vehicle fatal crashes had identical distribution of driver BAC levels. The hypothesis was rejected at 95% confidence level indicating that higher levels of driver BAC levels were associated with single vehicle fatal crashes. Another set of hypotheses regarding alcohol involvement in fatal crashes can be found in Zador et al. (2000). These investigators asserted that 21-34 year-old male drivers would have identical fatal crash risks when compared to 16-20 year-old and 35+ old males and all females with same age categories. The analyses and tests conducted by Zador, et al rejected the null hypothesis and indicated that statistically significant differences exist among the groups of gender and age. Only teenager males had higher risks than did the base group (i.e., 35+ males, 21-34 year-old and 35+ females); while the teenager female groups had comparable risks with the base group. In general, it was concluded that female drivers had lower fatal crash involvement risks while teenager drivers had the highest risks within gender groups. Based on these findings, the study built logistic regression models for estimating the odds for involving in fatal crashes by using age group, gender and BAC level as predictors. The models indicated that BAC variable was the strongest predictor and teenager male driver group had the highest sensitivity of relative risk to an increase in BAC levels.

There also exists a substantial amount of research on the minimum legal drinking age (MLDA) and underage drinking, and driving (Voas et al., 2001; and O'Malley and Wagenaar, 1991). Wagenaar and Maybee (1986) tested two hypotheses relevant to MLDA in Texas by using time-series models. They found that raising MLDA from 18 to 19 was associated with decrease in youth crashes while it had no significant impact on the crashes by 21 and over age driver group. Several studies report that, as a group, persons convicted of driving under influence of alcohol may be characterized as having higher levels of hostility, sensation seeking, irritability, driving aggression, and competitive speed compared with general population (Donovan et al., 1985; and Jessor, 1987). McMillen et al., (1992) examined six groups of drivers, 4 groups of drinking and 2 groups of non-drinking, to identify traits, behaviors and attitudes of drinking drivers as a sub-group. The results indicated that persons apprehended for DUI in traffic crashes or moving violations were the highest risk group and differed significantly from the remaining groups on measures of personality, behavior and attitude.

Studies on effects of speed and traffic safety usually focus on the changes in the posted speed limits on rural Interstate highways, which occurred in late 1980's. A majority of these studies implemented time-series models and regression techniques to test the null hypotheses that changes in the posted limit would not affect the number of fatalities and/or fatality rates. There was no universal agreement in the findings of these studies; one group rejected the null hypothesis (Rock, 1995; Lave, 1994; and Griffin, 1998); while another found marginal effects (Garber & Graham, 1990). Yet another group, did not reject the hypothesis (Chang and Paniati, 1990; Sidhu, 1989; and Lave and Elias, 1993).

Upon interviewing the drivers of speeding vehicles on rural and urban roads in Australia, Fildes et al. (1991) found that younger drivers, drivers without passengers, drivers of newer vehicles and high mileage drivers were over-represented in the speeding and speed limit violating sample.

Garber and Srinivasan (1991) found significant differences in elderly drivers' involvement in intersections of urban and rural areas. While Abdel-Aty et al. (1999) found that young and middle age drivers had significantly larger "odds ratios" for involving in crashes in urban areas. As explained in Section 3, an odds ratio is a statistical term which is obtained by dividing the probability of a occurrence of an event divided by the probability of non occurrence. The ratio is used as an index to compare two or more groups of drivers in terms of their likelihood of being involved in fatal crashes. Stamatiadis et al. (1991) and Abdel-Aty et al. (1999) reported that elderly drivers are more likely to involve in turning or angle type collisions. The presence of teenager passengers was found as a significant parameter that increased the crash risks for teenager drivers (Williams, 2000; Aldridge et al., 1999; Chen et al., 2000; and Doherty et al., 1998).

In a study analyzing DUI and driver behavior, Stuster (1997) revealed that drivers who were exceeding speed limits by 10 mph or more and were found to be DUI (BAC>0.08) made up only 9% of the all nighttime stops. While those speeding by less than 10 mph over the speed limit were found to be DUI in 48% of the stops. This rejected a plausible hypothesis of DUI and speeding association.

The decline of average weight of the vehicles in the traffic was considered as a contributing factor in crashes. Regression models have been constructed using weight of vehicles as a significant predictor of fatalities and injuries (Klein et al., 1991; and Hertz, 1997). However, these findings can be challenged based on the uncertainties in the estimates and the appropriateness of the models, data limitations, isolation of the vehicle weight, and detailed exposure data requirements, which were not clearly established in the studies.

Most other studies reported in the literature do not offer any exclusive statistical hypothesis testing. They generally elaborate on the significance of a factor in causing fatalities based on the observation and/or analysis of trends in the factor or appearance of a variable as a significant predictor in highway crashes. Nevertheless, the results from these observations and studies were still helpful in establishing hypotheses on factors influencing fatalities. Table 5.1 presents a summary of hypothesis testing reported in literature. As seen in Table 5.1, factors such as age (teenage drivers vs. other drivers), gender, land-use (urban- rural), alcohol involvement, and speeding are reported in literature. These factors are also included in testing hypotheses regarding the determinants of fatalities using the data compiled in our study.

5.3 Testing Hypotheses Based on Compiled Data

In this section, compiled data on motor-vehicle fatalities in Illinois is used to test hypotheses on the significance of such factors as alcohol, age, gender, etc. in causing fatalities. In each analysis, a hypothesis is defined, it is then tested using a 2x2 contingency table (as describe in Section 3). Results include also the odds ratios whenever appropriate.

Alcohol -- Over the study period, percentage of "alcohol-positive" drivers ranged from 25% to 35% of the total driving population. The definition "alcohol-positive" refers to a driver with any blood alcohol level. In contrast, an "alcohol-negative" driver is a driver without any blood alcohol concentration in his/her system. In order to test the hypothesis that alcohol is a contributing factor to fatal crashes, the annual VMT driven by alcohol-positive drivers had to be known. This information was not available; and as such data from other sources had to be sought. Miller et al (1999) estimated that percentage of VMT by alcohol positive drivers ranged from 2.25% to 1.2% nationally during the 1984-1993 period. Another piece of information that is perhaps an indicator of percentage of alcohol-positive drivers is the number of DUI arrests. On the average, there were 46,300 drivers arrested per year for DUI out of 7,700,000 drivers in Illinois in the 1993-98 period. Since the former estimate is more conservative, chi-square independence test was conducted using the estimates by Miller et al (1999). Accordingly, it was assumed that these national estimates also represent the statistics for Illinois. Table 5.2 summarizes the distribution of alcohol-positive drivers reported in FARS and estimates of alcohol-positive drivers in Illinois. The null hypothesis that population proportions of alcohol-positive drivers are equal to the proportions of alcohol-positive drivers involved in fatal motorway crashes was tested using the chi square test procedure.

Table 5.1 Summary of Hypothesis Tests from the Literature.

Reference	Factor Analyzed	Null Hypothesis	Result
Voas et al., 2000	Alcohol	BAC level distribution in fatal crashes remained identical after 0.08 Law of Illinois	Rejected
Zador et al., 2000	Age + Gender + Alcohol	Distribution of BAC levels and gender are identical across different age groups	Rejected
Perrine, 1989	Alcohol	BAC level distributions of single and multiple vehicle crashes are identical.	Rejected
Wagenaar &Maybee, 1986	Alcohol	Underage driver fatal crash involvement remained the same after raising MLDA in Texas	Rejected
Wagenaar &Maybee, 1986	Alcohol	21 or older driver fatal crash involvement remained the same after raising MLDA in Texas	Did Not Reject
Donovan et al, 1985 Jessor, 1987, McMillen, 1992	Alcohol	DUI of alcohol offenders have identical behavioral characteristics with other drivers	Rejected
Lave, 1994, Rock, 1995 Griffin, 1998	Posted Speed Limit	Number of fatalities and fatality rates remain identical after raising posted speed limits	Rejected
Sidhu, 1989, Chang & Paniati, 1990, Lave & Elias, 1993	Posted Speed Limit	Number of fatalities and fatality rates remain identical after raising posted speed limits	Did Not Rejected
Fildes et, al., 1991	Speeding + Age	Speeding drivers have identical age and driving habits with other drivers	Rejected
Garber & Srinivasan, 1991	Age + Intersections	Driver age distributions at different locations with respect to intersections are identical	Rejected
Abdel-Aty et al, 1999	Age + Land Use	Driver age distributions at urban and rural areas are identical	Rejected
Doherty et al, 1998, Aldridge et al., 1999, Williams, 2000, Chen et al, 2000	Teenager Drivers	Teenage passengers do not contribute to the risk of teenage drivers fatal crash involvement	Rejected
Stuster et al., 1997	Alcohol + Speeding	Distribution of BAC levels of highly speeding and slightly speeding rivers are identical	Rejected*

*Drivers with lower BAC levels are more likely to drive faster.

Table 5.2 Summary of Alcohol Positive Drivers in Illinois and in Fatal Crashes in Illinois.

		1985	1991	1993
FARS	Alcohol-Negative	69.81%	69.34%	74.13%
	Alcohol-Positive	30.19%	30.66%	25.87%
ILLINOIS*	Alcohol- Negative	97.75%	98.58%	98.84%
	Alcohol-Positive	2.25%	1.42%	1.16%
TOTAL CHI-SQUARE		7,406	11,712	10,107

*Estimates based on Miller et al (1999), p values <0.001 for all data

The large values of chi-square indicated that the null hypothesis is rejected, thereby proving that alcohol is a significant factor in fatal crashes. Furthermore, the growing values of chi-square over the time imply that the prominence of alcohol is also increasing.

Age -- The statistical significance of age factor is measured by comparing the age distribution of the Illinois drivers and the driver age distribution in fatal crashes. In order to account for the differences in travel habits of different age groups, expected frequencies of driver age groups in fatal crashes based on the information from NPTS, were used. This allowed testing hypotheses for the years 1977, 1983, 1990 and 1995. The age categories and the selection of years for the tests were based on the information provided by the sources relevant to earlier NPTS studies. Table 5.3 displays the driver age distribution in the fatal crashes and in the total VMT. The hypotheses states that involvement in fatal crashes is proportional to the VMT and the national VMT proportions by different age groups. The chi-square values in the table were utilized to test the null hypothesis that age distribution in fatal crashes is equivalent to the distribution that produces the total VMT. Based on the values in Table 5.3, the hypothesis is rejected, since all p-values are smaller than 0.001 for all years tested. This confirmed that age is an important factor in fatal crash involvement. When chi-square values for different age groups were obtained, it was seen that the large portion of the total chi-square values were produced by the teenage groups.

Gender -- Similar to the hypotheses developed for the age factor, gender also displayed differences in driving behavior. The hypothesis on gender factor was tested using information from NPTS. Table 5.4 provides the gender distribution in fatal crashes and in normal traffic conditions in Illinois. The null hypothesis states that gender distribution in fatal crashes and in normal traffic conditions is identical. The large chi-square values for different years reject the null hypothesis with p-values smaller than 0.001 for all years tested and confirmed the notion that gender (being a male) is a significant factor in fatal crashes. In Table 5.4, the odds ratios were calculated as the ratio of the odds of being male in a fatal crash to the odds of being female driving under the same conditions. The results indicate that males are more likely to involve fatal crashes than females by 63% to 96% over the time covered, and the likelihood had a growing pattern. This indicated that although the descriptive analysis showed increasing numbers and percentages of women drivers in fatal crashes, they still seemed to be safer drivers when their participation in total crashes was studied.

Table 5.3 Distributions of Driver Age in Fatal Crashes and in Total VMT.

PTS Years	Parameters	Driver Age Groups 16-20	21-34	35-54	55-64	65+	Total*
1977	Drivers in Fatal Crashes % Drivers in Fatal Crashes % VMT Chi-Square	601 21.8 4.8 **1,163**	1,148 41.7 41.6 **0**	638 23.2 37.3 **147**	218 7.9 11.3 **28**	149 5.4 5.0 **1**	2,754 100 100 **1,839**
1983	Drivers in Fatal Crashes % Drivers in Fatal Crashes % VMT Chi-Square	359 18.4 3.1 **1470**	826 42.3 41 **1**	470 24.1 37.9 **99**	165 8.4 12.7 **28**	134 6.9 5.3 **9**	1,954 100 100 **1,607**
1990	Drivers in Fatal Crashes % Drivers in Fatal Crashes % VMT Chi-Square	327 15.2 3.5 **841**	861 40.0 38.90 **1**	611 28.4 41.4 **88**	158 7.3 9.7 **12**	195 9.1 6.5 **22**	2,152 100 100 **964**

		16-18	19-20	21-24	25-34	35-49	50-64	65-79	80+	Total*
1995	Drivers in Fatal Crashes % Drivers in Fatal Crashes % VMT Chi-Square	185 8.7 2.3 **385**	144 6.8 3.1 **96**	253 12 7.1 **69**	488 23.1 23.6 **0**	574 27.1 37.5 **60**	214 10.1 19.0 **88**	193 9.1 6.6 **20**	65 3.1 0.8 **135**	2,116 100 100 **855**

Note: In 1995, the age distribution was changed to 8 sub-groups versus 5 in earlier years.
* $p < 0.001$

Table 5.4 Gender Distribution in Fatal Crashes and Normal Traffic in Illinois.

		1977	1983	1990	1995
FARS	Male	81.0%	80.1%	78.1%	74.3%
	Female	19.0%	19.9%	21.9%	25.7%
ILLINOIS	Male	72.3%	70.70%	64.60%	62.40%
	Female	27.7%	29.30%	35.40%	37.60%
Total Chi-Square		104	84	172	129
Odds Ratio (M/F)		1.63	1.67	1.96	1.75

Vehicle Type -- The composition of vehicle types in the total VMT was needed to develop and test hypothesis for this factor. Illinois Travel Statistics provided data on the vehicle type composition starting from 1982 only for passenger cars, trucks and buses. The null hypothesis states that the vehicle type distribution in fatal crashes and in normal traffic conditions is identical. The hypothesis test was then conducted for 1982 and continued with 5-years of increments after 1985 until the end of the study period. When the vehicle type categories included the motorcycles, large chi-square values were obtained indicating that this vehicle category had a high risk of fatal crash involvement. Table 5.5 summarizes the vehicle type distribution in FARS and Illinois traffic along with chi-square values. The differences in the distributions stem from the differences in the truck category. Until 1990, the percentage of trucks involved in crashes reported in FARS is higher than the percentage of trucks in the Illinois data. This difference is reversed after 1990.

Table 5.5 Distribution of Vehicle Types in Fatal Crashes and in Illinois Traffic.

		1982	1985	1990	1995	1999
FARS	Pass Veh.	91.0%	89.7%	89.6%	91.3%	89.0%
	Trucks	8.2%	9.4%	9.8%	7.7%	10.4%
	Buses	0.8%	0.9%	0.6%	1.0%	0.6%
ILLINOIS	Pass Veh.	92.6%	92.6%	92.0%	89.2%	88.2%
	Trucks	6.8%	6.9%	7.6%	10.2%	11.0%
	Buses	0.6%	0.5%	0.4%	0.6%	0.8%
Chi-Square		8	25	17	20	1
p-value		0.023	<0.001	<0.001	<0.001	0.504

The years 1995 and 1996 had exceptionally low truck involvement in fatal crashes. The vehicle type factor is found a significant factor only if motorcycles are considered. Otherwise, vehicle type factor is non-significant to only marginally significant for the later years in the study period.

Land Use -- FARS records land use information through a nominal variable with two levels: urban and rural. It is hypothesized that there would be differences in the number of fatal crashes in urban and rural areas possibly due to differences in traffic conditions, geometric standards, and levels of enforcement. The VMT has been estimated on urban and rural roads by IDOT and provided in periodical Illinois Travel Statistics. In developing and testing hypotheses, the VMT distribution was used to calculate expected frequencies of fatal crashes by land use. The 5-year increment scheme as discussed earlier was also used here. The null hypothesis states that distribution of fatal crashes to rural and urban areas is identical with the distribution of VMT to rural and urban areas. Table 5.6 summarizes the distribution of fatal crashes and traffic into urban and rural areas including chi-square and relevant statistics. The chi-square values indicated statistically significant differences in urban and rural areas. During 1975-1999, the odds ratio for land use categories indicated higher and growing risks for rural areas; the likelihood of fatal crash occurrence almost doubled over the study period (38% to 73%).

Table 5.6 Distribution of Fatal Crashes and in Illinois Traffic into Land Use Categories.

		1975	1980	1985	1990	1995	1999
FARS	Rural	40.0%	43.1%	38.5%	41.1%	44.9%	42.6%
	Urban	60.0%	56.9%	61.5%	58.9%	55.1%	57.4%
ILLINOIS	Rural	32.5%	33.7%	31.5%	31.3%	29.4%	30.1%
	Urban	67.5%	66.3%	68.5%	68.7%	70.6%	69.9%
Chi-Square*		46.2	70.1	31.1	63.7	160.7	97.3
Odds Ratio (R/U)		1.38	1.49	1.36	1.53	1.95	1.73

* All *p* values <0.001

Roadway Function Class -- In this section the proportionality of fatal crashes by VMT on different roadway classes is tested. Three broad roadway function categories (Interstate highways, highways, locals) were considered. Differences in the number of fatal crashes were expected due to the differences in posted speeds, capacity, level of enforcement. The VMT by road function class information was acquired from the Illinois Travel Statistics and covered the study period starting from 1981. The null hypothesis states that the distribution of fatal crashes by roadway class function is the same as the respective VMT distribution. Testing the hypotheses was done for 1981 and 1985 and for every five years afterwards. Table 5.7 displays a summary of a distribution of fatal crashes and VMT for different roadway class categories and relevant statistics. The null hypothesis states that distribution of fatal crashes to roadway function class categories is identical to the distribution of VMT to the roadway function class categories.

Table 5.7 Distribution of Fatal Crashes and VMT by Roadway Function Class.

		1981	1985	1990	1995	1999
FARS	Interstates	7.5%	8.5%	11.7%	10.6%	14.2%
	Highways	65.1%	65.1%	56.6%	52.9%	51.0%
	Locals	27.4%	26.4%	31.7%	36.5%	34.8%
ILLINOIS	Interstates	21.1%	22.0%	25.4%	27.4%	28.3%
	Highways	64.8%	63.6%	62.0%	60.6%	60.2%
	Locals	14.1%	14.3%	12.6%	12.0%	11.6%
Chi-Square		354	253	528	861	710
p-values		<0.001	<0.001	<0.001	<0.001	<0.001

The large chi-square values (*p*-values smaller than 0.001) indicated that the null hypothesis was rejected. The "highways" category, which included freeways, arterials and collectors, had proportional fatal crashes to the corresponding VMTs. The major contribution to these large chi-square values was from the "locals" category. The prominence of locals category was expected since the percentage of fatal crashes was on the rise given a decline in the amount of traffic this category handles. Interstates also had increasing fatal crashes trend with the growing traffic. Therefore, roadway functional class appeared as a significant parameter in the occurrence of fatal crashes.

Weather Conditions -- The null hypothesis in this case states that the distribution of fatal crashes on days with different weather conditions is identical to the distribution of number of days with different weather conditions in a given year. The numbers of rainy and snowy days were used in hypotheses testing for every five years. Table 5.8 provides the summary of the distribution of fatal crashes and the days of a year into different weather condition categories. The large chi-square values ($p<0.001$) indicated that the null hypothesis is rejected.

Table 5.8 Distribution of Fatal Crashes and Days of the Year by Weather Condition.

		1975	1980	1985	1990	1995	1999
FARS	Dry	87.1%	86.5%	84.3%	86.6%	86.4%	89.7%
	Rain	10.0%	9.3%	13.0%	11.8%	10.0%	7.7%
	Snow	2.9%	4.2%	2.6%	1.6%	3.6%	2.7%
WEATHER IN ILLINOIS	Dry	64.1%	68.2%	62.5%	67.7%	69.3%	71.8%
	Rain	31.2%	27.4%	32.9%	30.4%	27.7%	25.2%
	Snow	4.7%	4.4%	4.7%	1.9%	3.0%	3.0%
Chi-Square		419	293	272	233	212	211
p-value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Day of the Week -- Day of the week variable can be considered as an important variable in the analysis of fatal crashes since the traffic conditions can change during the week, particularly, in the weekends. The variable analyzed in this section has two levels that indicate whether the day of a crash is a weekday or a weekend day. In order to calculate expected frequencies of fatal crashes, VMT distribution to days of week was estimated by utilizing the daily distribution of AADT in urban and rural Interstates provided in 1999 Illinois Travel Statistics. Furthermore, it was assumed that the remaining roadway classes would have similar distribution. Table 5.9 presents a summary of the distribution of fatal crashes and VMT into the days of week and relevant statistics. The null hypothesis states that weekdays and weekends have fatal crashes proportional to the VMT on these days.

Table 5.9 Distribution of Fatal Crashes and VMT by Days of the Week.

		1975	1980	1985	1990	1995	1999
FARS	Weekday	58.1%	56.7%	61.3%	59.6%	60.2%	60.8%
	Weekend	41.9%	43.3%	38.7%	40.4%	39.8%	39.2%
ILLINOIS	Weekday	65.8%	65.7%	65.8%	65.8%	65.8%	65.8%
	Weekend	34.2%	34.3%	34.2%	34.2%	34.2%	34.2%
Chi-Square		48	64	12	24	20	15
p-value		<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Odds Ratio (WD/WE)		0.72	0.68	0.82	0.77	0.78	0.80

Based on the *p*-values, the null hypothesis was rejected. The likelihood of a fatal crash during weekend is about 20-33% higher. Additional statistical tests on these proportions indicated that the difference is significant. However, broad assumptions behind the estimation of VMT distribution estimates impede the reliability of the test. More specific data on the VMT divided by weekday and weekend traffic will be needed to obtain more reliable test results.

A summary of hypotheses tested based on the compiled data is provided in Table 5.10

Table 5.10 Summary of Hypothesis Tests Based on Compiled Data.

Factor	Null hypothesis	Result*
Alcohol	Population portions of alcohol-positive drivers are equal to the proportions of alcohol-positive drivers involved in crashes.	Rejected
Age	The involvement in fatal crashes is proportional to the VMT and the national VMT proportions by different age groups.	Rejected
Gender	The gender distribution in fatal crashes and in normal traffic conditions is identical.	Rejected
Vehicle Type	The vehicle type distribution in fatal crashes and in normal traffic conditions is identical.	Rejected for 1985, 1990, 1995 data; but did not reject for 1982 and 1990 data
Land Use	The distribution of fatal crashes to rural and urban areas is identical with the distribution of VMT to urban and rural areas.	Rejected
Roadway Function Class	The distribution of fatal crashes by roadway class function is the same as the respective VMT distribution.	Rejected
Weather Conditions	The distribution of fatal crashes on days with different weather conditions is identical to the distribution of number of days with different weather conditions in a given year.	Rejected
Days of Week	Weekdays and weekends have fatal crashes proportional to the VMT on these days.	Rejected

* $p \leq 0.001$

6.0 RESULTS

6.1 Descriptive Analysis of Fatalities in Illinois

Table 6.1 presents a listing of dates and events in Illinois with an impact on potential motor vehicle crashes. Within each period, any decrease or increase in fatality trend is also noted.

Table 6.1 Important Events and Dates for Traffic Safety in Illinois.

Periods	Trend	Years	Descriptions
Period I	Increase	1973	19-20 year-olds were allowed to purchase beer and wine
		1974	Maximum speed limit was reduced to 55 mph.
Period II	Decrease	1980	Legal drinking age was established as 21 for all types of alcoholic beverages
		1982	Legal BAC was established as 0.10 & penalties increased
Period III	Increase	1985	Safety Belt Law required safety belt use by drivers and front seat passengers
		1986	DUI Law was reinforced
		1987	Speed limit raised to 65 mph on rural Interstates
		1988	Safety Belt Law amended to make non-use of safety belts secondary offense
Period IV	Decrease	1990	Mandatory Insurance Law required minimum liability limits
Period V	Increase	1995	Zero Tolerance Law for drivers under 21
		1995	Maximum speed limit raised on certain Interstate and Freeways
Period VI	Decrease	1997	Legal BAC reduced to 0.08
Period VII	Increase	1998	Graduated driver's license established for drivers under 21 years of age.

Source: Illinois Crash Facts and Statistics 1998, IDOT DOTS

The plot of fatalities with time indicates an overall decline. While peaking at 2126 in 1977, there were only 1456 fatalities in 1999. During the study period (1995-1999), on the average there were 1675 fatalities per year as a result of motorway crashes in Illinois. Based on this trend, it can be speculated that in the near future the trend might stabilize itself around a mean value slightly less than the most current reading. The solid broken line in Fig. 6.1 can be used to represent the general pattern in fatalities. This line was plotted based on the three graphs shown in Fig. 6.1. It is noted that the plot indicating "Injuries" reveals the number of injuries in fatal motorway crashes only.

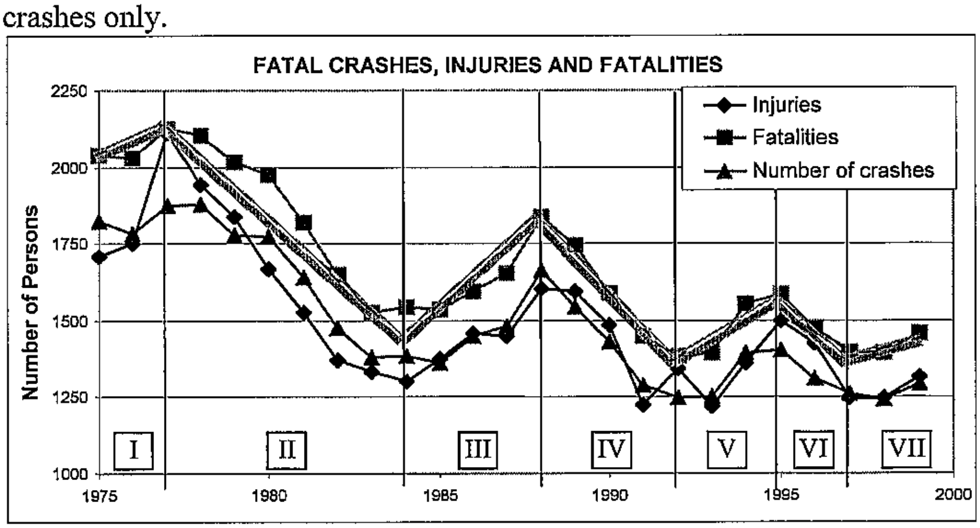


Fig. 6.1 Trends in Number of Injuries and Fatalities in Fatal Crashes

The seven periods (as listed in Table 6.1 and marked in Fig. 6.1) selected in this study are explained below.

Period I (1975-1977) -- This period covers the first three years of FARS data where a slight increase in fatalities (less than 5%) was observed. While the mean value of fatalities was the highest in this period, there were no significant changes in policies regarding to traffic safety.

Period II (1977-1984) -- During this period, there was a significant decrease (almost 30%) in the number of fatalities. There had been changes in legal drinking age and legal BAC levels later in the period. Although these changes may seem to contribute to the decline in the fatalities, further investigation on alcohol involvement (as presented later) indicated that the contribution was not significant. This period also corresponds to the 1979 oil crisis. Staring from 1977, the VMT showed some decline (see Fig. 6.2) and started to pick up in 1980. Subsequently, the VMT level in 1983 reached the same level as in 1977. It is noted that such factors as limiting non-mandatory trips, and driving at slower speeds for saving fuel were changes that occurred during this period.

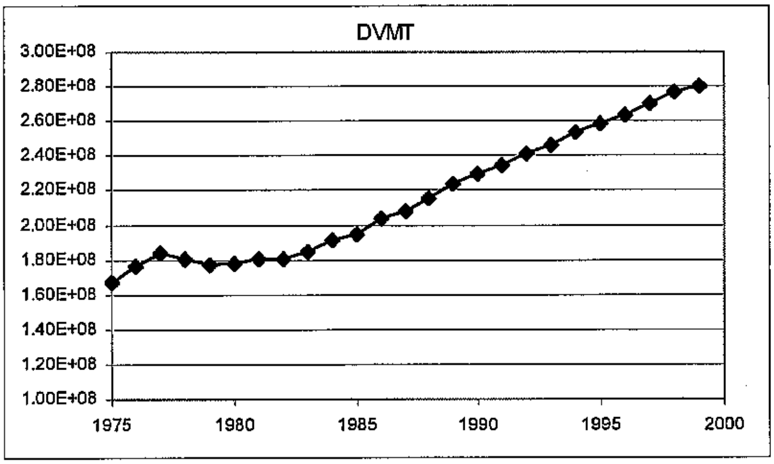


Fig. 6.2 Change in Daily Vehicle Miles Traveled

Period III (1984-1988) -- This mid-eighties period witnessed a prominent increase in fatalities, in the1984-1988 period, slightly lower than 25%. A major change that occurred in this period was the implementation of the increase in the maximum speed limit to 65mph on rural Interstate highways. However, as discussed later on the significance of the "Road Functional Class", the increase in fatalities may not be attributed entirely on the increased speed limit. It is noted that a slight increase occurred in Interstate fatalities in this period. However, this increase was not significant compared with the increase in total fatalities during this period.

Period IV (1988-1992) -- The fatality numbers showed a decline of approximately more than 25% over the 1988-1992 period. The list of important Illinois laws during this period does not contain a major change that may point to the observed decline.

Period V (1992-1995) -- Fatalities increased by nearly 15% during the 1992-1995 period; while there was no important change in Illinois laws until at the end of the period.

Period VI (1995-1997) -- Zero tolerance law for drivers under 21 and increases in speed limits on some Interstate highways occurred in 1995; while fatalities had about a 12% decline. These changes may have affected the fatalities on Interstate highways and fatalities among the younger drivers.

Period VII (1997-1999) -- There was a slight increase (less than 5%) in fatalities during the 1997-1999 period. Since the legal BAC was reduced to 0.08 in this period, one may expect a decline in fatalities. However, the plots of alcohol involvement show an increase. Although, there might be a decline in the number of drivers with unlawful BAC levels; since alcohol involvement is indicated by BAC>0 for the plots in this study, any decline in number of drivers with BAC level>0.08 cannot be determined.

It is noted that usually a change in Illinois law is intended to target a specific type of fatal crashes, such as crashes involving young drivers, drivers with high BAC levels, etc. And as such, the impact of a specific change in laws on total fatalities may not easily be understood. In order to gain an insight into the impact of any change in laws, fatality rates in groups, that are directly affected by the change, must be studied.

An overall investigation of the fatality data shows that the age, BAC level, rural vs. urban driving, speeding and VMT are among the most important factors affecting fatalities. Figure 6.3 shows the fatality rates based on population and VMT in Illinois during the study period. The trends in both variables were remarkably similar. However, they exhibited some differences when compared to the total fatality trend. During the periods when increases in the total fatalities were observed, fatality rates appear as either constant or with almost insignificant increases. Fatality rates were obtained by dividing total fatalities either by the population or by the VMT. When fatality rate (rather than total fatalities) was considered, it can be stated that the observed increases were due to the increases in population and VMT. Furthermore, any decrease in total fatalities resulted in more significant reductions in fatality rate. This was possibly driven by changes in laws and enforcement levels, and continuous efforts in traffic safety education and awareness.

The first period (1975-1977) had a slight decrease in fatality rates. This reduction proceeded by several years with no changes or with only slight increases in fatality rates. However, as it is evident from Fig. 6.3, with an increase in the population and VMT, the fatality rates were in general on decline with the exception of two peaks appearing in 1987 and 1995.

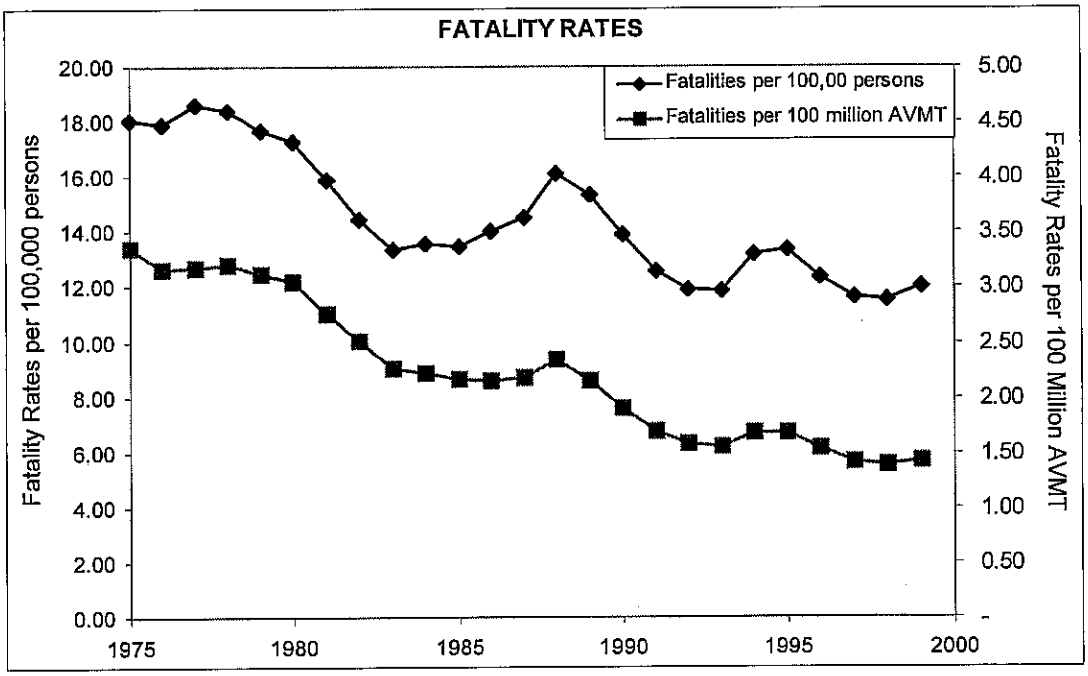


Fig. 6.3 Trends in Fatality Rate Based on Population and AVMT

6.1.1 Descriptive Analysis and Trends in the Factors Involved in Fatal Crashes

Fatalities resulting from motor vehicle crashes constitute unique events in the sense that each event involves a variety of physical, physiological, and behavioral factors. Generally, the most significant behavioral and physiological attributes such as, fatigue, level of distress, aggressiveness, level of awareness, level of anxiety of the drivers, can not be measured by the data collection methods employed in the FARS database. Data collected by FARS mainly reflect the physical elements that contributed to fatal crashes. One can use such factors as the BAC level, age, gender, driver residence location, driver traffic law violation history, and some of the police and/or witness reported factors as a means to draw conclusions on the physiological and behavioral factors influencing fatalities. In this section, a comprehensive analysis of factors reported in the FARS database is presented in an effort to provide an insight into the importance of various factors in fatalities and fatality rates in Illinois.

Alcohol Involvement -- According to Moskowitz and Fiorentino (2000), alcohol involvement of a driver in a fatal crash is indicated by BAC levels greater than zero. On the average, only 70% of drivers involved in fatal crashes on highways are recorded (NHTSA, 1999). This figure is approximately 90% in Illinois. However, the BAC records of surviving drivers are considerably limited. To overcome this limitation, NHTSA developed a system that allows the assignment of a BAC level to every driver in a fatal crash. Variables that indicate alcohol involvement in FARS are designated as DRINKING, DR_DRINK, ALC_RES. These variables tend to underreport the number of drinking drivers; and as such, the alcohol involvement is determined by utilizing the information in "alcohol files." Figure 6.4 shows the trends in the number of drivers with and without alcohol consumption. The trends started only from 1982 since

NHTSA's algorithm could not incorporate the information on the BAC level (as coded) prior to 1982. The trend showed that in the past 17 years, there was a 9% decline in the percentage of drivers with alcohol consumption with a sharp decline in the 1983-1987 period. While there had been several changes in laws for more stringent penalties for DUI in 1982, there was an increase of about 2% in percentage of drivers with alcohol in the 1987-1991 period. In the 1991-1994 period, there was a decline of approximately 6% in percentage of drivers with alcohol consumption. After 1994, the percentage remained nearly constant fluctuating ±1% for the rest of the study period.

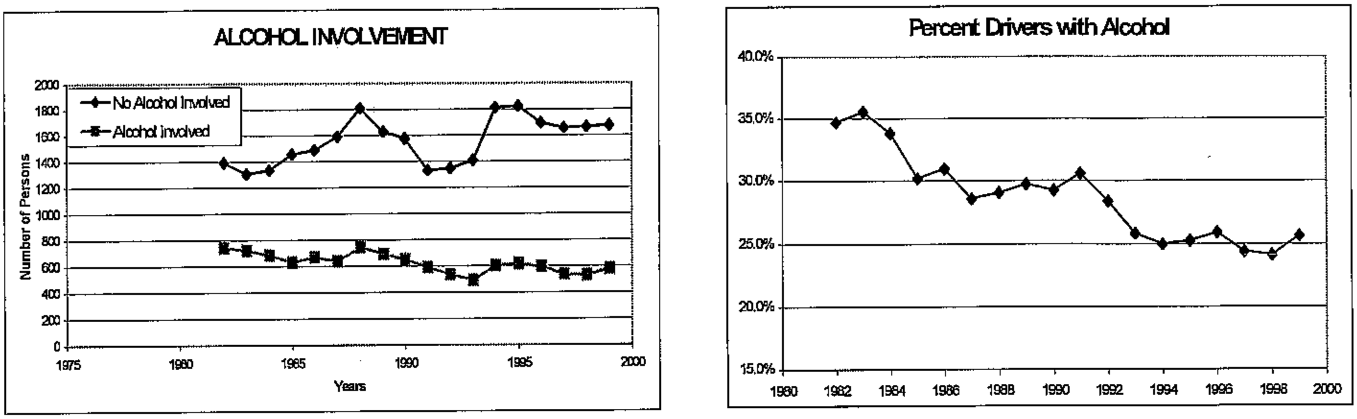
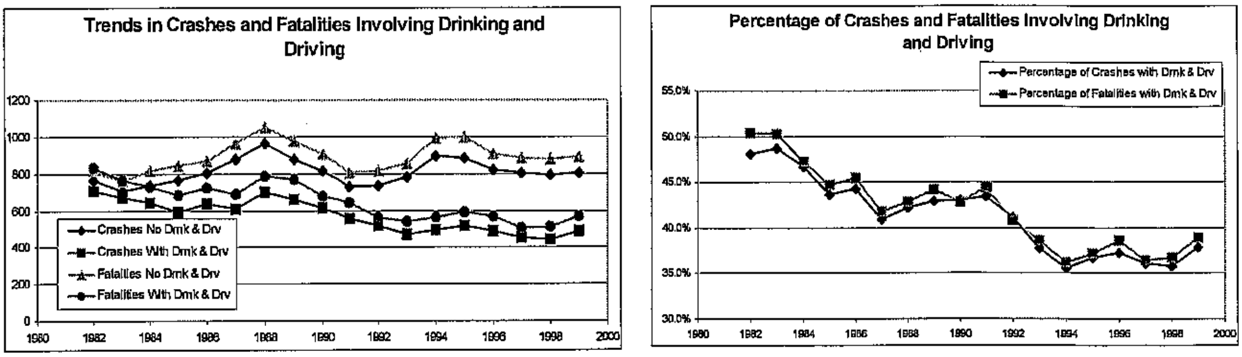


Fig. 6.4 Trends in Drinking and Driving Drivers in Fatal Crashes

Alcohol appeared to be an important contributor to fatal crashes. Approximately 30% of all drivers in fatal crashes had alcohol in their systems. When the downward trend in alcohol consumption was considered (estimated 20% decline between 1982 and 1999), the prominence of the drinking and driving behavior in Illinois could better be emphasized. Evidently, the number of drivers with alcohol has a significant correlation with the number of fatalities and the VMT-based fatality rate. The correlation coefficients were 0.839 and 0.909, respectively. However, when the percentage of drivers with alcohol (based on the total population) was considered, the corresponding correlation coefficients with the total number of fatalities and fatality rate were 0.377 and 0.831, respectively. It is emphasized that the computation of the fatality rate based on populations may not offer a good estimate; since in some urban areas many licensed people do not drive regularly. In this regard, the VMT-based rate offers a more reliable measure for the fatality rate.



(a) (b)

Fig. 6.5 Trends in Fatal Crashes and Fatalities Involving Drinking and Driving

Figure 6.5a displays the trends in number of fatal crashes and fatalities involving drinking and driving behavior. Starting from early eighties, both the numbers of fatal crashes and fatalities involving alcohol were in decline. Especially after 1991, for a period of four years, the figures for alcohol-related crashes showed a dramatic decline considering the fact that there had been an increase in the numbers of non-alcohol-related crashes. Figure 6.5b displays the percentage of crashes and fatalities in alcohol-related cases and shows that the 1982-1987 and 1991-1994 periods were the most successful periods in reduction of alcohol-related crashes. Overall, the percentage of alcohol-related crashes decreased by 12% in past 17 years. Although, some increase in the past 6 years was evident. This indicated that the effectiveness of 0.08 BAC level law of 1997 could not be observed. Voas et. Al (2000) reported a significant increase in the number of alcohol-positive (BAC level$\geq$0.01) drivers. They studied the monthly trends in the number of alcohol-positive drivers to end of the 1998. In 1999, the number of alcohol-positive drivers and both the numbers of alcohol-related crashes and fatalities increased. The plot in Fig. 6.5a agreed with the study showing a slight increase after 1998 (again, alcohol-positive divers are those with any BAC level in their systems).

The correlation between the number of crashes and fatalities involving alcohol and total number of fatalities and VMT-based fatality rate was similar to the correlation between the number of drinking and driving drivers and total fatalities as discussed earlier. While the total number of alcohol-related crashes had very high correlation with both total fatalities and the fatality rate, when the percentage of alcohol-related crashes (based on total crashes) was considered, the strong correlation was only with the fatality rate (see Table 6.2).

Speeding -- Hendricks et al. (2001) found speeding as the second largest contributor of traffic crashes, while driver's inattention was the largest contributor. Speeding not only increased the chances of human errors but also the extent of damage to the vehicle and its passengers. This effect was in fact increased by the square of the rate of change in the speed. In case of head-on collisions the impact of speed could be very dramatic.

Table 6.2 Correlation among Fatalities, Fatality Rates, Alcohol-Positive Drivers, Crashes and Fatalities Caused by Alcohol-Positive Drivers.

Variables	Descriptions	FATALITY	FRAT_VMT	ALCOHOL	PER_ALC	ACC_ALC	P_ACCALC	FAT_ALC	P_FATALC
FATALITY	Number of Fatalities	1.000	0.771	**0.839**	**.377***	**0.792**	**0.399***	**0.788**	**.402***
FRAT_VMT	Fatality Rate Based on VMT		1.000	**0.909**	**0.831**	**0.962**	**0.835**	**0.964**	**0.841**
ALCOHOL	Number of Alcohol Positive Drivers			1.000	0.752	0.939	0.749	0.944	0.760
PER_ALC	Percentage of Alcohol Positive Drivers in Fatal Crashes				1.000	0.854	0.991	0.858	0.990
ACC_ALC	Number of Crashes Involving Alcohol-Positive Drivers					1.000	0.873	0.993	0.868
P_ACCALC	Percentage of Crashes Involving Alcohol-Positive Drivers in Fatal Crashes						1.000	0.871	0.992
FAT_ALC	Number of Fatalities in Crashes Involving Alcohol-Positive Drivers							1.000	0.880
P_FATALC	Percentage of Fatalities in Crashes Involving Alcohol-Positive Drivers								1.000

* Indicates non-significant correlation at 0.95 confidence level

Traveling speed is not recorded in FARS as a measured variable. Estimates of travel speeds were available for very limited number of crashes (less than 1%). Initially, posted speed limits were considered as an indicator of speed; but the literature survey revealed that there exist controversial research results on the relationship between posted speed limits, and actual travel speeds and fatalities (Stuster et al., 1998). Furthermore, in certain roadways, the speeding vehicle may have been affected by the "spillover effect." This may especially be a factor when emerging from a roadway with a high speed limit to a surface or local road occurs. The spillover speed effect in local roads can be due to the driver's ignorance, poor signage, poor visibility, etc.

Figure 6.6 shows the distributions of fatal crashes to different posted speed zones. The first five years of the study period (i.e., 1975-1980) had unreliable data due to large amount of missing data. The discussions pertaining to posted speed limit zones did not include any information prior to 1980. Figure 6.6 shows that the fatal crashes mostly happened in high-speed zones; however, the zone that had the second highest fatal crashes was 15-30 mph. Most probably this zone corresponded to fatal crashes in local roads. These two categories showed a statistically significant resemblance with each other and the general fatal crash statistics. The corresponding correlation coefficients were 0.602, 0.814 and 0.652, respectively. The fatality trend for the 55-

mph speed zone seemed to stay constant around its mean of 690 for most of the study period. Starting from 1994, the trend shows a decline of about 25% over a 5-year period ending in 1998. However, there was a slight increase in fatalities in 1999. This might be the beginning of an increasing fatality trend as was observed twice in the study period.

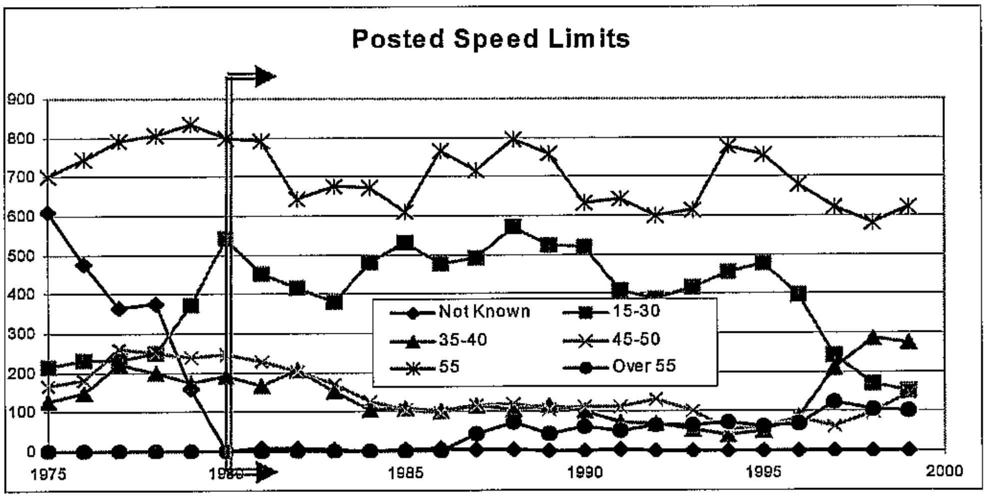


Fig. 6.6 Number of Fatal Traffic Crashes in Different Posted Speed Zones

The fatality trend in the 15-30-mph speed zone exhibited some fluctuations until 1995. After this year, fatal crashes in this zone dropped by 68% just in four years. However, during the same time period, fatal crashes in the speed zone category of 35-40-mph increased dramatically (by 450%). Several factors were believed to be responsible for these latest trends. These include: (1) changes in the posted speed limits from 30 to 35 or 40; (2) improved signage in local roads and streets with low speed limits; (3) perhaps a shift in the levels of enforcement between these areas; and (4) the effect of spillover speed in 35-40-mph roadways..

Both the 35-40 and 45-50-mph zones showed similar patterns through the study period, except in the last 5 years of the period. The fatalities showed a decline in early 80's until 1984 by about 50%. However, fatality trends for both zones stayed constant for six years and showed a gradual decline for another four years until 1995. During the 15 years after 1984, the decline in fatal crashes was almost 80% for both speed zone categories.

Finally, the speed zone category of over 55 mph had an increasing fatal crash trend starting at 1987. Notice that this was the year when the maximum speed limit increased to 65 mph for some rural Interstate highways. In ten years following 1987, the fatal crashes in this category increased by 170%; while the increase in VMT at rural Interstates was only around 48%. The discussions on the distribution of fatal crashes to different posted speed zones and associated trends suggest that speed is one of the most important factors contributing to fatal crashes.

Police reports on speeding involvement (as reported in FARS data files) were further used in the analysis of speeding behavior. It is emphasized that the information is subjective and is based on police and/or witness accounts. The reports on speeding prior to the year 1983 seemed to overstate the speed related crashes. This might have been caused by the changes in the data collection in 1981 where the number of factors causing a crash was expanded in the FARS data collection instrument. Based on this database, on average, there were 376 (27.5%) speed related fatal crashes per year. The trend in Figure 6.7 shows a steady pattern until 1992 and starting from the same year, a slight increase of about 6% occurred during the last 7 years. The correlation between non-speeding crashes and total crashes and total fatalities indicated almost perfect similarity, i.e., 0.959 and 0.949 correlation coefficients, respectively. Although the effect of speeding may seem constant during the study period, the trend in the proportion of fatal crashes involving speeding (see Fig. 6.8) was growing. During the last 18 years of the analysis period, the percentage of fatal crashes due to speeding has increased by 10%.

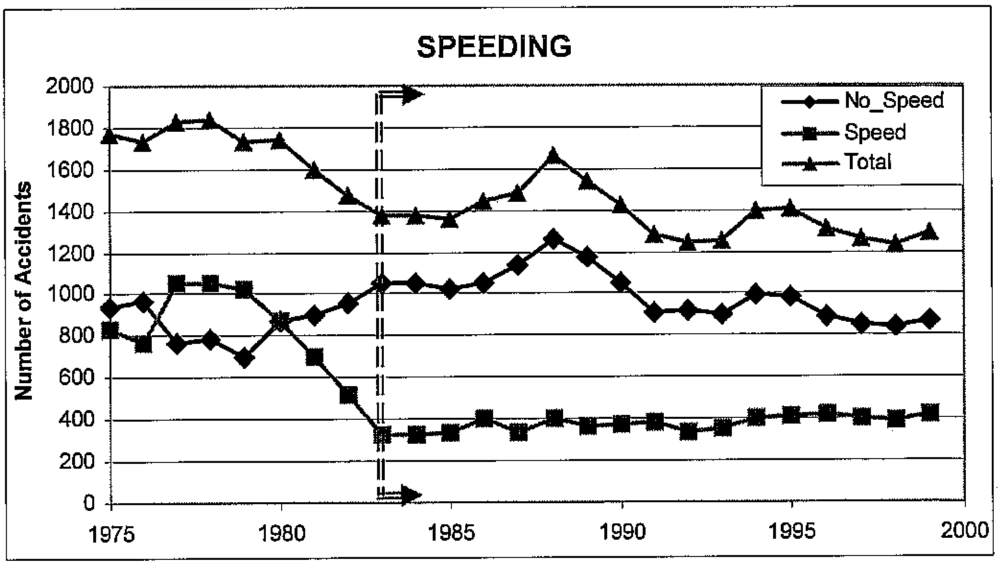


Fig. 6.7 Trends in Number of Fatal Crashes Due to Speeding (Based on FARS Data)

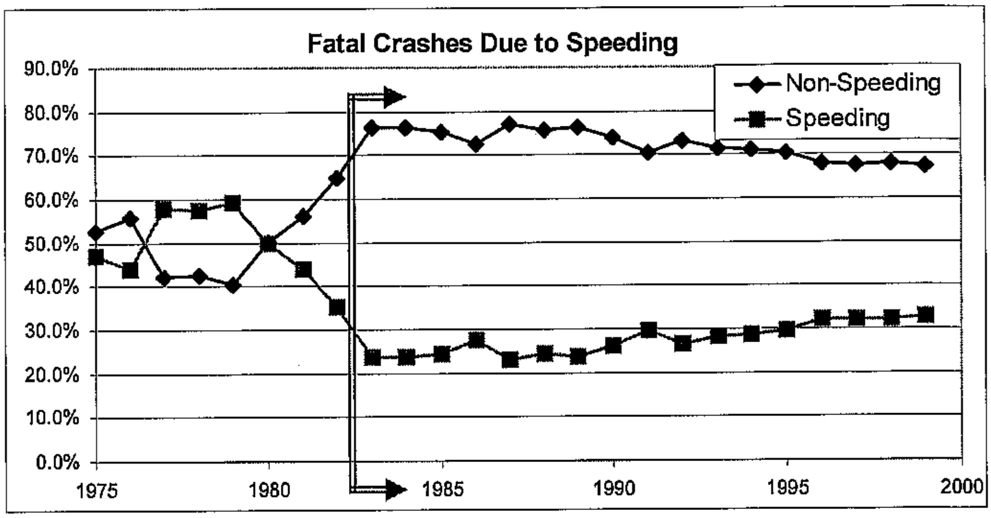
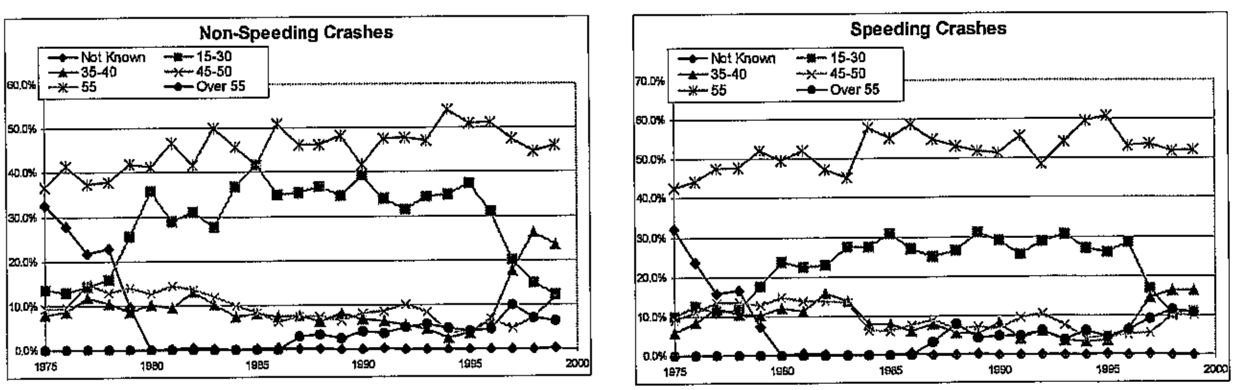


Fig. 6.8 Trends in the Proportions of Fatal Crashes Due to Speeding

In order to identify peculiarities of speeding behavior at different speed limit zones, distributions of fatal crashes not involving speeding and involving speeding by posted speed limit were plotted separately as shown in Fig. 6.9. The plots indicate that speeding is more of problem in 55-mph speed zones in which nearly half of the fatal crashes happened. As seen in this figure, the likelihood of speeding in 15-30 mph speed zones was small; even though, this zone had a significant effect on fatal crashes. The other posted speed limit zones had nearly equal likelihood for fatal crashes.



(a) (b)

Fig. 6.9 Trends in the Proportions of Fatal Crashes in Different Speed Limit Zones

Drivers' Age -- The driver's age appeared as another factor in fatal motorway crashes. Numerous studies showed that younger drivers were more likely to cause or be involved in fatal crashes due to their lack of experience under certain conditions, especially in quick decision making, and willingness to take higher risks (Ferrante et al., 2001). Williams (2000) points out the significance of fatal crashes when teenager drivers take responsibility to transport teenage passengers. Another high-risk group was elderly drivers. Cerrelli (1996) showed that the group of drivers of 85 years old or older may have a VMT-based fatality rate that was 17 times of the rate for middle aged driver group. Age-related decline in abilities associated with safe driving and greater vulnerability to injury and death were major causes that lead to fatal crashes by elderly drivers. The decline in abilities can be described in five broad categories. These are: (1) Sensory, (2) Attentional, (3) Perceptual, (4) Cognitive, and (5) Psychomotor. In general, older drivers have problems in comprehending instructions, judging gaps, visual search, and maintaining the proper speed. The behaviors that reflect caution more than ability have not shown consistent deficiency in this age driver group (McKnight and McKnight, 1999; Zador et al., 2000; and Cerrelli, 1996).

Figure 6.10 displays the number of drivers in fatal crashes by age groups. Almost 40% of the drivers involved in fatal crashes belong to 21-34 year-age group. The 35-54 years-age group had the second highest percentage with 24%. It is noted that the volume of travel by these two groups was high and therefore their high involvement rates might be misguiding. However, very high correlation between the 21-34 years-age group and the total fatalities and VMT fatality rate (0.934 and 0.938) suggested that the changes in the trend of the overall statistics might be attributable to the changes in this age group.

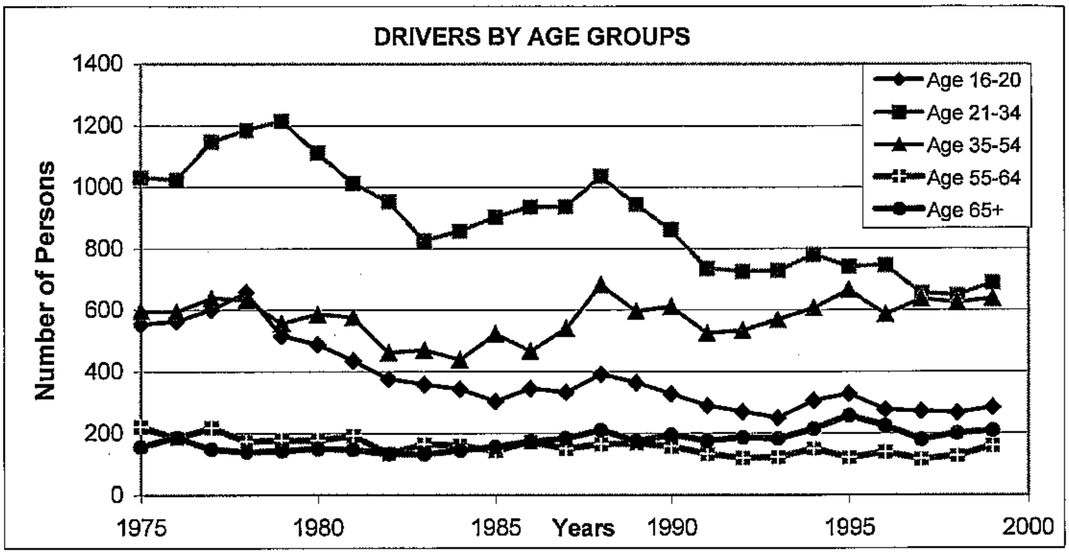


Fig. 6.10 Trends in the Number of Drivers in Fatal Crashes by Age Groups

While the declining trend in the 21-34 years-age group was consistent with the overall decline in fatalities and fatality rates, the increase in the 35-54 years-age group shows some similarity with the VMT trend. The correlation between VMT and age groups has negative signs except for the 35-54 years-age and 65 years and up groups. The trend in elderly drivers showed a positive high correlation of 0.777. This indicated that the changes in the fatality rate in 35-54 years-age group may not be substantial, while elderly fatality rate was more of a function of the total VMT. On the other hand, changes in VMT by elderly drivers had to be analyzed in order to correctly identify any problems in the elderly driver involvement in fatal crashes. The teenager group had the third place in fatal crash involvement with an average of about 17% of total crashes. The trend in this group was in decline and had the highest correlation with total fatalities and VMT fatality rate (0.966 and 0.942, respectively). Similarly, 55-64 years-age group had a positive high correlation with general trends while their involvement was the least (only 7.4%). The relationship between fatality trends in different age groups and general fatality trends revealed that teenager and 21-34 years-age groups had close similarities, and that the 35-54 years-age group was the only group that had an increase in the fatality trend.

When comparing different age groups with each other, the differences in the amount of travel made by each group had to be considered. However, this type of information is generally collected outside the traffic safety scope through the National Personal Transportation Surveys (NPTS). The surveys are conducted every 5-7 years and provide the necessary information on travel at the national level. Conducted in 1969, 1977, 1983, 1990, and 1995 by the Federal Highway Administration and several cosponsors, the NPTS provides national level statistics on travel by all modes. The NPTS is designed primarily to cover local, repetitive travel, although long-distance trips are also reported. NPTS data are intended to provide insights on travel by trip purpose and mode, social and economic characteristics of the trip makers, changes in vehicle ownership, vehicle and fuel usage, the changing travel patterns of women and minorities, increased mobility of the older driver population, and a host of other topics. These data was used in the analysis of trends in travel and the relative use of different modes of transportation.

NPTS data collection efforts seek information on

- Household level - household size, number of household vehicles, income, location.
- Person level - age, gender, education, relationship within the household, driver status, annual miles driven if a worker, worker status, if drive as an essential part of work if employed, seat belt use.
- Customer service questions - rating of potential problems in traveling, such as mobility, congestion, safety, traffic conditions, and pavement conditions.
- Vehicle level - annual miles driven (based on odometer readings recorded typically two months apart), make, model, and model year.
- Trip level - trip purpose, mode, length (in miles and minutes), time of day, vehicle characteristics (if a household vehicle was used), number of occupants, driver characteristics (for private vehicle trips only and if a household member was driving).

The latest completed NPTS 1995 was conducted by Research Triangle Institute during May 1995 through July 1996. Over 42,000 households were surveyed. Reports, public use data set, detailed documentation are available, particularly for 1990 and 1995 NPTS, on tape, diskette, CD-ROM, or from the Internet web sites: (http://www-cta.ornl.gov/npts/1995/Doc/index.shtml, and http://www-cta.ornl.gov/npts/1990/index.html).

In this part of the analyses, it was assumed that percentages of VMT by different age groups in Illinois did not differ significantly from those at the national level. There were only four NPTS conducted during the study period; therefore, the trends provided by this section were subject to approximations. The relative risk (see Section 3 for the definition of relative risk) for each age group is also provided by dividing the percentage of fatalities by the percentage of VMT by each age group. This measure indicates a likely percentage change in fatality proportions given a one- percent change in a VMT share by a group. Table 6.3 summarizes the distributions of fatalities, VMTs, and associated relative risk estimates for the NPTS years.

The teenager driver involvement in fatal crashes in the year 1977 was 21.8% of crashes for all driving age population. This was one of the highest rates in the study period. In 1983, this percentage was 18.4%; while in 1990 and 1995, the percentage was slightly over 15%. It is noted that during the study period, on the average, crashes involving teenage drivers make up about 17.2% of crashes for all driving age population. Further analysis of crashes involving teenage drivers shows that the change in the relative risk for teenagers follows a different path. In 1983, the relative risk increased by 1.4 points given the decrease in involvement rate by 3.4%. In 1990, the relative risk was back to the 1977 level; although the involvement rate was lower (i.e., 6.4%) and there was a decrease in relative risk by 0.5 points given equal rate of involvement. Until the last quarter of the study period, the risk associated with teenage drivers was not decreased, although there was a continuous decline in the involvement rate. This decline was partially due to the decline in VMT by teenagers especially after the oil crisis of 1979. The VMT levels in 1977 was reached prior to 1995 and only after that date some improvement was observed in the relative risk of the teenager drivers. The 1995 statistics also showed that the high risk of being involving in fatal crashes was still a problem for drivers of 21-24 years of age.

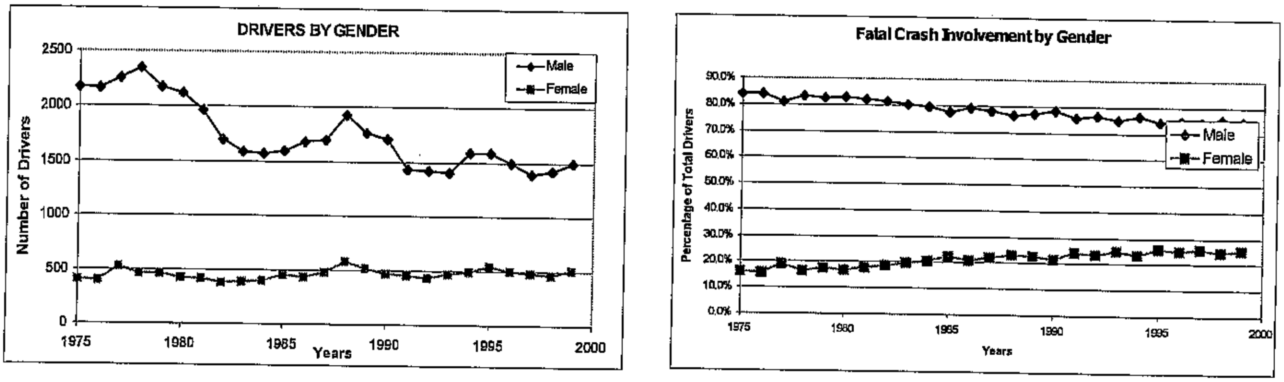
The relative risks of involvement in crashes for the middle age drivers did not change over time significantly. The fatal crash involvement rate followed the changes in VMT by this age group for the entire study period except for in 1995. Older middle age group (50-64) had improved relative risk values, mostly due to an increase in the number of drivers in that age group.

The elderly driver group is the second group that had relative risks higher than unity. Over the study period, the fatal crash involvement rate increased even though VMT by this group only slightly increased. The 1995 data indicated that the problem of increased relative risk over time became serious for older drivers in the 65 and older category. The relative risk was almost tripled for the drivers of 80 years of age or older when compared to the drivers of 65 to 79 years of age. NHTSA (1993) reported that the fatalities per crashes (non-fatal, fatal) started to increase for 60 year-old drivers; and for drivers older than 85 years could be as high as four times the rate for the middle age drivers. The distribution of injury types received by the drivers in fatal crashes showed that the proportion of fatalities within the drivers involved in fatal crashes is nearly 50% higher than that for the drivers of 65 years of age or older.

Table 6.3. Fatalities and Percent VMTs by Driver Age Groups.

NPTS Years	Parameters	Driver Age Groups				
		16-20	21-34	35-54	55-64	65+
1977	Drivers in Fatal Crashes % Drivers in Fatal Crashes % VMT Relative Risk	601 21.8 4.8 **4.5**	1,148 41.7 41.6 **1.0**	638 23.2 37.3 **0.6**	218 7.9 11.3 **0.7**	149 5.4 5.0 **1.1**
1983	Drivers in Fatal Crashes % Drivers in Fatal Crashes % VMT Relative Risk	359 18.4 3.1 **5.9**	826 42.3 41 **1.0**	470 24.1 37.9 **0.6**	165 8.4 12.7 **0.7**	134 6.9 5.3 **1.3**
1990	Drivers in Fatal Crashes % Drivers in Fatal Crashes % VMT Relative Risk	327 15.2 3.5 **4.3**	861 40.0 38.90 **1.0**	611 28.4 41.4 **0.7**	158 7.3 9.7 **0.8**	195 9.1 6.5 **1.4**
1995	Drivers in Fatal Crashes % Drivers in Fatal Crashes % VMT Relative Risk	329 15.5 3.4 **4.6**	741 35.0 27.6 **1.3**	666 31.5 50.3 **0.6**	122 5.8 10.7 **0.5**	258 12.2 7.9 **1.5**

Gender -- Female drivers accounted for 49.6% of all licensed drivers in the US in 1996 (Cerrelli, 1998). Although the number of drivers seemed to be equal in males and females, the number of drivers involved in fatal crashes was dominated by male drivers by an average of 78.5%. However, the trends in Fig. 6.11a, indicated two different phenomena. Fatalities for male divers had an overall decline similar to the total fatality and fatality rate trends with very high positive correlation coefficients of 0.993 and 0.989, respectively. Fatalities for female display a slight increase and show a positive moderate correlation (0.521) with VMT trend. The analysis of NPTS data indicated that female



(a) (b)

Fig. 6.11 Trends in the Number of Drivers Involved in Fatal Crashes by Gender drivers share in the total VMT in Illinois was constantly on the rise. In 1977 it was estimated that female drivers drove only 27.7% of the total VMT and made up 19% of the drivers in fatal crashes. The NPTS 1995 data indicated that female drivers made 39.2% of the total VMT in Illinois, while 25.7% of the drivers in fatal crashes were females. Figure 6.11b shows a 10% decline in driver involvement for males and a 10% increase for females. Table 6.4 summarizes the relative risks for driver gender groups. The relative risks for females stayed constant during the period of 1977-1995. This indicated a strong relationship with VMT (the share of fatal crash involvement and the share of VMT by females changed almost at the same rate). The male driver relative risk had slightly increased due to a more rapid decrease in VMT than the fatal crash involvement.

Table 6.4 Fatalities and Percent VMT by Driver Gender.

	1977		1982		1990		1995	
	Males	Females	Males	Females	Males	Females	Males	Females
Drivers in Fatal Crashes	2231	523	1566	388	1409	448	1573	543
% Drivers in Fatal Crashes	81	19	80.1	19.9	75.9	24.1	74.3	25.7
% VMT	72.3	27.7	70.7	29.3	64.6	35.4	62.4	37.6
Relative Risk	1.12	0.69	1.13	0.68	1.17	0.68	1.19	0.68

Vehicle Type -- The information on the VMT by vehicle type was given in the annual Illinois Travel Statistics since 1982. The categories of vehicle types in these reports were limited to passenger vehicles (4-tire), single units (six tire and 3-axle trucks and buses), and multiple units (3 or more tractor-trailer combinations). In order to maintain a baseline consistent with FARS data, the following vehicle type categories were selected: (1) passenger vehicles (4-tire vehicles, includes utility vehicles, pick-up trucks); and (2) buses and trucks (both single and multiple unit trucks. It is noted that the NHTSA statistics on vehicle types uses six categories of vehicles; passenger cars, light trucks, large trucks, motorcycles, buses and other vehicles.

According to the Illinois Travel Statistics records of 1982-1999, 91.2% of VMT was produced by passenger vehicles, 8.2% by trucks and 0.5% by the buses. The VMT produced by trucks increased significantly (61.8%) from 6.8% in 1982 to 11.0% in 1999. Since the VMT by buses almost stayed constant, the VMT by passenger vehicles must have decreased. This decrease was 92.6% to 88.1% during the same period. The trends in fatal crashes involvement by vehicle types revealed the following statistics: Passenger vehicle involvement had the highest share with an average of 84.1% of total crashes. Trucks made up 8.4% of the vehicles in fatal crashes while the buses share was only 0.8 percent. A significant amount of motorcycles (6.8%) was found in the vehicle population in fatal crashes. Unfortunately, an estimate on the motorcycle traffic was not available for calculating rates. However, indications are that motorcycles would have the highest rate. The vulnerability to serious injuries by motorcycle drivers is probably the main cause for such a high rate. When vehicles other than motorcycles were considered, the new involvement rates for cars, trucks and buses were 90.1%, 9.0%, and 0.8%, respectively. These figures indicated a slight overrepresentation by trucks and buses in fatal crash involvement. The average relative risks, in Table 6.5, identified that there was 10% and 57% more risk for every vehicle-mile traveled by trucks and buses, respectively, compared to passenger vehicles. This could be attributed to the size and weight of these vehicles, which can cause more serious damage to the vehicles resulting in more serious injuries to the persons involved.

Table 6.5 Fatalities and Percent VMT by Vehicle Type.

		Without Motorcycles			With Motorcycles			
Year (1)	Parameters (2)	Cars (3)	Truck (4)	Bus (5)	Cars (6)	Truck (7)	Bus (8)	Motor-cycles (9)
1982	Vehicles in Fatal Crashes	1728	155	16	1728	155	16	195
	% Vehicles in Fatal Crashes	91.0	8.2	0.8	82.5	7.4	0.8	9.3
	% VMT	92.6	6.8	0.6	92.0	6.8	0.6	0.62
	Relative Risk	**0.98**	**1.19**	**1.51**	**0.90**	**1.09**	**1.37**	**15.0**
1983	Vehicles in Fatal Crashes	1632	147	12	1632	147	12	177
	% Vehicles in Fatal Crashes	91.1	8.2	0.7	82.9	7.5	0.6	9.0
	% VMT	92.6	6.9	0.5	92.1	6.8	0.5	0.53
	Relative Risk	**0.98**	**1.19**	**1.35**	**0.90**	**1.09**	**1.24**	**17.0**
1984	Vehicles in Fatal Crashes	1654	149	14	1654	149	14	166
	% Vehicles in Fatal Crashes	91.0	8.2	0.8	83.4	7.5	0.7	8.4
	% VMT	92.5	7.0	0.5	92.0	7.0	0.5	0.51
	Relative Risk	**0.98**	**1.16**	**1.62**	**0.91**	**1.07**	**1.50**	**16.4**
1985	Vehicles in Fatal Crashes	1675	175	17	1675	175	17	187
	% Vehicles in Fatal Crashes	89.7	9.4	0.9	81.5	8.5	0.8	9.1
	% VMT	92.6	7.0	0.5	92.1	6.9	0.5	0.51
	Relative Risk	**0.97**	**1.35**	**2.01**	**0.89**	**1.23**	**1.83**	**17.8**
1986	Vehicles in Fatal Crashes	1737	194	18	1737	194	18	181
	% Vehicles in Fatal Crashes	89.1	10.0	0.9	81.5	9.1	0.8	8.5
	% VMT	92.7	6.9	0.5	92.2	6.8	0.5	0.51
	Relative Risk	**0.96**	**1.45**	**1.98**	**0.88**	**1.33**	**1.82**	**16.6**
1987	Vehicles in Fatal Crashes	1823	193	19	1823	193	19	162
	% Vehicles in Fatal Crashes	89.6	9.5	0.9	83.0	8.8	0.9	7.4
	% VMT	92.4	7.1	0.5	92.0	7.1	0.5	0.49
	Relative Risk	**0.97**	**1.33**	**1.96**	**0.90**	**1.24**	**1.82**	**14.9**
1988	Vehicles in Fatal Crashes	2095	232	21	2095	232	21	180
	% Vehicles in Fatal Crashes	89.2	9.9	0.9	82.9	9.2	0.8	7.1
	% VMT	92.5	7.1	0.5	92.0	7.0	0.5	0.49
	Relative Risk	**0.96**	**1.40**	**1.87**	**0.90**	**1.31**	**1.75**	**14.4**
1989	Vehicles in Fatal Crashes	1948	200	12	1948	200	12	138
	% Vehicles in Fatal Crashes	90.2	9.3	0.6	84.8	8.7	0.5	6.0

Table 6.5, Continued

	% VMT	92.3	7.2	0.4	91.9	7.2	0.4	0.49
	Relative Risk	**0.98**	**1.28**	**1.24**	**0.92**	**1.21**	**1.17**	**12.1**
1990	Vehicles in Fatal Crashes	1833	200	13	1833	200	13	152
	% Vehicles in Fatal Crashes	89.6	9.8	0.6	83.4	9.1	0.6	6.9
	% VMT	92.0	7.6	0.4	91.6	7.6	0.4	0.45
	Relative Risk	**0.97**	**1.29**	**1.51**	**0.91**	**1.20**	**1.42**	**15.5**
1991	Vehicles in Fatal Crashes	1605	161	16	1605	161	16	117
	% Vehicles in Fatal Crashes	90.1	9.0	0.9	84.5	8.5	0.8	6.2
	% VMT	92.1	7.4	0.5	91.7	7.4	0.5	0.42
	Relative Risk	**0.98**	**1.22**	**1.96**	**0.92**	**1.15**	**1.84**	**14.6**
1992	Vehicles in Fatal Crashes	1588	151	15	1588	151	15	108
	% Vehicles in Fatal Crashes	90.5	8.6	0.9	85.3	8.1	0.8	5.8
	% VMT	92.0	7.6	0.5	91.6	7.5	0.5	0.43
	Relative Risk	**0.98**	**1.14**	**1.82**	**0.93**	**1.08**	**1.72**	**13.6**
1993	Vehicles in Fatal Crashes	1590	149	12	1590	149	12	121
	% Vehicles in Fatal Crashes	90.8	8.5	0.7	84.9	8.0	0.6	6.5
	% VMT	91.3	8.3	0.4	90.9	8.3	0.4	0.43
	Relative Risk	**0.99**	**1.03**	**1.72**	**0.93**	**0.96**	**1.62**	**15.0**
1994	Vehicles in Fatal Crashes	1750	166	26	1750	166	26	148
	% Vehicles in Fatal Crashes	90.1	8.5	1.3	83.7	7.9	1.2	7.1
	% VMT	90.3	9.3	0.5	89.9	9.2	0.5	0.43
	Relative Risk	**1.00**	**0.92**	**2.82**	**0.93**	**0.86**	**2.63**	**16.3**
1995	Vehicles in Fatal Crashes	1867	157	21	1867	157	21	104
	% Vehicles in Fatal Crashes	91.3	7.7	1.0	86.9	7.3	1.0	4.8
	% VMT	89.2	10.2	0.6	88.9	10.1	0.6	0.40
	Relative Risk	**1.02**	**0.75**	**1.76**	**0.98**	**0.72**	**1.68**	**12.0**
1996	Vehicles in Fatal Crashes	1732	146	11	1732	146	11	105
	% Vehicles in Fatal Crashes	91.7	7.7	0.6	86.9	7.3	0.6	5.3
	% VMT	89.4	10.0	0.5	89.1	10.0	0.5	0.40
	Relative Risk	**1.03**	**0.77**	**1.08**	**0.97**	**0.73**	**1.02**	**13.2**
1997	Vehicles in Fatal Crashes	1611	166	14	1611	166	14	81
	% Vehicles in Fatal Crashes	89.9	9.3	0.8	86.1	8.9	0.7	4.3
	% VMT	88.8	10.6	0.6	88.5	10.5	0.6	0.38
	Relative Risk	**1.01**	**0.88**	**1.33**	**0.97**	**0.84**	**1.28**	**11.3**
1998	Vehicles in Fatal Crashes	1593	185	13	1593	185	13	97
	% Vehicles in Fatal Crashes	88.9	10.3	0.7	84.4	9.8	0.7	5.1
	% VMT	88.8	10.4	0.8	88.5	10.4	0.8	0.37
	Relative Risk	**1.00**	**0.99**	**0.96**	**0.95**	**0.95**	**0.91**	**13.7**
1999	Vehicles in Fatal Crashes	1670	195	12	1670	195	12	103
	% Vehicles in Fatal Crashes	89.0	10.4	0.6	84.3	9.8	0.6	5.2
	% VMT	88.1	11.0	0.8	87.8	11.0	0.8	0.37
	Relative Risk	**1.01**	**0.94**	**0.76**	**0.96**	**0.90**	**0.73**	**14.2**
Average	Vehicles in Fatal Crashes	1730	173	16	1730	173	16	140
	% Vehicles in Fatal Crashes	90.1	9.0	0.8	84.1	8.4	0.8	6.8
	% VMT	91.2	8.2	0.5	90.8	8.2	0.5	0.46
	Relative Risk	**0.99**	**1.10**	**1.57**	**0.93**	**1.05**	**1.52**	**14.6**

When the relative risk was studied in detail (see columns 3-5 of Table 6.5), it can be seen that the relative risk by trucks diminished after 1993 and stayed under 1.00 afterwards. There were some improvements in the buses category in which the relative risk for buses reduced to levels smaller than 1.00 for the last two years. In order to estimate the rates and risks in motorcycle category, it was assumed that the proportion of VMT by motorcycles in Illinois was equal to national proportion. FHWA (1998) provides national estimates for VMT with different vehicle types starting from 1970 to 1996 (for the remaining three years in the study period, figures were extrapolated). Upon including motorcycles as a vehicle category, the results showed that this category had the highest relative risk of involving a fatal crash per VMT. On the average, a motorcyclist is nearly 15 times more likely to be involved in a fatal crash compared to a driver in a passenger vehicle.

The trends in the number of vehicles in fatal crashes displayed in Fig. 6.12 indicated a strong similarity between the number of passenger vehicles trend and total fatality and fatality rate trends. The correlation analysis also found a strong positive correlation between passenger vehicle trend and total fatality and VMT fatality rate (correlation coefficients of 0.974 and 0.861, respectively).

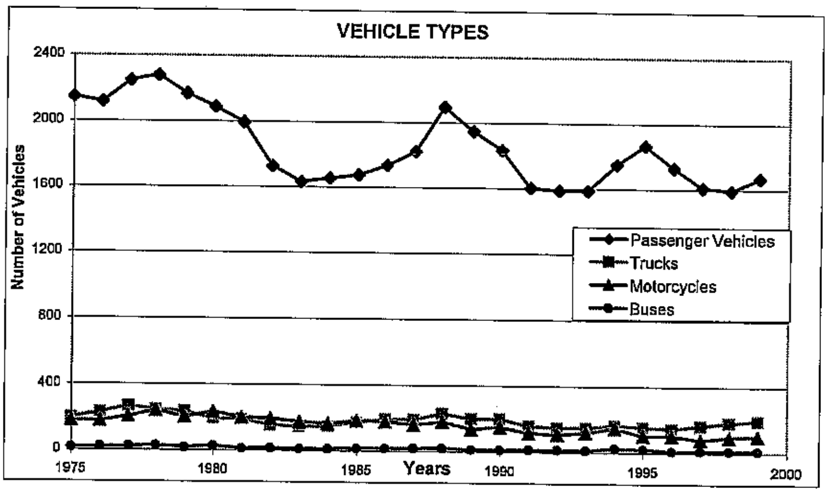


Fig. 6.12 Number of Vehicles Involved in Fatal Crashes by Four Vehicle Types

The motorcycle trend had the strongest and the bus trend had the weakest relationships with the general trends among the categories besides passenger vehicle. Thus, it can be stated that majority of the causes of fatal crashes were being shared by only a few vehicle types. In order to study this further, the number of vehicle type categories were expanded to 7: passenger cars, light truck and vans, sport utility vehicles (SUV's), single unit trucks, multiple unit trucks, motorcycles and buses. Figure 6.13 shows the number of vehicles involved in fatal crashes by the new vehicle type classification.

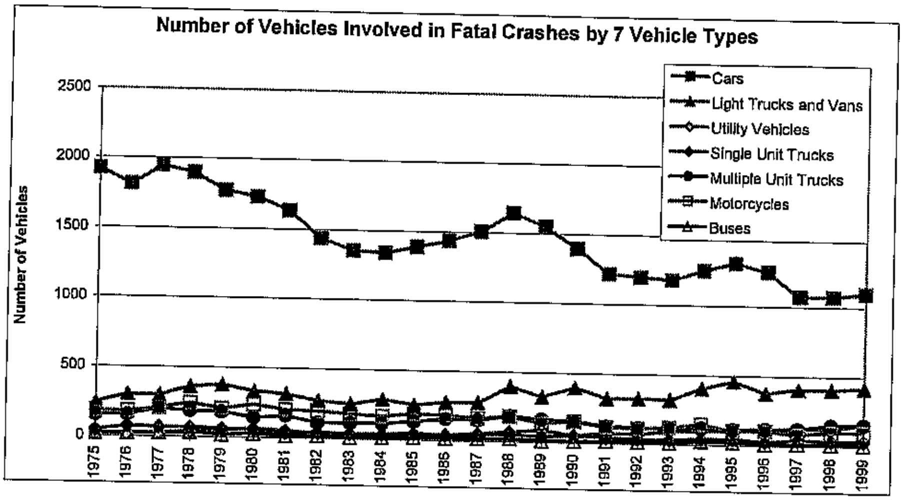


Fig. 6.13 Number of Vehicles Involved in Fatal Crashes by Seven Vehicle Types

On the average, during the study period, 65% of the vehicles in fatal crashes were passenger cars; 15.5% light trucks and vans, 7% the motorcycles, 6.5% multiple unit trucks, 3% utility vehicles, 2% single unit trucks and 1% buses. Table 6.6 presents the correlation coefficient between fatal crashes and vehicle types. In addition, correlation coefficient between VMT and vehicle types are provided. As seen in the table, it was found that passenger cars have the highest correlation between the total fatalities and VMT fatality rate trends (correlation coefficient of 0.979 and 0.963, respectively).

Table 6.6 Correlation between Fatal Crash Involvement by Vehicle Type and General Trends.

	Pass. Cars	Light Trucks & Vans	Utility Vehicles	Single Unit Trucks	Multiple Unit Trucks	Motor-cycles	Buses
Fatalities	0.979	-0.217*	-0.628	0.791	0.733	0.795	0.668
VMT-based Fatality Rate	0.963	-0.468	-0.796	0.688	0.586	0.885	0.572
VMT	-0.829	0.708	0.924	-0.482	-0.360	-0.906	-0.400

- Not significant at 95% confidence level

The 'light trucks and vans' is the only category that had an overall increase trend. It is noted that this category excludes the sport utility vehicles. While following a similar pattern with the other categories until 1990, the number of vehicles in fatal crashes from this class sustained its levels with a slight increase over years until the end of the study period. The 'Light trucks and vans' category had insignificant correlation with the fatality trend and negative moderate correlation with VMT fatality rate (correlation coefficient of –0.468). The trend had a very high correlation with the VMT trend (correlation coefficient of 0.708) indicating some evidence that the number of vehicles and fatalities in this category were a function of VMT. Another category displaying similar characteristics was the utility vehicles. While having a high negative correlation with fatality and VMT fatality rate trends, the correlation coefficient of 0.924 with VMT trend indicated a stronger relationship with VMT.

The classification with seven vehicle types also provided a more detailed analysis of the truck category. IDOT's Illinois Travel Statistics provided the annual VMT for both single unit and multiple unit trucks. On the average, during the period 1982-1999, multiple unit trucks produced 68% of the total truck VMT volume. The percentage VMT by single unit trucks stayed constant, while it was doubled for multiple unit trucks. Table 6.7 provides a comparison of single and multiple unit truck fatal crash involvement and their VMT proportions. Overall, the truck category had a slightly higher relative risk per VMT. Multiple unit trucks had a higher risk than did the single unit trucks. The relative risk for single unit trucks fluctuated around a constant value of 0.75. However, the relative risk for multiple unit trucks increased for four years and starting from 1986 it declined significantly from 1.70 to 0.68 in 1995.

Table 6.7 Fatalities and Percent VMTs by Single and Multiple Unit Trucks.

Year	Parameters	Single Unit Trucks	Multi. Unit Trucks	Total Trucks
1982	Vehicles in Fatal Crashes	43	112	155
	% Vehicles in Fatal Crashes	2.0	5.3	7.4
	% VMT	2.8	4.1	6.8
	Relative Risk	**0.74**	**1.30**	**1.08**
1983	Vehicles in Fatal Crashes	36	114	150
	% Vehicles in Fatal Crashes	1.8	5.8	7.6
	% VMT	2.8	4.1	6.9
	Relative Risk	**0.65**	**1.41**	**1.10**
1984	Vehicles in Fatal Crashes	36	113	149
	% Vehicles in Fatal Crashes	1.8	5.7	7.5
	% VMT	2.7	4.4	7.0
	Relative Risk	**0.67**	**1.29**	**1.06**
1985	Vehicles in Fatal Crashes	42	133	175
	% Vehicles in Fatal Crashes	2.0	6.4	8.5
	% VMT	2.7	4.3	7.0
	Relative Risk	**0.77**	**1.49**	**1.22**
1986	Vehicles in Fatal Crashes	40	156	196
	% Vehicles in Fatal Crashes	1.9	7.3	9.1
	% VMT	2.6	4.3	6.9
	Relative Risk	**0.72**	**1.70**	**1.33**
1987	Vehicles in Fatal Crashes	46	152	198
	% Vehicles in Fatal Crashes	2.1	6.9	8.9
	% VMT	2.6	4.5	7.1
	Relative Risk	**0.80**	**1.52**	**1.26**
1988	Vehicles in Fatal Crashes	51	183	234
	% Vehicles in Fatal Crashes	2.0	7.2	9.2
	% VMT	2.6	4.5	7.1

Years	Single Unit Trucks	Multi. Unit Trucks	Total Trucks
1992	36	115	151
	1.9	6.2	8.1
	2.6	5.0	7.6
	0.74	**1.24**	**1.07**
1993	35	117	152
	1.9	6.2	8.1
	2.6	5.7	8.3
	0.72	**1.09**	**0.98**
1994	45	123	168
	2.1	5.9	8.0
	2.2	7.0	9.3
	0.96	**0.83**	**0.86**
1995	46	112	158
	2.1	5.2	7.3
	2.6	7.6	10.2
	0.84	**0.68**	**0.72**
1996	29	118	147
	1.5	5.9	7.4
	2.4	7.6	10.0
	0.59	**0.78**	**0.73**
1997	44	122	166
	2.3	6.5	8.9
	2.8	7.8	10.6
	0.85	**0.83**	**0.84**
1998	36	150	186
	1.9	7.9	9.8
	2.9	7.5	10.4

Table 6.7, Continued

	Relative Risk	**0.79**	**1.60**	**1.30**
1989	Vehicles in Fatal Crashes % Vehicles in Fatal Crashes % VMT Relative Risk	41 1.8 2.6 **0.69**	163 7.0 4.6 **1.52**	204 8.8 7.2 **1.22**
1990	Vehicles in Fatal Crashes % Vehicles in Fatal Crashes % VMT Relative Risk	50 2.3 2.6 **0.87**	153 6.9 5.0 **1.38**	203 9.2 7.6 **1.21**
1991	Vehicles in Fatal Crashes % Vehicles in Fatal Crashes % VMT Relative Risk	41 2.1 2.5 **0.85**	121 6.3 4.9 **1.30**	162 8.5 7.4 **1.14**

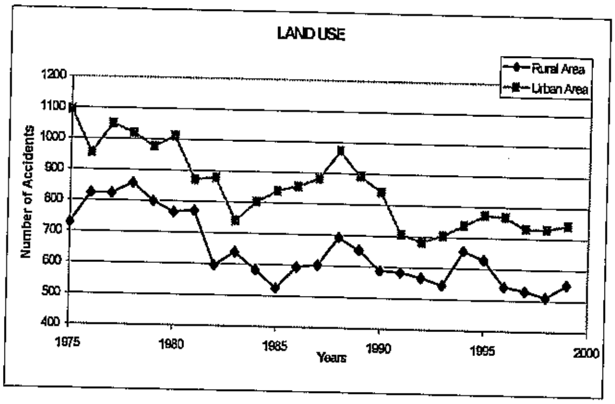
	0.65	**1.06**	**0.94**
1999	38 1.9 2.8 **0.67**	155 7.8 8.2 **0.96**	193 9.7 11.0 **0.88**
Average	41 2.0 2.6 **0.75**	134 6.5 5.6 **1.22**	175 8.4 8.2 **1.05**

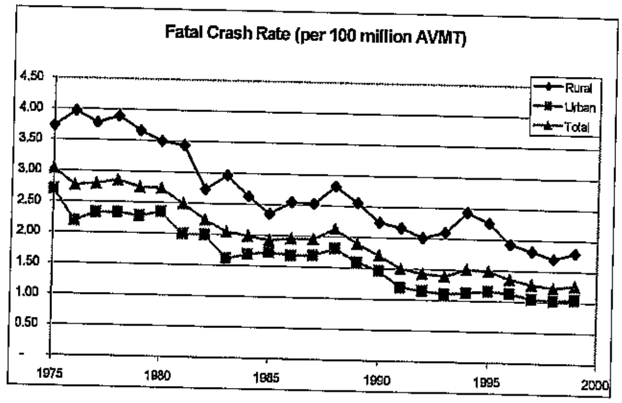
After 1995, the relative risk for multiple unit trucks was in an increasing trend even though their proportion of VMT increased significantly during the last 4-5 years of the study period.

Land-Use -- The conditions of environment are represented with several variables in FARS. Weather conditions, surface conditions, time of day, road functional class, number of lanes, roadway separation and land-use information are the main indicators of the environmental conditions that may influence a fatal crash. The land-use, as a factor, classifies the crash location as either urban or rural. While national trends indicated that 55% of the fatal crashes happened in rural roads (Blatt and Fruman, 1998), the trends in Fig. 14a show that in Illinois the majority of the fatal crashes happened in urban areas. Both trends had similar patterns -- an overall decline -- with a correlation coefficient of 0.797 with fatalities and VMT fatality rates. The correlation coefficient matrix indicated nearly perfect correlation between the number of fatalities and number of urban and rural crashes with correlation coefficients of 0.950 and 0.942, respectively. Similar relationships were observed with VMT fatality rates where correlation coefficients of 0.914 and 0.883 were found between VMT fatality rate and number of urban and rural fatal crashes, respectively.

When fatal crash rates per VMT were plotted, as in Fig. 14b, it was found that the rates for rural roadways were significantly higher than those for the urban roadways. Similar to trends in the numbers of crashes, trends in VMT rates showed close resemblance with both the land use categories and the total VMT fatality rates. The relative risks indicated that rural roadways had 37% higher exposure than the average and 65% higher exposure than that of the urban roadways.

The statistics on land use did not identify any particular differences except the higher fatality rates for rural roadways.



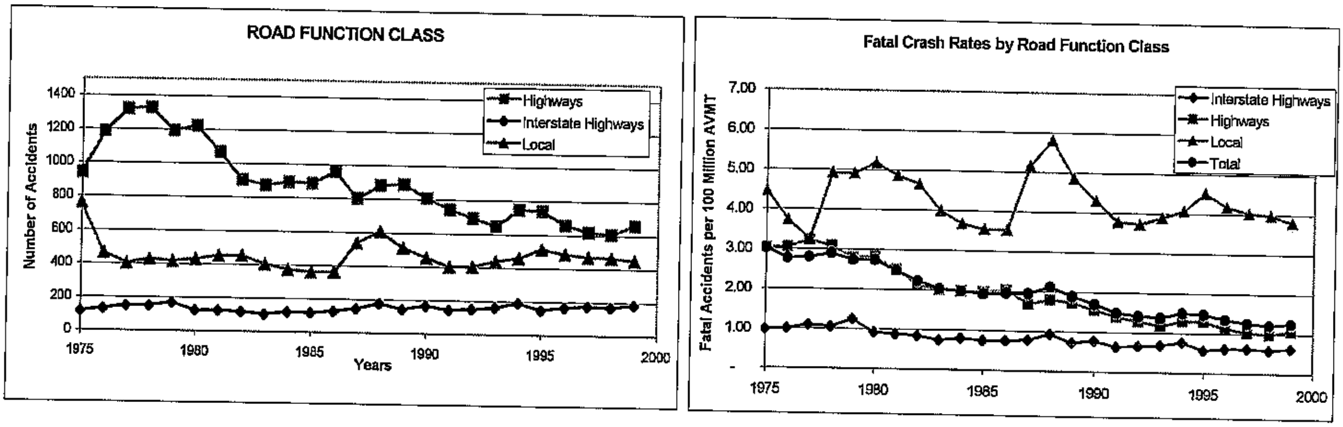


(a) (b)

Fig. 6.14 Trends in Number of Fatal Crashes and Fatal Crash Rates by Land Use

Roadway Functional Class -- Roadway functional class is another variable that makes up the traffic environment. Both the FARS and IDOT Illinois Travel Statistics provided a detailed classification of this factor for later years in the study period. The changes in classification schemes by both sources within the study period limited the level of detail of a classification scheme. Three broad categories were used; namely, (1) Interstate Highways; (2) Other Highways and Arterials; and (3) Local Roads and Streets. This scheme would not allow a clear distinction between highways, arterials, and collectors; therefore, another scheme that distinguishes these categories, incorporating land uses, will be provided later in this section. The trends in the number of fatal crashes by road functional class are plotted in Fig. 6.15(a). As seen in the figure, highways and arterials had the highest number of fatal crashes during the study period. Over 25 years, the number of fatal crashes in this category nearly reduced to half. The fatal crashes in local roads had around 400 fatal crashes annually except for the period from 1987 to 1990. The fatal crashes on Interstates slightly increased over the 25 years. Only the highways and arterials had significant correlation with fatalities and VMT fatality rate (correlation coefficients of 0.913 and 0.927, respectively). When the numbers of fatal crashes were normalized by VMT and plotted against time (see Fig. 6.15b), the VMT fatal crash rate for local streets and roads fluctuated around a steady mean while the rates of the other categories of road function class had a decline. This was due to increases in VMT. Highways and arterials category had the highest decline during the study period. The fatal crash rate reduced to one third of the rate in the mid-1970s. The decline in fatal crash rates on Interstates was around 30%. The total VMT crash rate had significant and positive correlation with Interstates, and highways and arterial categories (correlation coefficient of 0.901 and 0.986, respectively). The relative risks indicate that the local streets and roads category had the highest exposure to fatal crashes with an increasing trend, which nearly doubled (1.47 to 3.05) during the last 25 years. The other categories were less exposed to fatal crashes. For example, the Interstates category averaged at 0.42 and highways and arterials category averaged at 0.95 on the relative risk over the study period. The implications of the statistics and relationships in these discussions can be summarized as follows:

- The number of fatal crashes on highways and arterials had similar trends with total number of fatal crashes. Therefore analysis of crashes in this category might be useful for explaining the variation in total number of fatal crashes and fatalities.
- For explaining the variations in the VMT fatality rate trend, adding Interstate category to highways and arterials might be useful.



(a) (b)

Fig. 6.15 Trends in the Numbers and the Rates of Fatal Crashes by Road Function Class

To further study the trends in the highways and arterials category, road function class was re-categorized as indicated in the FARS analytic reference guide (NHTSA, 1997). The analysis in this section consisted of the years between 1981 and 1999 only. This was due to lack of detail in prior years' data on the road function classification. This classification also incorporated the land use information. The categories were as follows: (1) rural Interstate (2) highways, (3) rural principal arterials, (4) rural minor arterials, (5) rural major collectors, (6) rural minor collectors, (7) rural local roads and streets, (8) urban Interstate highways, (9) urban expressways and freeways, (10) urban principal arterials, (11) urban minor arterials, (12) urban collectors, and (13) urban local roads and streets. Since detailed VMT information was not available until 1993 in IDOT's Illinois Travel Statistics, VMTs were estimated for FARS classification scheme based on the proportion of various road types available through other sources.

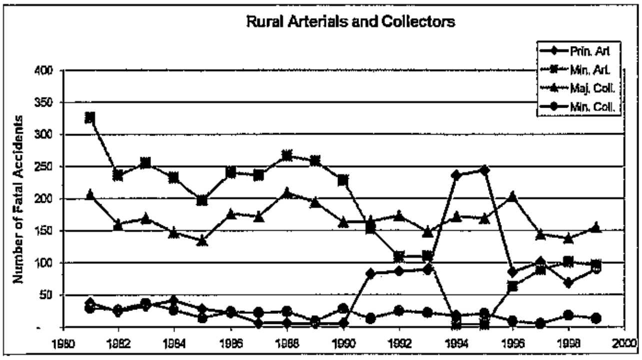
Of the total VMT, 31% was produced on rural roadways. Over the study period, rural VMT increased by 37%. The highest increase in VMT was observed in rural Interstate highways by 99%. Urban roadways produced the remaining 69% of the total VMT in Illinois. Interstate highways principal and minor arterials had close proportions of urban VMT, although the mileage of these categories varied significantly. The urban VMT increased by 64%. The VMT on urban Interstates, and urban expressways increased more than 100%. Table 6.8 summarizes more details on proportions of VMTs, changes in VMTs and centerline mileage by road function class.

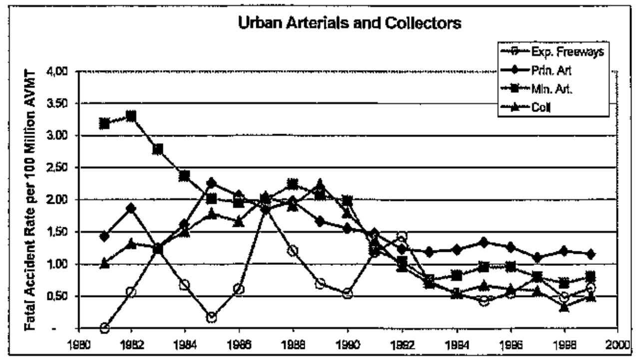
Table 6.8. Percentages of VMT, Road Mileage and Changes in VMT by Road Function Class.

	% Mileage	% VMT	Change in VMT from 1981 to 1999
Rural Interstate Highways	1.1%	8.8%	99.4%
Rural Principal Arterials	1.9%	5.4%	28.2%
Rural Minor Arterials	3.5%	5.9%	20.5%
Rural Major Collectors	10.2%	6.1%	11.9%
Rural Minor Collectors	2.5%	0.6%	-1.7%
Rural Local Roads And Streets	54.8%	4.2%	15.8%
RURAL SUBTOTAL	73.8%	31%	36.9%
Urban Interstate Highways	0.5%	16%	112.2%
Urban Expressways And Freeways	0.1%	0.9%	105.8%
Urban Principal Arterials	1.9%	16.2%	69.8%
Urban Minor Arterials	2.8%	18.9%	44.0%
Urban Collectors	2.7%	8.3%	45.3%
Urban Local Roads And Streets	18.3%	8.8%	34.2%
URBAN SUBTOTAL	26.3%	69.0%	64.3%
SYSTEM TOTAL	100%	100%	55.0%

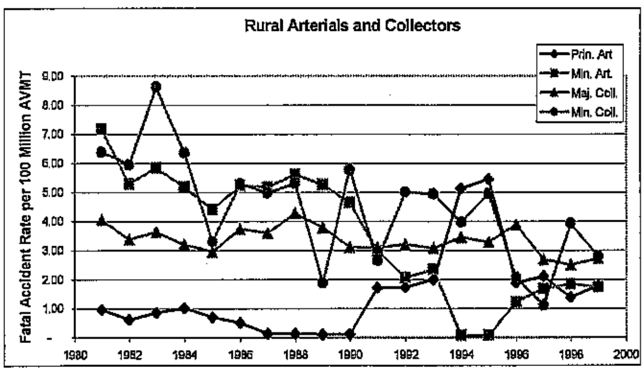
The numbers of fatal crashes on rural and urban arterials and collectors are shown in Figs. 6.16(a) and 6.16(b). In both rural and urban areas, the number of crashes were comparable; however, patterns in the trends displayed differences. In Figure 6.16(a), the only significant relationship was the inverse relationship between principal arterials and minor arterials with correlation coefficient of -0.864. The urban arterials and collectors plot had more categories with similar patterns. While having the highest number of fatal crashes in earlier years, starting from 1988, the rural minor arterials showed a decline in the number of fatal crashes to one third of the number in the beginning of the study period. The sudden increase in the rural principal arterials and sudden drop in the rural minor arterials during 1994-1996 remained unexplained. The number of fatal crashes on rural minor collectors fluctuated around a steady mean and had the highest number of crashes among the rural arterials and collector categories at the end of the study period. The trend in the number of fatal crashes on rural principal arterials was in increase especially after 1990. The fatal crash number in this category reached to the number of rural minor arterials with more than 100% increase. The number of fatal crashes on rural minor collectors declined slightly during the study period, while this category had the lowest number of crashes.

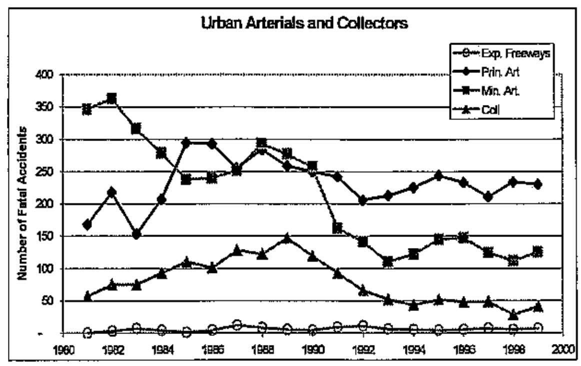
The fatal crash rates in Figure 6.16 (c) indicated that the problem in the rural minor collectors was comparable to the rural minor arterials and rural major collectors. The trends of rate of fatal crashes on both minor arterials and minor collectors were on decline. The decline in minor arterials was much more significant than the minor collectors since not only the number of fatal crashes was decreasing, the VMT was also increasing in the minor arterials while the VMT on rural minor collectors remained unchanged.





(a) (b)





(c) (d)

Fig. 6.16 The Numbers and Rates of Fatal Crashes on Arterials and Collectors in Urban and Rural Areas

The rate for major collectors decreased very slightly. The reason for such a decrease can be attributed to the change in VMT over the study period where the VMT on rural major collectors increased by 12%. The rural principal arterials category had the lowest average rate. However after 1990 rates increased to levels comparable to other categories. The plot in Figure 6.16(c) implied that principal arterials and major and minor collectors were the most problematic classes when VMT based fatal crash rate in rural areas was considered.

The trends of urban expressways and freeways, and principal arterials, had almost identical patterns (0.989 correlation coefficient); whereas, the number of fatal crashes is much higher in the principal arterials category. Similar to rural minor arterials, urban minor arterials had the highest number of fatal crashes for earlier years; and the crash level was reduced to more than half at the end of the study period. After a short fluctuation, urban principal arterials had steep increase starting from 1983 until 1986. After 1986, it had a consistent decline except for 1987-1992 where the trend retained a steady mean until the end of the study period. The urban principal arterials had the highest number of fatal crashes for the period staring from 1991. The urban expressways and freeways always had the lowest number of fatal crashes while their pattern was almost the same with urban principal arterials.

When fatal crash rates based on VMT were calculated and plotted (see Fig. 6.16d), the fatal crash rates on urban arterials and collectors showed lower values (by 2-2.5 times lower) than the rural arterials and collectors' crash rate. The trends in Figure 6.16d displayed similar characteristics as those generally observed. In the first half of the analysis period, there was a decrease for 4-5 years until 1993 followed by a stable period afterwards. The only category that did not follow this pattern was the urban minor arterials which had a decline pattern in the beginning followed by a stationary pattern for 4-5 years starting at 1985. The plot of fatal crash rates on urban arterials and collectors indicated that the category of urban principal arterials had perhaps more severe problems with fatal crashes than did the rest of categories. The average rate after 1993 was 1.21 fatal crashes per 100 million AVMT. This was almost twice as much as the average rate of the remaining categories. The second highest rate was found in urban minor arterials as 0.83 fatal crashes per 100 million AVMT. However, the rate reduced to one fourth of that in the first year of the analysis period. The collectors had the third rank with an average of 0.59 fatal crashes per 100 million AVMT while the reduction in the rate was 50% throughout the analysis period. The fatal crash rate trend for urban expressways and freeways fluctuated significantly prior to 1990 followed by a smooth pattern afterward.

The discussions on the numbers and rates of fatal crashes on arterials and collectors can be summarized as follows:

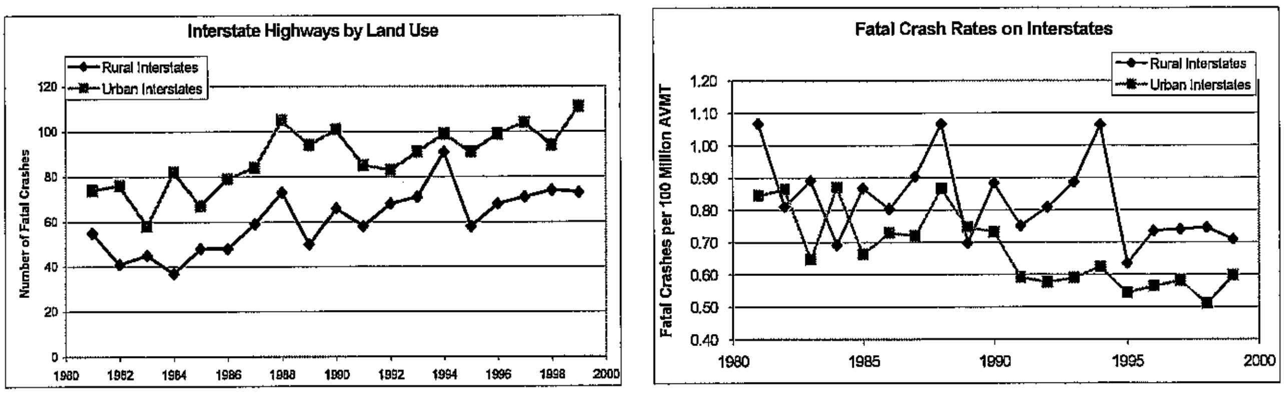
- There exist some similarities in trends of fatal crash rates in both urban and rural arterials and collectors.
- The differences among the rates of different categories tend to diminish over time.
- Rural arterials and collectors have 2.0-2.5 times higher fatal crash rates than do urban arterials and collectors.
- While there is an overall decline in the numbers of fatal crashes in rural arterials and collectors, rural principal arterials had an increasing trend; and the number of fatal crashes on rural major collectors remained constant.
- The average rate of rural minor collector category is found to be the highest; with the rate of fatal crashes on rural principal arterials having an increasing trend as well.
- The decline in the number of fatal crashes on urban principal arterials is not as significant as that in urban minor arterials.
- The trends on the rates of fatal crashes on urban arterials and collectors generally follow a similar pattern.
- On the average, urban principal arterials have the highest number and rate of fatal crashes although both trends are on a decline.

- Both rates of fatal crashes on rural and urban minor arterials have very high correlation coefficients with the rate of fatal crashes on highways and arterials.

The following section discusses the trends in the number and the rates of fatal crashes on Interstate highways. Figure 6.17(a) exhibits the plot of the number of fatal crashes for both rural and urban Interstate highways. The rural Interstate trend is particularly important due to the change in maximum speed limit from 55 to 65 mph in 1987. The plots in Fig. 6.17(a) indicated an overall increasing trend for both rural and urban Interstate highways while urban Interstate highways had more fatal crashes than did the rural Interstate highways throughout the analysis period. The correlation coefficient of 0.720 indicated that the trends were similar. However, neither trends showed any relationship with the trend in the total number of fatal crashes.

The trend in rural Interstates had a unique pattern. Starting from 1984, after several years of increase, there were sudden drops followed by another period of increase. The trend seems to be stabilized after 1996 where the rate of increase was not significant. The change in posted speed limits in rural Interstates seemed to have an immediate adverse effect on the number of fatal crashes. Similar increases were also observed in urban Interstates. The number for 1989 was at the 1986 level and followed an increasing trend until 1994.

The rate of increase in fatal crashes on urban Interstates had slowed down at later years after a short period of pause and declined between 1988-1992. This might be caused by the reduced average traveling speeds and /or variance of travel speed due to increased traffic over the years.



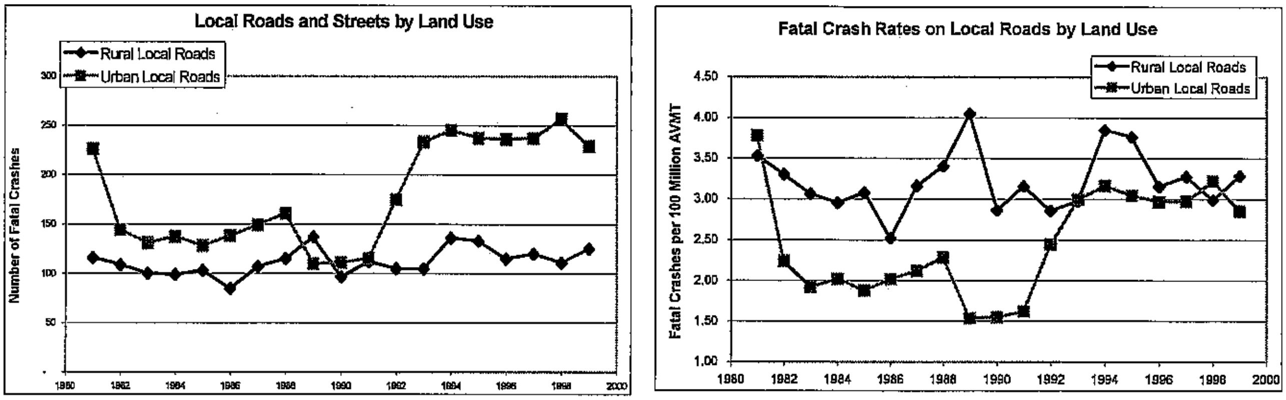
(a) (b)

Fig. 6.17 The Numbers and Rates of Fatal Crashes on Interstate Highways in Urban and Rural Areas

Figure 6.17(b) displays the plots of the fatal crash rates. Consistent with the discussions on land use, rural Interstate highways had higher fatal crash rates than did the urban Interstate highways (although the volume of fatal crashes was higher for urban interstates). Both trends displayed a significant decline in fatal crashes for the entire study period (although the numbers of fatal crashes were increasing). The similarity between the trends was not substantial. While the urban Interstate highway trend resembled the total fatal crash rate trend with a correlation coefficient of 0.878, rural Interstate fatal crash rate had no significant relationship with total fatal crash rate trend.

The rural Interstate fatal crash rate trend fluctuated around a steady mean until 1996 and stabilized after 1996 around a new lower rate. The drops were more significant than the growths due to the constantly increasing VMT over the years. The urban Interstate fatal crash rate fluctuated only until 1988, then declined significantly until 1991 and changed its pace to a very slight decline until the end of the study period. This pattern was also similar to minor arterial trends in both urban and rural areas. Figure 6.18(a) shows the trends in the number of fatal crashes on local road and streets. Both trends had different patterns than did the total number of fatal crashes and the road function class categories.

The number of fatal crashes on rural local roads had a stationary trend throughout the analysis period. In 1989, the number of fatal crashes declined by 32% and remained constant for three years. Both in 1992 and 1993, the number of fatal crashes increased dramatically, (about 100% in two years) and the trend became stable for the rest of the analysis period.



(a) (b)

Fig. 6.18 The Numbers and Rates of Fatal Crashes on Local Roads and Streets in Urban and Rural Areas

Fatal crash rates are plotted in Fig. 6.18(b). It can be seen that the pattern for rural local roads fluctuated around a steady mean, which was significantly higher than the mean rate for urban local roads (3.22 versus 2.45). However, similar to the urban local road fatal crash trend, the urban local road fatal crash rate after 1991 reached to rural local road rate levels. The average relative risks in Table 6.9 show that rural local roads had the third highest exposure rate among all categories. Average relative risks for the first ten years of the study period and the average relative risks after 1993 were also calculated. Table 6.9 shows that the exposure rate for rural local roads moved up two ranks, (i.e., 4th to 2nd) and the exposure rate for urban local roads moved from the sixth rank to fourth.

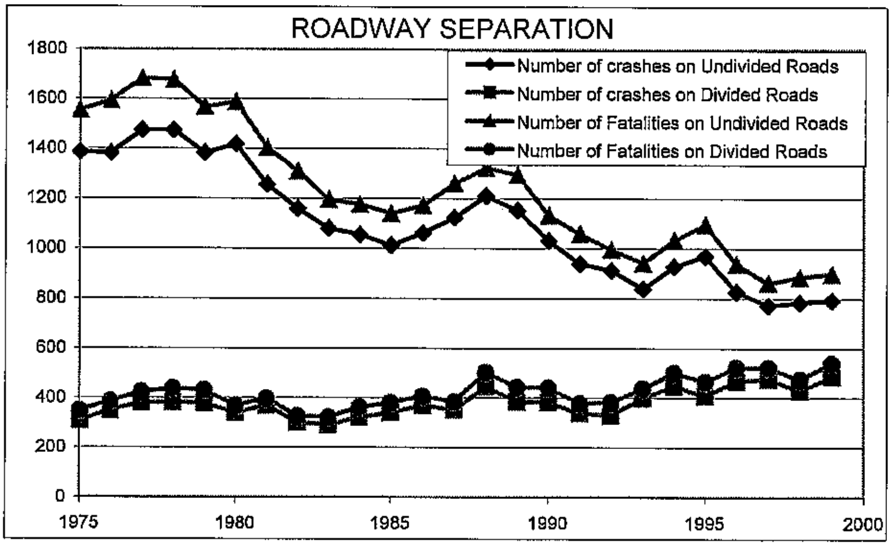


Fig. 6.19 Trends in Number of Crashes and Fatalities by Road Separation

The trend for crashes on undivided roadways had a very similar pattern with the trends of annual fatalities and VMT fatality rate. This was also supported by the correlation coefficients of 0.966 and 0.978, respectively. The divided roadway trend had a slightly increasing pattern and had an insignificant correlation with the annual statistics while had high to moderate correlation (0.756) with the annual VMT trend. Therefore, analysis of crashes on undivided roadways might be more useful for identifying the reasons behind the variation in annual statistics. Since information on VMT and mileage by roadway separation was not available, relevant rates were not produced. The difference between the number of crashes and fatalities on undivided roadways seemed larger than the one for divided roadways.

Lighting Conditions -- Illumination is regarded as an important variable since inexperienced and elderly drivers reportedly have difficulties while driving in poorly lighted areas. The variable is recorded in FARS data throughout the study period. The distinction of dawn and dusk was added in 1980. However, in order to maintain consistency in the statistics, dawn and dusk categories were kept aggregated in a single category. Figure 6.20 presents the plots of the number of fatal crashes and fatalities broken into four different categories of lighting conditions. During the first nine years of the study period, the numbers of crashes under daylight and in the dark are very close. After 1983, the trend of crashes in the dark continued to decline for another two years where the number of daylight crashes climbed. In 1988 both categories had growth but the growth in the crashes in the dark was half of the growth in daylight crashes. In 1990 and 1993, there were declines in the number of crashes in the dark while the daylight crashes slightly increased.

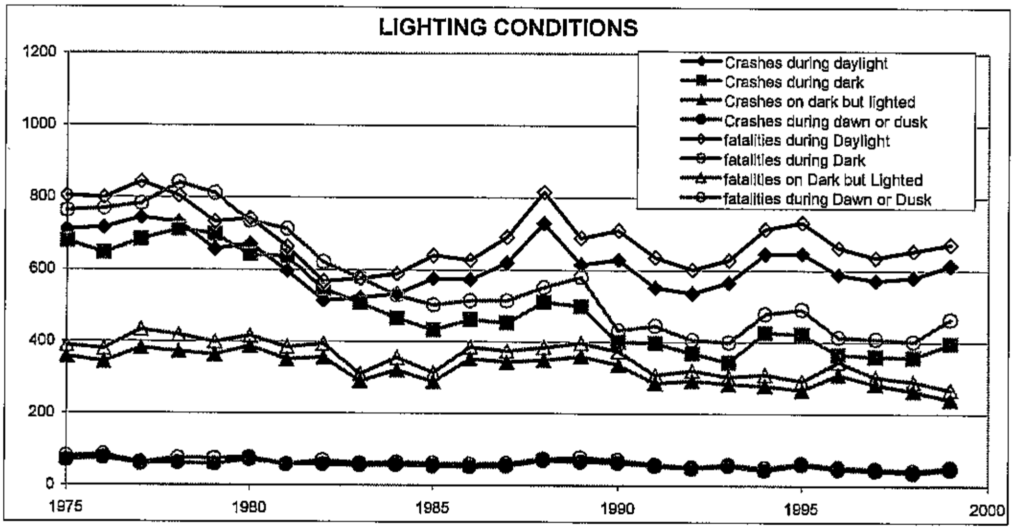


Fig. 6.20 Trends in Number of Crashes and Fatalities by Lighting Conditions

These different events increased the gap between these two categories making the daylight crashes a dominating category. In later years, both categories had a significant decline when compared to the beginning of the analysis period. However, the decline in the crashes in the dark is about four times of the decline in the daylight crashes category. The trend of crashes in the lighted areas had several stationary periods within the study period. The trend stayed steady until 1983 where there was a decline of almost 25%. This decline stayed at this level for two years and then was changed to the same levels as those in 1982 and earlier. In 1991, there was a similar decline; and the number of crashes in this category remained stationary until 1996 in which the number of crashes increased slightly and started to decline gradually afterwards. The category of crashes in dusk or dawn had the lowest number of crashes and had a fluctuating pattern that resulted in approximately 35% decline (from 70 to 45 fatalities/year). All the categories had a strong correlation with the annual fatality and VMT fatality rate trends with correlation coefficients ranging from 0.613 to 0.975. The highest level of similarity is found in the crashes in dark category (correlation coefficients of 0.956 for annual fatalities and 0.975 for VMT fatality rate). Overall, it can be stated that similar factors were effective in the occurrence of fatal crashes in Illinois under different conditions of lighting.

Weather and Pavement Surface Conditions -- These two closely-related factors have important impacts on driving. While rain, snow, and fog degrades visibility, the presence of water, snow, ice, dirt, oil or sand on the surface of the pavement reduces the braking capability due to reduced friction between the road surface and tires. Excessive water, snow or ice may cause hydroplaning and/or skidding resulting in loss of control, rolling over, running off the road, and collision. The effects of adverse weather and surface conditions are expected to be amplified when they are combined with speeding, and alcohol, and lack of experience. Although it is a well-known fact that under adverse weather and visibility conditions drivers tend to reduce their speed (May, 1998; and Kyte and Khatib, 2000) and pay closer attention to driving (Andrey and Knapper, 1993), the volume of crashes is still remarkably high especially when the significant decline in VMT under adverse weather conditions is considered.

The weather and surface condition information were available in FARS throughout the study period. The category of fog was added to the weather variable in 1980. In 1982 two new categories were added; fog and rain, and fog and sleet. The categories of the surface condition variable were consistent throughout the analysis period.

In order to have a manageable number of categories, rain and sleet categories were aggregated under "rain" and all categories involving fog are aggregated under "fog." The number of fatal crashes and fatalities under different weather conditions were plotted in Fig. 6.21 which shows an overwhelming majority of fatal crashes and fatalities under normal weather conditions. The correlation coefficients of 0.988 and 0.906 implied that the trends of fatal crashes and fatalities under normal weather conditions are perfectly similar to the trends of annual fatal crashes and fatalities, respectively. The second largest number of fatal crashes and fatalities occur under rainy weather. The trends of fatal crashes and fatalities showed a slight decline and had moderate levels of similarity between annual statistics (correlation coefficients of 0.507 and 0.681). Numbers of fatal crashes and fatalities under snow are slightly higher than the foggy weather fatal crashes and fatalities while the trends from both categories were stationary trends and had an insignificant correlation with annual statistics.

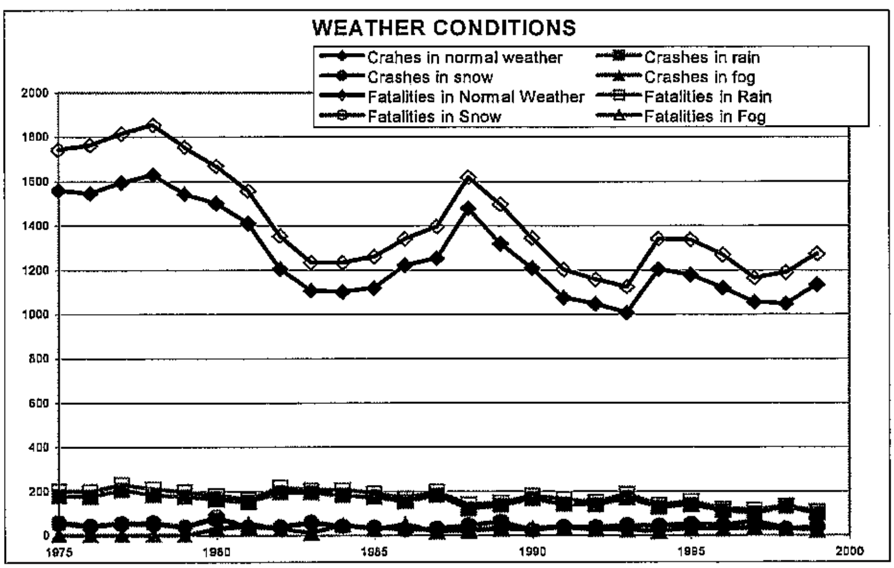


Fig. 6.21 Trends in Number of Crashes and Fatalities by Weather Conditions

Since no estimates of VMT under different weather conditions were available, VMT-based fatality rates were not computed. The daily fatal crash and fatality rates were estimated by dividing the number of fatal crashes and fatalities by the numbers of rainy and snowy days obtained from Illinois State Water Survey. This new variable indicated an estimate of the annual average of daily fatal crashes and fatalities under different weather conditions. The rates produced by this variable were not exact due to possible temporal mismatches between a fatal crash and a weather event. For example, a fatal crash may take place prior to rain or snow on a rainy or snowy day and the weather condition would be recorded as normal. Figure 6.22 shows daily fatal crash and fatality statistics under different weather conditions. Throughout the study period more crashes and fatalities per day occurred in dry days than in rainy and snowy days. The trends for dry days had a declining pattern which was almost identical to the pattern of annual fatalities and VMT fatality rate. The correlation analysis indicated that "dry day fatal crash rate" had correlation coefficients of 0.962 and 0.930 between annual fatalities and VMT based fatality rate, respectively.

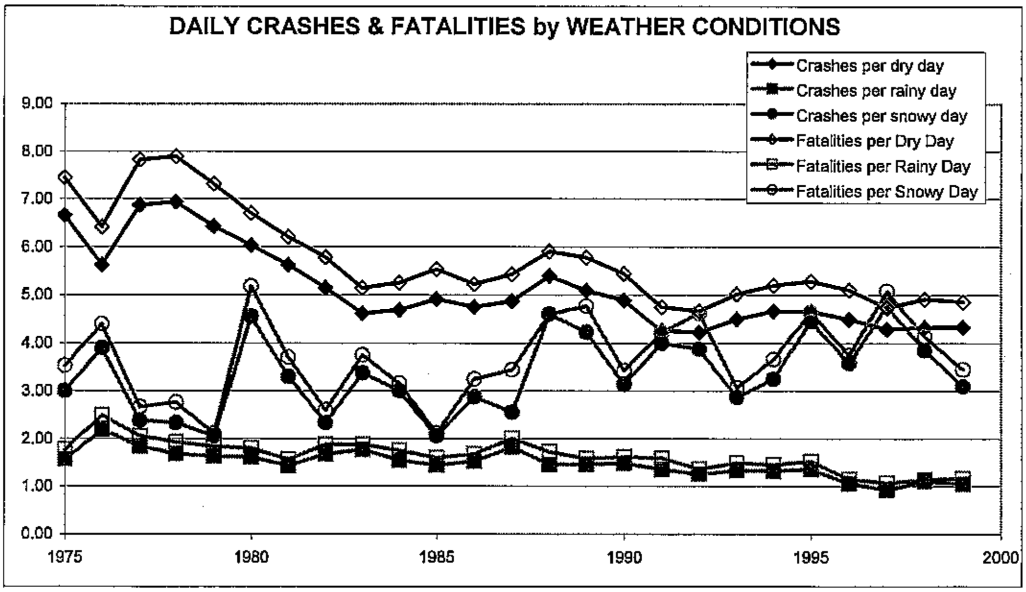


Fig. 6.22 Trends in the Number of Daily Crashes and Fatalities by Weather Conditions

The most unusual trends were found in the snowy day fatal crash and fatalities rates. There was no significant relationship between these trends and annual fatality and VMT fatality rate trends. The trends for snowy days fluctuated around a stationary mean until 1988. Starting from 1988, trends started to vary around a new stationary mean. Overall, there was no change in the number of fatal crashes and fatalities from the beginning and the end of the study period, although there was an important decline for the last two years in the study period. The extent of the problem became more severe when the difference in VMT during a snowy day and a dry day was considered. Although not quantified, the VMT in a snowy day was much less than the VMT in a dry day. This made the snowy days as the highest risk factor for the weather condition category. Therefore, it may be useful to analyze the crashes during snow for developing strategies that may reduce the number of fatal crashes and fatalities.

Rainy day fatal crash and fatality rates had the lowest levels throughout the study period, approximately one fourth of the dry day rates. The trends had a declining pattern with high to moderate levels of correlation (0.687 and 0.733) with the annual fatalities and VMT fatality rate trends, respectively. These indicators implied that rain may not appear as a significant factor in fatal crashes. Although, rain degrades visibility, increases stopping distances and weakens the grip between tires and the pavement surface, the effects might not be as severe as to cause fatal crashes. The reduction of traveling speed, increasing following distance, and paying more attention to the task of driving during rain might be influential on the lower values for rainy day rates. Moreover, the rates were not as alarming as those in snowy days, since decline in VMT during rainy days was not significant as it was in snowy days.

Pavement surface condition is particularly important in fatality analysis since it carries more precise information than does the weather condition if poor surface condition is a factor in a fatal crash. Figure 6.23 presents the trends in fatal crashes and fatalities on different pavement surface conditions.

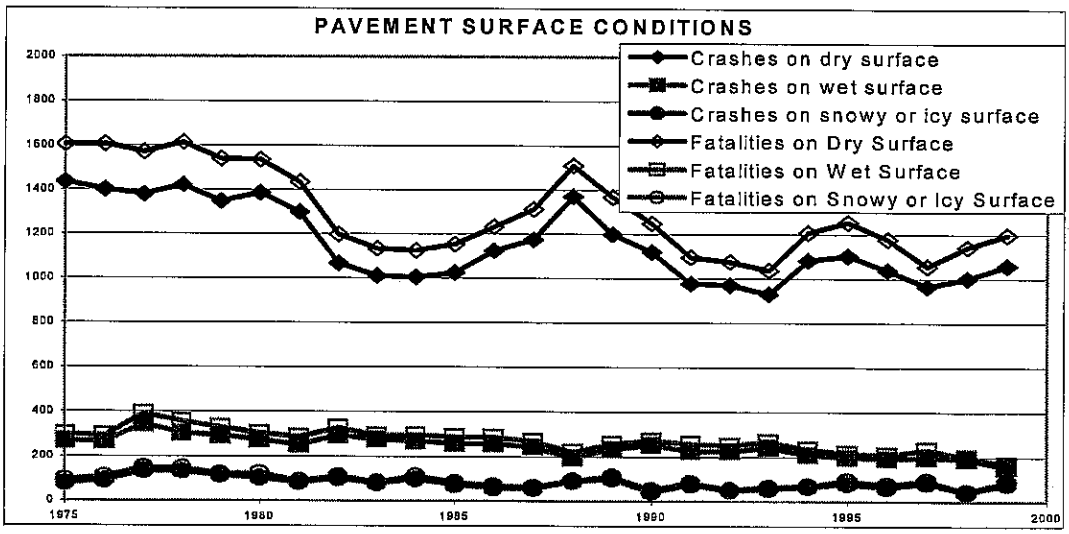


Fig. 6.23 Trends in the Number of Daily Crashes and Fatalities by Pavement Surface Conditions

The patterns in the trends of fatal crashes and fatalities on dry and wet surfaces were almost identical with those of normal and rainy weather conditions. Both trends showed similar characteristics with the annual fatality and VMT fatality rate trends. The number of fatal crashes on dry surfaces had stronger relationship with annual fatality and VMT fatality rate (correlation coefficients = 0.968 and 0.879) than did the number of fatal crashes on wet surfaces (correlation coefficients = 0.662 and 0.795). The trend in the combined snowy and icy surfaces showed a different pattern than did the snowy weather trend. Although similar patterns might be expected between fatal crashes in snowy days and fatal crashes on the combined snowy and icy surfaces, the averages indicated that there were more fatal crashes on the combined snowy and icy roads (n=81) than in snowy days (n=41) and more fatal crashes on wet surfaces (n=245) than in rainy and foggy days (n=182). These implied that snow had prolonged effects due to its physical characteristics and capability to melt and change into ice.

Day of the Week -- Important differences in the characteristics of traffic during weekdays and weekends exist. The amount of recreational trips, probability of consuming alcohol, probability of driving on unfamiliar roads, speed variances are some of the contributing factors that are more likely to increase fatalities during the weekend trips. IDOT (1999) reported that the number of crashes increases significantly during weekends, including on Fridays, while the remaining days of the week have steady figures. FARS reported crashes by weekend and weekday categories. Weekends include Friday evening, starting from 6:00 p.m., and Sunday nights ending 11:59 p.m. The distribution of fatal crashes and fatalities are presented in Fig. 6.24. Trends in both weekday and weekend categories displayed similar patterns with annual fatality and fatality rate statistics. Trends in Fig. 6.24 had correlation coefficients that ranged between 0.876 and 0.976. The majority of fatal crashes and fatalities took place during weekdays; but when daily rates were calculated, it was seen that, on the average, weekend fatal crashes were higher by 46% and fatalities by 49%. During the study period, the weekday fatal crashes declined 26% and weekend fatal crashes by 34%. Although these different rates of decline might be associated with several factors, the more awareness on the hazard of drinking and driving may be a contributing factor.

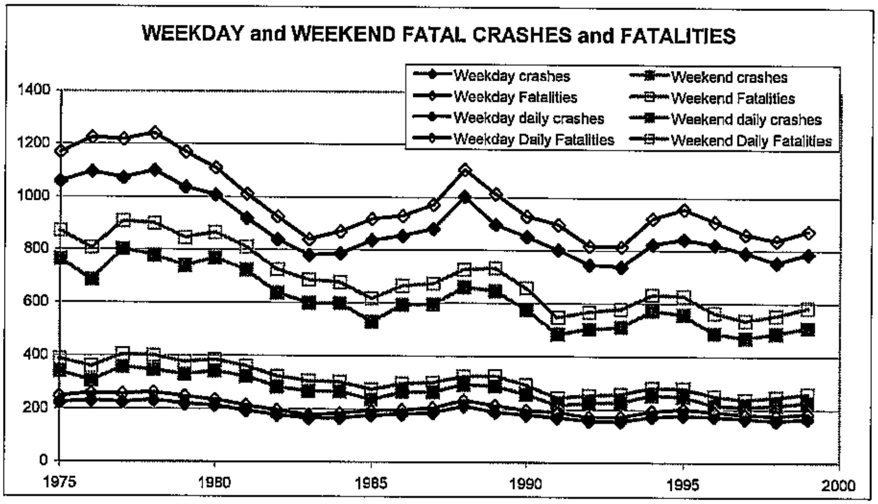


Fig. **6.24** Trends in the Number of Total and Daily Crashes and Fatalities by Weekday/End

Manner of Collision -- Collision type is an important variable since certain types of collisions are more likely to result in fatalities. They may impose greater risks for certain groups of drivers, and as such can be eliminated by taking precautions and improving road safety measures. NHTSA (1993) found that elderly drivers had higher exposure in intersection-related angle type collisions. Head-on or angle-type collisions are expected to impose more fatalities and severe injuries. Roadside improvements, roadway separation, proper signage and markings may also prevent certain types of crashes such as colliding with objects not in transport, sideswipes, head-on, and angle collisions. The information on the manner of collision is recorded consistently in FARS throughout the analysis period. Figure 6.25 shows the trends in different categories of collision types.

The trend for the collision involving stationary objects had a strong supremacy over the rest of the categories. This type of collisions include hits with roadside barriers, median barriers, ditches, embankments, impact attenuators, and other types of fixed objects, parked vehicles and so forth. The trend had a perfect correlation with the annual fatality rate.

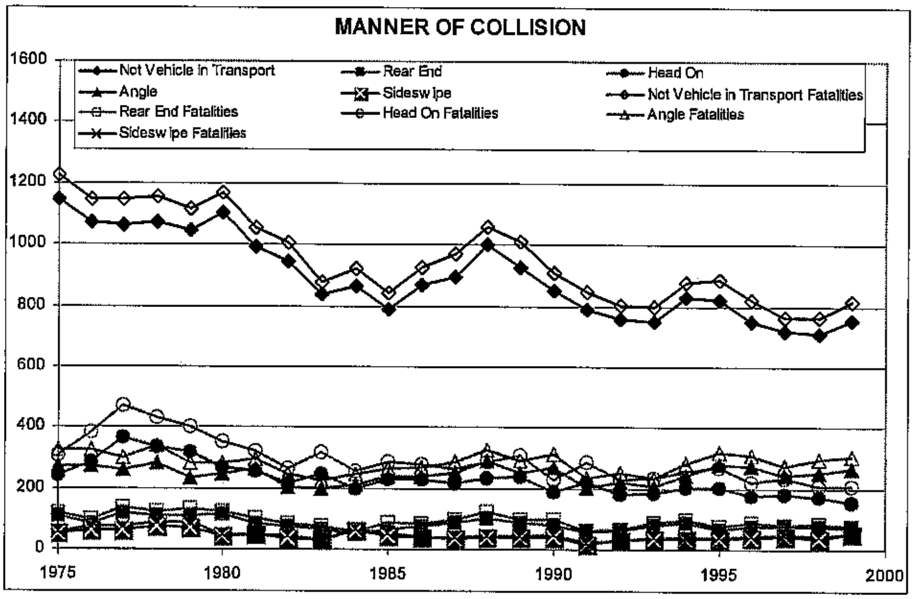


Fig. 6.25 Trends in the Number of Crashes and Fatalities by Collision Type

The second largest category is the angle type collisions by a small margin. On the average, there were 247 crashes that caused 284 fatalities. The trend fluctuated around a stationary mean and had no significant correlation with the annual fatality and fatality rate trends.

The third largest category is the head-on collisions. Although there were more head-on collisions than the angle-collisions in earlier years, the number of fatal crashes and fatalities were reduced to angle collisions levels in early 1980's and started to diminish below the angle-collision levels after 1993. Furthermore, although the head-on collision category is the third in fatal crashes, it had the second largest fatality numbers. On the average, there were 1.27 losses of lives per fatal head-on collision crashes. This rate averaged around 1.07 for collision with an object not in transport category and 1.15 for the remaining categories. The trend had a declining pattern -- the number of fatal crashes and fatalities declined by 36.5% and 32.2%, respectively, during the analysis period. Strong correlation coefficients of 0.867 and 0.858 were found between the number of fatal head-on crashes and annual fatalities and fatality rate trends, respectively.

The rear-end collisions averaged 83 annual fatal crashes with 94 annual fatalities. It had high to moderate levels of correlation with the annual fatality and fatality rate trends (correlation coefficients of 0.850 and 0.727, respectively). Declines of 34% and 37.5% were observed in the number of fatal crashes and fatalities.

Sideswipe collisions averaged 44 annual fatal crashes with 50 annual fatalities. The trend displayed similar characteristics with rear-end trend. It had also high to moderate levels of correlation with annual fatalities and fatality rate trends (correlation coefficients of 0.771 and 0.719, although the correlation between rear-end collisions was only 0.576). When the last year of the analysis period (i.e.1999) was excluded, a decline of 27% was observed at both the number of fatal crashes and the number of fatalities.

Relation to Intersection -- The location of a crash provides for information that can be utilized in developing countermeasures to reduce fatal crashes and fatalities at certain locations. Relation of the crashes to intersection is one of the reported factors in FARS. The variable indicates the location of a fatal crash in relation to an intersection or interchange. Figure 6.26 shows the trends in the categories of relation to intersection variable.

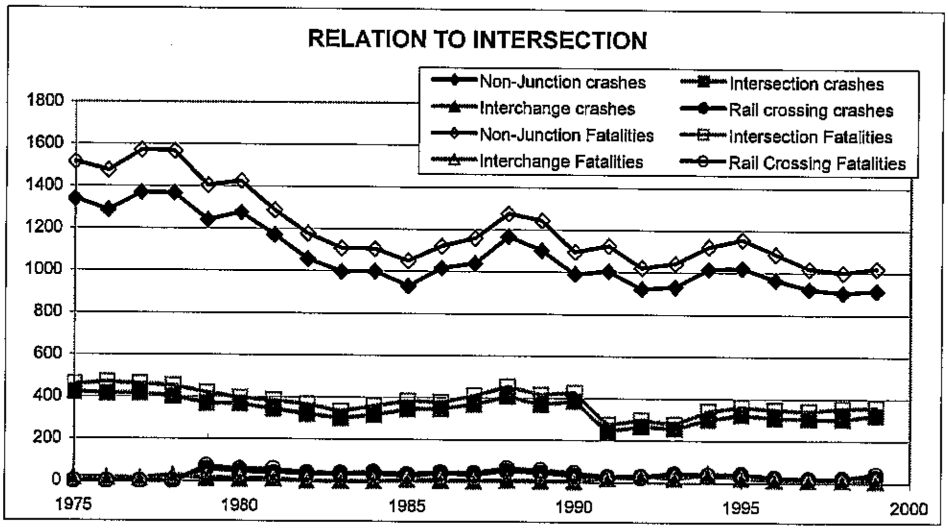


Fig. 6.26 Trends in the Number of Crashes and Fatalities by Relation to Intersection

The majority (72%) of the fatal crashes and fatalities occurred on non-intersection related locations. The number of fatal crashes followed a similar declining pattern with annual fatalities and fatality rate. During the analysis period, the number of fatal crashes and number of fatalities decreased by 31.7% and 32.7%, respectively.

The second largest number of fatal crashes and fatalities (22.7%) took place in the intersection related fatal crashes category. Although the trend in this category showed a high level of similarity (correlation coefficients of 0.852 and 0.766) with the annual fatality and fatality rate trends, fatal crashes and fatalities declined by 22.7%.

The remaining 5% of the total fatal crashes and fatalities were distributed among interchange related, rail crossing and other categories. About 1% of the fatal crashes occurred in interchange related locations. The trends in this category had a unique pattern which exhibited an unanticipated sudden fluctuation which corresponded with the change in the coding of the 'relation to intersection' variable in FARS. Therefore, the patterns in this category will not be further investigated.

The fatal rail crossing crashes were categorized after 1979. Therefore, readings for earlier years are zero in Fig. 6.26. Rail crossings constituted 2.2% of the fatal crashes and 2.5% of the fatalities that took place annually. On the average, 34 fatal crashes and 42 fatalities occurred in this category. The trends had declining patterns with similarities with annual fatalities and fatality rate trends. The number of fatal crashes on rail crossings had correlation coefficients of 0.868 and 0.861 with the annual fatalities and fatality rate trends, respectively. Over the study period, the fatal crashes on rail crossing decreased 52.6% and fatalities by 40.8%. These numbers implied significant reductions and proved the success of programs such as Operation Lifesaver and the establishment of very high fines for violators of rail crossing rules. Although there was a substantial success in the reduction of fatal crashes and fatalities on railway crossings, this category is still the deadliest. The average number of fatalities per crash is 1.26 while the average for the remaining categories is 1.11. This number is more critical than the head-on collisions since there is only a single motorway vehicle involved in these crashes.

6.2 Results of Time Series Analysis (Future Fatality Trends in Illinois)

The selected model for estimating future trends in fatality is ARIMA (1,0,0) (0,1,2) as described in Appendix B. The model was used to generate forecast results with 99 % and 95% confidence, respectively. These results appear in Figs. 6.27 and 6.28. They represent fatality estimates per quarter year.

In Figs. 6.27 and 6.28, three estimates are plotted. The forecast results are provided into the year 2010. Each estimate is the number of fatality per quarter in the given year. The middle graph shows the estimates; whereas, the upper and lower curves are the corresponding confidence intervals. As seen in these figures, the confidence intervals are widening as more estimates into distant future years are sought. In general, the fatality data shows a downward trend into future years. This is assuming that no dramatic change in factors that affect fatalities would occur in the future. Introduction of any new law affecting the driving habits of various age groups in the State can also trigger changes in future fatality rates. Also, it is emphasized that the future estimates, as depicted in Figs. 6.27 and 6.28, are based on the IDOT data received for the period starting from 1975. No reliable data prior to 1975 was available. However, the 25-year data range used in the study is considered to represent a sufficiently long period of time to produce reliable forecast estimates for fatalities in Illinois.

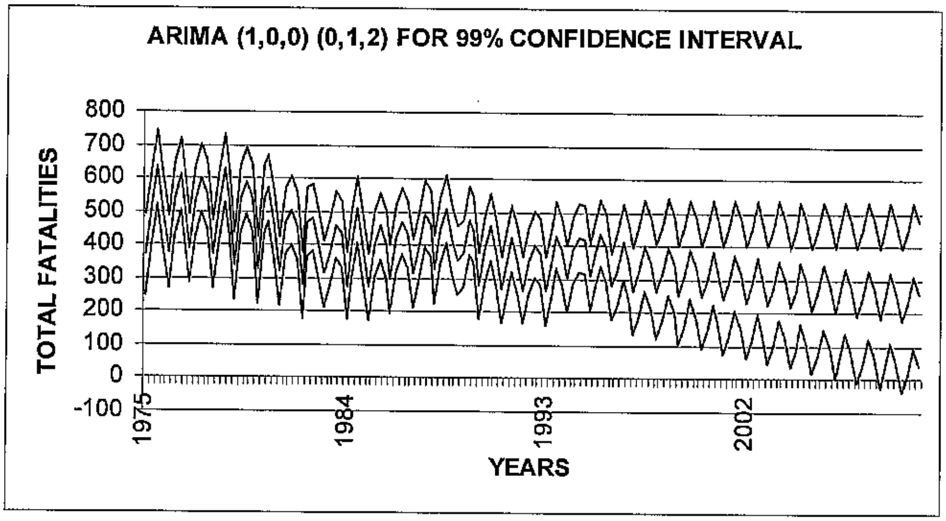


Fig. 6.27 Forecast fatalities based on 99% Confidence

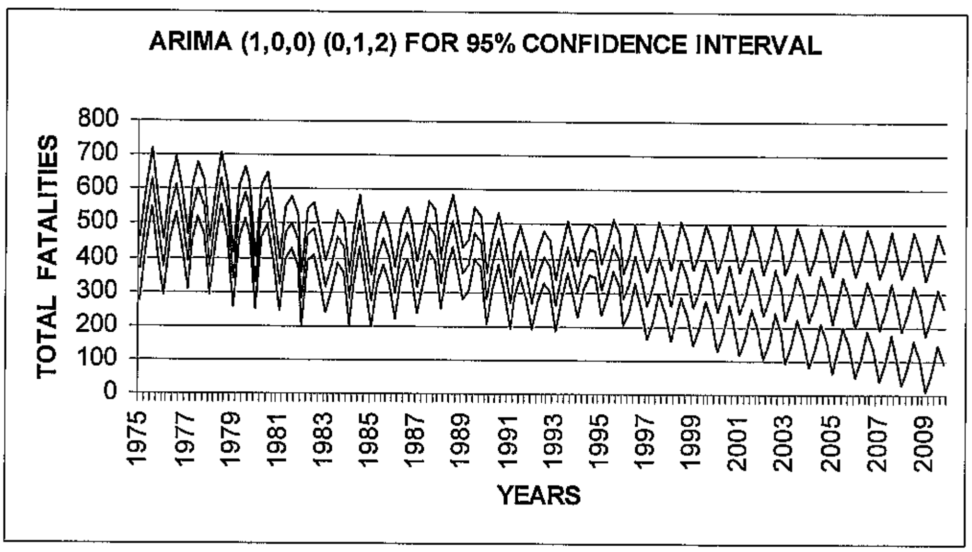


Fig. 6.28 Forecast fatalities based on 95% Confidence

As it is evident from the future estimates, motor vehicle fatalities are on decline in Illinois for the period up to the year 2010. The average reported fatalities in Illinois are about 1675 per year in the period 1975-1999. This average has been reduced in more recent years. Further analysis of the results indicates that over future years, the average should stabilize at around 1240 fatalities per year. This is based on an upper bound for future trends at 99% confidence level and about ±30% variation in short term estimates and 55% variation in long-term estimates. It is emphasized that the future estimates obtained in this study are based on current data. The variation in the results are rather large especially when estimates in distant future years are sought. This is due to the uncertainties in the data and due to the estimates obtained for the future. It is also emphasized that any change in travel patterns, VMT variation, introduction of new laws, changes in distribution of certain types of vehicles, etc. may influence future fatality trends in Illinois.

6.3 Multivariate Analysis (Regression and Correlation Analyses)

6.3.1 Correlation and Regression Analysis at County Level

The purpose of this analysis is to gain an insight into regional trends in fatalities. Specifically, we wish to determine whether the dependence of fatalities on various factors is consistent across the State. The county-level analysis was conducted for a 10-year period (1990 to 1999). The reason behind selecting this time period was the fact that the data on population, VMT, and other factors can only be obtained for this period, even though the fatality database covers the 1975-1999 period. For the purpose of this analysis, the entire State is divided into 29 regions. Each region involves either only one county or a cluster of counties. Less populated counties are in the latter category of regions; whereas, counties with high population concentrations form regions with only one county in them. The 29 regions selected provided for a reasonable pool of sample data in terms of variability in both fatality and the corresponding influencing factors (such as population, VMT, etc.). Table 6.10 summarizes the distribution of counties in the 29 regions. Figure 6.29 shows the geographical locations of the 29 regions across the State. The software: "Statistical Package for Social Science (SPSS)" was used for regression and correlation analyses.

Table 6.10 Regional Distribution of Counties within Each Selected Region.

Region	Counties within the Region
1	Madison + Saint Claire
2	Clinton + Marion + Jefferson + Franklin
3	Jackson + Willamson
4	Pope + Hardin + Saline + Gallatin
5	Union + Johnson + Alexander + Pulaski + Massic
6	Monroe + Randolph + Perry + Washington
7	Champaign
8	Boone + DeKalb + Ogle + Lee
9	LaSalle
10	Livingston + Grundy + Kendall
11	Peroria + Tazewell + McLean
12	Jasper + Crawford + Richland + Lawrence + Wabash
13	Clay + Wayne + Edwards + Hamilton + White
14	Sangamon + Macon
15	Douglas + Moultrie + Piatt + Dewitt + logan + Mason + Menard + Cass + Morgan + Schuyler + Brown
16	Edgar + Clark + coles + Cumberland + Shelby + Effingham + Fayette + Bond
17	Pike + Scott + Greene + Cohoun + Jersey + Macoupin + Montgomery + Christian
18	Rock Island + Whiteside + Henry + Knox
19	Adams + Hancock + McDonough + Fulton
20	Mercer + Henderson + Waren
21	Bureau + Stark + Putnam + Marshall + Woodford
22	Jo Daviess + Stephenson + Carroll
23	Winnebago
24	Kane + McHenry
25	Lake
26	DuPage
27	Will
28	Cook
29	Vermilion + Ford + Iroquois + Kankakee

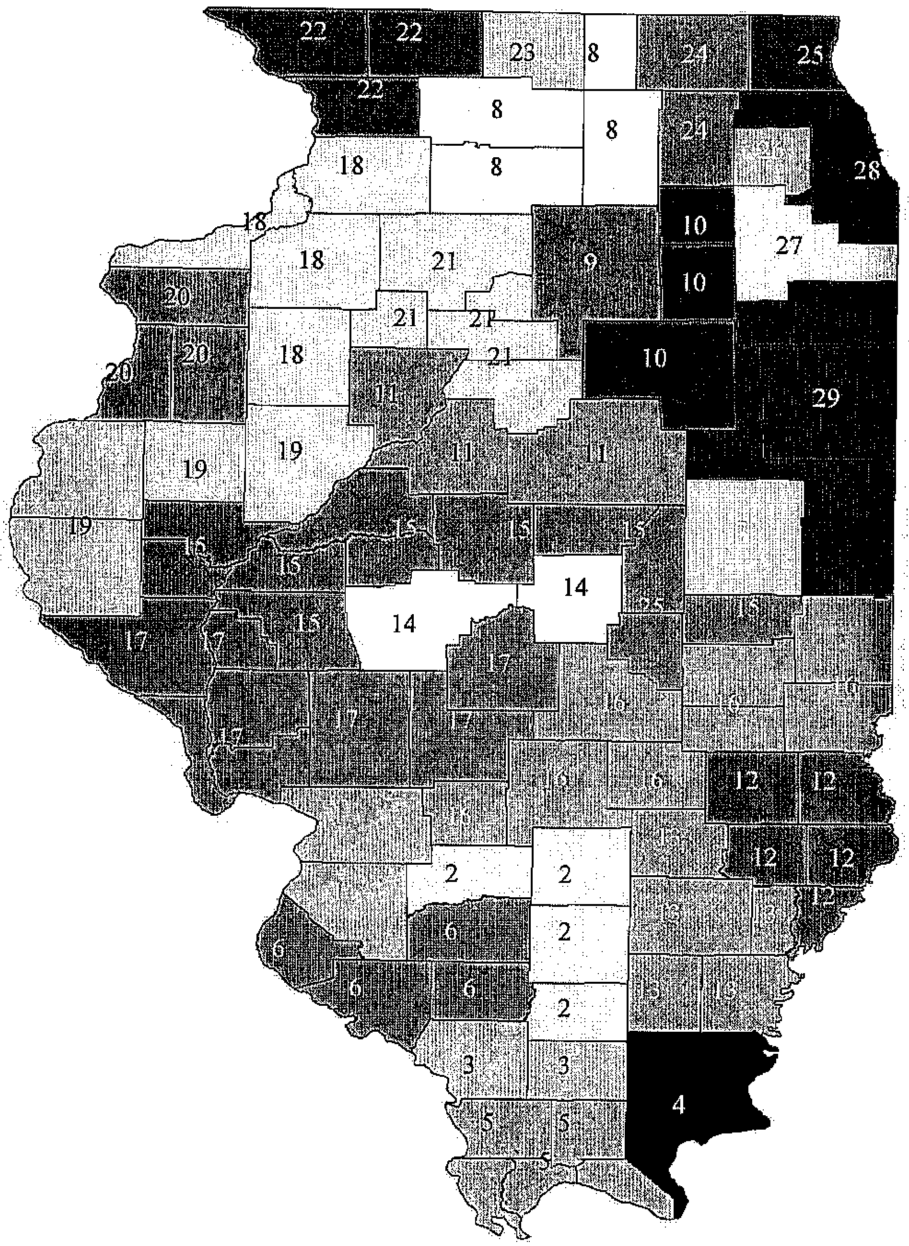


Fig. 6.29 Geographical Distribution of Regions Used in Analysis

The dependent variable for the regression analysis was the fatality rate (fatality rate was obtained as the ratio of the number of fatalities to the VMT). Table 6.11 provides a listing of independent variables that were used in the study. Several rounds of correlation analyses were conducted looking into any correlation between the fatality rate and individual independent variables for the duration of the study period. In most cases, no conclusive results were observed to indicate that there are many factors with dominating effect on fatalities in various regions in Illinois. Only a handful of factors (see Table 6.11) have regional differences in affecting fatality rates across the State.

Table 6.11 Independent Variables and Their Influence on Fatality Rate.

Variable	Influence on Fatality Rate
Average number of snowy day	High
Average number of wet days	High
Number of alcohol-positive drivers Adjusted by VMT	High
Ratio of 16-20-year-old population To total driving population	Moderate

The selection of the variables in Table 6.11 is based on the factor groups identified and listed in Section 2 and availability of data. Furthermore, the regression analysis necessitated use of variables for which measurable values can be obtained through available data.

The dependence of fatality rate on the variables listed in Table 6.11 was investigated through a correlation matrix which was established for all variables. Sample size n was 29 and reflected the regions identified and reported in Table 6.10. The correlation analyses were repeated for every year in the 1990-1999 period. The results indicated that only the variables listed in Table 6.11 had a significant correlation with the fatality rates consistently over the entire period of the study.

It is noted that the fatalities in the 16-20-year-old age group constituted a significant portion of the total fatalities. The dependence of the fatality rate on this variable was also stressed in Section 6.1. However, the regression of fatality rate on this variable indicates that this dependence is more at the State level rather than at the local level. Generally, there is no evidence that certain regions in the State have substantially different fatality rates than the others, when considering the 16-20-year age group as an indicator of fatality rate. Excluding this variable from regression analysis, the analysis of the dependence of fatality rate on the other three variables (i.e., the alcohol-positive drivers, average number of snowy days and average number of wet days) resulted in statistics provided in Table 6.12. As seen in Table 6.12, for the years where the data was tested, the ratio of alcohol-positive drivers to VMT and the average number of snowy days are the two factors that show significant regional effects on the fatality rate.

Table 6.12 R^2 Values and Significance Levels (County Level Analysis).

Year	R Square Value	Sig. Level for alcohol-positive drivers	Sig. Level for snowy days*
1990	0.534	0.001	0.021
1991	0.7	<0.001	
1992	0.619	<0.001	0.008
1993	0.622	<0.001	0.066
1994	0.339	0.025	
1995	0.481	<0.001	
1996	0.462	0.001	0.104
1997	0.381	0.004	
1998	0.471	0.001	
1999	0.347	0.004	

* Blank cells indicate that no reliable data was available

A more refined analysis at the regional level was also conducted to provide an insight into the differences inherent in fatality rates and any differences in population and/or other factors that may be more prevalent at the regional level. The following presents the findings:

1. The fatality rate was the lowest in Champaign, Sangamon, Macon, and Cook and surrounding counties. These counties also had the lowest relative population who consumes alcoholic beverages. The low fatality rate can be attributed with combined efforts by the State, counties and municipal law enforcement agencies against alcohol consumption and driving.

2. The fatality rate was high in several southern counties including Hamilton, Franklin, Williamson, Saline, Pulaski, Alexander counties and several north central counties including Woodford, Livingston, Grundy and Bureau counties. Further investigations showed a higher per capita concentration of recreation areas especially in the southern counties. This may be one of the factors resulting in high fatality rates in southern counties.

3. Fatality rates in Madison and St. Clair counties were relatively high as compared with the rate for the Cook County. These two counties are near St. Louis and are among the counties with the lowest average income in the State.

6.3.2 Correlation and Regression Analyses at the State Level

The State-level correlation and regression analyses were intended to identify how different factors simultaneously affect fatalities in Illinois. No regional differences among factors were considered. The analysis was performed for 22 sample data covering the 1975-1996 period. Only variables for which data was available were used in the analysis. Again, the dependent variable was taken as the fatality rate (number of fatalities divided by VMT). However, for the State-level analysis, this variable represents the data for the entire State. The independent variables are those listed in Table 6.13. With the exception of the number of snowy and rainy days, each variable is either adjusted based on the total driving population or by the VMT as indicated.

Table 6.13 Independent Variables Used in State Level Analysis.

Designation	Variable
Age1	Number of persons in 16-20-year age group involved in crashes divided by total driving population
Age2	Number of persons in 21-34-year age group involved in crashes divided by total driving population
Age3	Number of persons in 35-54-year age group involved in crashes divided by total driving population
Age4	Number of persons in 55-64-year age group involved in crashes divided by total driving population
Age5	Number of persons in 65-year-and-older age group involved in crashes divided by total driving population
BAC	Number of alcohol-positive drivers involved in crashes divided by the VMT
Speed	Number of drivers involved in crashes at speeds over the posted speed divided by the VMT
P-Speed	Number of drivers involved in crashes at the posted speed divided by the VMT
Weekend	Number of persons involved in weekend crashes divided by total driving population
Weekday	Number of persons involved in weekday crashes divided by total driving population
Urban	Number of crashes on urban roads divided by the average urban VMT
Rural	Number of crashes on rural roads divided by the average rural VMT
Passenger	Number of crashes involving passenger cars divided by the average passenger car VMT
Truck	Number of crashes involving trucks divided by the average truck VMT
Passenger	Number of crashes involving busses divided by the average bus VMT
Snow	Average number of snowy days
Rain	Average number of rainy days

With a few exceptions, the data were mostly available for the entire 1975-1996 period. In some years, certain data was missing. The missing data were a very small fraction of the available data and were as supplemented from other sources (see Section 4 for sources of data).

The purpose of the multi-variable regression analysis at the State-level was to identify the main indicators of motor-vehicle fatalities within each factor group as listed in Section 2. For example in different age groups, the analysis was intended to determine the particular age group which may have contributed significantly to fatalities consistently over the entire study period. First, a comprehensive correlation analysis was conducted considering all variables in Table 6.13. Second, those variables that had large correlation coefficients with the fatality rate were used in a multi-variable regression analysis to determine whether as a group they affect fatalities at the

State level. These analyses further complemented the findings based on the descriptive analysis reported in Section 6.1.

Driver Factors -- Within this group, age, BAC level, speeding, weekend/weekday driving and night/day driving were investigated. The BAC factor showed the most significant effect on fatalities. Thus within this group, BAC was used in the multi-variable regression analysis (as described later). The following presents findings on all factors within the driver factor group.

Age: Within different age groups, the proportion of 16-20-year persons in the total driving population had the highest correlation coefficient with the fatality rate (r=0.957). The population in the 35-54-year age group had moderate correlation with fatality rate (r=0.574). This correlation was however the lowest among all drivers younger than 65 years. In general, considering various age groups, the 16-20-year population appears to be the major contributor to fatalities. This confirms with the results of the descriptive analysis. However, it is emphasized that the significance of this factor on fatalities is pronounced only when the factor is compared with other age groups; and within the driver-related factors, BAC level still appears to be a more significant indicator of fatalities (as described later in this section).

The age group at 65 years and older shows an inconsistent result from year to year. In general, the total number of crashes involving this group is low. However, it is noted that this group drives less than the others do and have driving habits that may be different from those of other age groups. In order to obtain a more conclusive result on the significance of this age group on fatality rate, perhaps a separate analysis will be needed to exclusively look into the driving habits, average travel time and causes of fatal crashes involving older drivers. It is also desirable to further divide this group into two; namely those between 65 to 84; and those 85 years and older. The descriptive analysis resulted in a significant relation between the fatality rate and crashes involving drivers in the latter group.

BAC level: Alcohol involvement is a major indicator in fatal crashes and fatalities. Among all factors studied, this variable had the highest correlation with fatality rate (r=0.984). This finding, along with the result of the descriptive analysis reported in Section 6.1, is consistent with national trends. This factor was reported to be more prevalent in fatal crashes than in personal injury and property damage crashes. For example in 1996, there were 17,126 alcohol-related fatalities – about 40.9 percent of the total traffic fatalities for the year (NHTSA 1996).

Speeding: The correlation analysis included crashes with speeding drivers as well as those involving drivers that drive at the posted speed. As expected, those that involve speeding drivers have a much higher correlation with the fatality rate. However, it is noted that, the relationship between vehicle speed and crash severity is unequivocal. As it was also reported in Section 5, the studies on speeding and crashes have not produced consistent results. For example, Solomon (1974) examined the relationship between travel speed and the severity of injuries sustained in a crash, and reported an increase in crash severity with increasing vehicle speed on rural roads.

Weekend / Weekdays: In general, the risk of crashes and injury is greater during weekend because of increased travel and recreational activities. Statistics show that almost twice as many young people were involved in fatal crashes per day in weekend crashes as compared with weekday crashes. However, considering the overall numbers, there are more fatalities during weekdays. When fatality rates are considered, the rate is higher for weekend crashes as compared with weekday crashes. Despite of this, the correlation indicated that the fatality rate is equally depended on both weekday and weekend crashes. And as such, comparing the two factors, neither one can be used as a stronger indicator of fatalities.

Night / Day: Both daytime and nighttime crashes had high correlation with the fatality rate. The analysis however resulted in a slightly higher coefficient for the nighttime factor. If the fatality rate is adjusted based on the nighttime VMT (rather than the total VMT), the rate for nighttime fatalities will be higher than that for the daytime rate. This is consistent with the published data and descriptive analysis. Crash statistics show that more than 50 percent of fatal crashes occur during dark hours. Since only 25 percent of travels occur during the same period, the night-time fatality rate is about three times higher than the daytime fatality rate (Griffith, 1994), if the rate based on the night VMT is computed. Thus, the nighttime factor can be considered as an indicator of fatalities.

Environmental Factors -- Within this group, urban versus rural crashes and weather were considered.

Urban / Rural: The correlation analysis resulted in a moderate correlation between fatality rate and crashes occurring on urban or rural highways; with correlation coefficient between fatality rate and urban crash factor being higher. Generally, more vehicles are involved in crashes on rural highways (56% of all fatal crashes in 1996 were on rural highways). However, VMTs for these two types of highways are different and as such affect the fatality rate outcome. The multi-variable correlation analysis indicated that the fatality rate depended equally on both urban and rural crashes with a slightly larger correlation between fatality rate and the urban crash rate. As it is evident from the descriptive analysis, the prevalence of other factors contributes more to the difference in fatality rates of urban versus rural highways. Among these factors are speed, patrol control, driver's fatigue and the emergency medical service accessibility. To better understand the significance of urban versus rural highway crashes on fatalities, a separate analysis will be needed to exclusively look into the role of other factors that may influence the crash rates in urban versus rural highways. Using the Illinois data, the urban crash rate resulted in a larger correlation coefficient with the fatality rate; and as such, it was used in the multi-variable regression analysis.

Weather: The correlation analysis shows that at the State level there is a moderate correlation between fatality rates and the average number of snowy days. The number of rainy days had no significant effect on the fatality rate. The average number of snowy days is certainly an indicator of fatalities, however, more at the county rather than at the State level.

Vehicle Factors -- Within this factor, vehicle types were investigated. The correlation analysis resulted in a high correlation between the fatality rate and the number of passenger cars involved in crashes. Among various vehicle types, the passenger vehicle is therefore regarded as an important indicator of fatal crashes. Excluding motor cycles involved in crashes, this finding is consistent with the descriptive analysis presented in Section 6.1. Large vehicles are more stable and provide better protection for their own occupants than small cars do. However, larger vehicles present a grater risk to other road users. This seems to have contributed to the higher correlation obtained between fatality rate and crashes involving passenger cars in this analysis.

6.4 Remarks

The correlation analysis at the State level resulted in the following actors as indicators of fatalities and fatality rate in Illinois.

- Age group in the 16-20-year category
- Alcohol-positive drivers
- Speeding drivers
- Night drivers
- Snowy days
- Passenger cars
- Rate of crashes on urban versus rural roadways

A multi-variable regression analysis further showed a consistent dependence of fatality rates on the alcohol-positive drivers (as reflected in the BAC level), average number of snowy days and rate of crashes on urban roadways. These are considered to be the major indicators of fatalities in Illinois. Using these three variables in the multi-variable regression analysis, the values of the parameters of the regression equation (see Eq. 3.1) were computed as summarized in Table 6.14.

Table 6.14 Parameters of the Multi-variable Regression Equation (State-Level Analysis).

Parameter	Designation in Eq. 3.1	Value	Standard error
Constant	a	3.25E-07	0
Snowy days	b_1	6.24E-08	0
BAC level	b_2	1.627	0.055
Urban crash rate	b_3	0.20	0.028

Table 6.15 summarizes descriptive statistics for the dependent variable (fatality rate) and independent variables (snowy days, BAC level and Urban crashes).

Table 6.15 Descriptive Statistics of Dependent and Independent Variables in State-Level Regression Analysis.

Variable*	Mean	Standard Deviation	Coeff of Variation
Fatality Rate	8.94E-06	2.928E-06	0.33
Snowy days	13.0	4.2	0.32
BAC level	4.10E-06	1.50E-06	0.36
Urban crash rate	5.96E-06	2.60E-06	0.46

* See Table 6.13 for description of these variables and their units.

The influence of BAC level on fatality rate is especially noted here. The significance of this factor as an indicator of fatality rates at the State level was also confirmed through descriptive analysis. The other factors listed in Tables 6.14 and 6.15 as well as younger drivers (among different age groups) are also considered as significant indicators of fatalities at the State level. Efforts by the State to control these factors would have a positive impact on reducing fatalities. At the local and regional level, the alcohol-positive drivers and the number of snowy days are also noted as indicators of fatality rates. A comparison between regions with high fatality rate to those with lower rates point to the effectiveness of specific measures that reduce fatalities. Among these measures, better law enforcement, better access to the emergency medical services (which may be the case in Urban areas) and programs aimed at educating the public on the consequences of drinking and driving can be mentioned as discussed in Section 7.

7.0 DISCUSSION OF THE RESULTS AND LIMITATIONS OF THE STUDY

This section presents an overview of results obtained from analyses conducted on fatality data. Two types of correlation analyses were conducted. In one analysis the objective was to look into regional effects of various factors on fatalities in Illinois. The second type of analysis was on State-wide and national fatality trend data. It was conducted to determine whether changes occurring to various factors overtime affect fatality rates with the same pace. At the State level, also a time series analysis was conducted to identify how the fatality rate may change into the future. Furthermore, a time series analysis was conducted to estimate future trends in fatalities at the State level.

7.1 Fatality Analysis at the County Level

The results of multi-variable correlation and regression analyses were reported in Section 6. This analysis was primarily conducted for the purpose of identifying whether certain counties in Illinois show specific fatality trends that may be alluded to the prevalence of contributing factors specific to a region or county. Factor groups considered included the four categories of (1) driver; (2) vehicle; (3) highway/environment; and (4) demographics. Among these, more specific attention was placed on identifying any driving habit variations, level of area traffic law enforcement, alcohol consumption, volume of traffic, weather conditions, population and age distributions as indicators of fatalities.

For the county-level analysis, the State was divided into 29 regions. Each region consists of one or more counties. The selection of these regions was based on populations and proximity of counties to one another. The following presents a discussion on the findings.

Driver factors -- In this group, BAC level, speed, seatbelt use and fatigue were listed as those factors that can directly be controlled to reduce fatalities; whereas, age, gender, driving hours, day/night driving and weekend/weekday driving are those that may not be directly controlled. In most part, the analysis did not provide any conclusive results to point to one or more factors that may impose regional differences in affecting fatalities in Illinois. The alcohol consumption was perhaps the only factor that indicated a rather significant regional difference and correlation with higher fatalities in areas where per capita alcohol consumption is higher than those in other areas. The information on regional differences in alcohol consumption was compiled through data on liquor taxes and the number of employees in drinking establishments as well as the data on the number of crashes involving persons with any BAC levels in their systems. It is emphasized that the finding on the effect of alcohol is not conclusive. The prevalence of other factors such as the level of traffic law enforcement, better education and awareness on adverse effects of alcohol consumption, and social/economical status may influence fatality rates in certain regions where per capita alcohol consumption is higher than in other areas in the State. The analysis indicated a significant correlation between fatalities and alcohol consumption in less populated areas, regions with lower per capita income and especially in southern Illinois counties where there is a rather large concentration of recreational areas. More populated areas such as Cook County and counties in the Chicago area have lower per capita traffic fatalities. With consumption of alcohol in these areas being comparable with other regions, the lower fatality rates can be attributed to the fact that a large percentage of population in this area use public transportation. Furthermore, better education and awareness of public on drinking-and-driving hazards and better law enforcement may be other contributing factors. Also, in Champaign County, there is a lower fatality rate with a high concentration of younger age groups. The low rate can again be the result of similar programs.

On other factors such as speeding and use of seatbelt, age and driving hours, the analysis did not support any significant variations across the State. Any program (such as more stringent crackdown on speeding drivers, laws to curb driving hours for teenagers) implemented at the State level should indirectly influence these factors in abating fatality rates. Driver's fatigue can especially benefit from any education and awareness program. Data indicates that one out of every five drivers experience sleep behind the wheels at one time or another (Johnson, 1998). This contributes to thousands of fatalities per year at the national level.

Vehicle Factors -- Vehicle factors that can be controlled include safety equipment, car defects and airbag deployment. Those that cannot be directly controlled are vehicle type and size. With the exception of the vehicle type, information on these variables was not available in a format suitable for a common statistical correlation analysis. The data on crashes involving different vehicle types reveals that the type of vehicle is an indicator of fatalities at the State level. The descriptive analysis of data on the vehicle type did not reveal any evidence that this factor had any regional variations across the State.

Highway/Environment Factors -- In this category, factors that can be controlled were posted speed, roadside safety devices, geometric design of highway, median and feeder ramps. Those that cannot be directly controlled were weather and urban/rural highway use. Among these factors, only weather showed significant regional differences in affecting fatalities. The effect of weather was considered by using the average number of wet days experienced by various regions in Illinois. Specifically, the numbers of snowy and icy days contribute significantly to fatality rates. These are especially critical in rural roadways where less frequent snow removal and deicing material applications are implemented. Of course, the number of wet days cannot be controlled; however, measures such as road closing, more frequent snow and ice removal, public education on tips for driving in bad weather conditions and public broadcast informing drivers of road closing may help reduce fatalities.

Demographics -- Under this group, the level of law enforcement and the availability of emergency medical services are those factors that can be controlled; whereas, type of area (rural vs. urban), change in travel patterns, VMT and socioeconomic composition are factors that may not be directly controlled. Among these factors, the VMT was used as a common denominator in computing fatality rates and in normalizing several factors from the other three groups. No other specific analysis on the significance of other demographics factors at the county-level was conducted.

7.2 State-Level Analysis

Several analyses were conducted at the State level. These were:

1. Hypothesis tests on factors affecting fatalities

2. A multi-variable correlation analysis
3. Analysis of fatality patterns over time
4. Time series analysis

A limited number of factors are reported in the literature for which hypothesis tests have been conducted. Comparable results are reported in several studies on alcohol effect in fatalities. The tests conducted on speed revealed inconclusive results. Several studies tested hypotheses on the significance of age along with other factors affecting fatalities. These tests primarily resulted in the rejection of the notion that age was not a factor among speeding drivers, among urban/rural drivers or among different locations with respect to intersections. In our study, hypothesis tests were conducted on several factors. Due to the nature of data available in this study, we were not able to exactly repeat the hypothesis tests reported in the literature. Based on the available data, such factors as alcohol, age, gender, vehicle types, urban/rural highways, roadway function class, weather conditions and days of week were used in testing hypotheses. The purpose of testing these hypotheses was to determine whether the notion that: "the distribution of crashes involving a particular factor is the same as the distribution of the general traffic involving that factor" can be supported statistically. The rejection of this notion is an indication of the strong effect of the factor in causing fatalities. With the exception of the vehicle type, for all other factors the hypothesis was rejected for all the years the data was tested. For the vehicle type, the hypothesis was rejected in some years were the data was tested.

In conducting a multi-variable analysis the objective was to identify how different factors simultaneously affect fatalities in Illinois. No regional differences among factors were considered. A correlation and regression analysis was performed for 22 sample data covering the 1975-1996 period. Only variables for which data was available were used in the analysis. Considering the four factor groups listed in Section 2, factors utilized as independent variables in the correlation and regression analysis included: (1) Driver factors such as age, BAC level, and speeding; night /day time; and weekend /weekday driving; (2) Environmental factors including weather, and urban /rural highway use; (3) Vehicle factor including vehicle types; and (4) Demographics including VMT. Again, the VMT was used as a common denominator for computing fatality rate and normalizing several factors that affect fatalities.

Among the driver factors, the ratio of drivers in 16-120-year age group involved in crashes to the total driving population had a very high correlation with the State-level fatality rate. On the significance of other driver-related factors, alcohol-positive drivers (i.e., drivers with any BAC level in their systems) involved in crashes contribute significantly to the traffic fatalities. The same is true for speeding drivers involved in crashes. Combining these analyses, it can be stated that drivers in the 16-120-year age group along with speeding drivers with any BAC level in their systems across the State contribute significantly to fatality rates. Specific programs aimed at these factors should abate fatality rates. Programs such as limited driving hours and graduation programs for drivers under 18 years of age can substantially reduce fatality rates. A few states (including Illinois) implement the graduation program via which younger drivers start their driving with supervision for a specific length of time and upon satisfactory results they can move on to become independent drivers without additional supervision. With regard to other factors more stringent traffic law enforcement, crackdown on speeding and drinking-and-driving, better and more widespread education programs should help reduce fatality rates.

In regard to other driver factors and the environment and highway factors, the significance of weekday/weekend, night/day, urban/rural driving and snowy/rainy day conditions was investigated. The analyses revealed comparable results for weekday versus weekend driving. However, with equal conditions, weekend drivers contribute more to fatalities. This can be attributed to the fact that most weekday driving are travel to and from work and involve much less alcohol involvement. When night versus daytime driving was considered, the correlation analysis revealed a strong correlation between the fatality rate and crashes occurring during dark hours. Comparing rural versus urban crashes, the statistics of fatalities reveal comparable correlation between the fatality rate and both rural and urban crashes. However, the difference in the VMT between these two groups of highways results in a higher fatality rate for rural highways. Finally, the average number of snowy days showed a moderate correlation with fatality rates. Combining these factors, the high-risk situation for fatalities includes nighttime driving during weekend under bad weather conditions on rural highways. Again, several of the measures discussed earlier in this section can indirectly help these factors in abating fatality rates.

On vehicle-related factors and demographics, vehicle types were investigated. Three types of vehicles were considered namely passenger cars, trucks and buses. Crashes involving passenger cars showed a strong correlation with the fatality rate. Further analysis of fatality data indicated that passenger cars especially cause fatality risks to their own drivers and occupants; whereas heavier vehicles such as trucks contribute to the fatalities of other roadway users.

To further analyze the significance of fatality-causing factors, a descriptive analysis was also conducted. When the needed data on some factors at the State level was not adequate, trends at the national levels were used to gain an insight into how various factors influence fatality trends. Nearly all factors identified in Section 2 were used along with the fatality data to evaluate the trends observed in these factors over the 1975-1999 period. The results were presented in the form of graphs and tables. Correlation analyses were also conducted to determine whether trends in individual factors followed the trends in fatality rates. Among various factors studied, several had significant prevalence in fatal crashes and fatalities. These were:

- Alcohol involvement
- Speeding
- Age
- Rural versus urban highways
- Divided versus undivided highways
- Snowy and icy days
- Location of crashes in relation to the intersection
- Railroad crossing

In regard to age, the descriptive analysis confirmed the contribution of the 16-20-year age group to higher fatality rates. The above factors are also among those that can be controlled (either fully or partially) to reduce fatalities. In general, more patrol control may reduce the number of fatalities on rural highways. The enforcement on drinking-and-driving, especially in areas with higher concentration of recreational facilities, is an effective method to reduce fatalities at the regional level. Awareness and educational programs such as the Operation Lifesaver along with stiffer penalties have shown promising results in reducing fatalities at railroad crossings. These strategies can be further enforced and implemented for other factors such as speeding and crossing intersections at red lights. Snowy and icy days have a pronounced effect on fatal crashes. Strategies to reduce fatalities may include dissemination of driving tips, programs to close more roads in rural areas, and more frequent snow removals. The findings of the descriptive analysis in most parts were consistent with those from the correlation analyses at the State and regional levels. Regarding the divided versus undivided highways, a separate analysis will be helpful to specifically address the fatality rates considering the VMT differences between the two types along with the importance of other factors such as speeding.

To identify how fatalities will change in future years, a time series analysis was conducted. The results indicated that in general motor vehicle fatalities are on decline in Illinois. The average reported fatalities in Illinois are about 1600 per year. This average has been reduced in more recent years. The time series analysis was conducted for the year 2002 to 2009. The level of uncertainties in the results increases as estimates in long-term futures are sought. Considering a short-term future, the estimates for fatalities in years 2002 and 2003 will be about 1240 per year. This estimate is an upper bound value based on 99% confidence level and about ±30% variation. Considering longer term estimates, the analysis resulted in 1230 fatalities in 2008 and 2009. Again, this is an upper bound value based on a 99% confidence level and ±55% variation. The margin of variation is rather large due to the uncertainty in the forecast estimates, especially when estimates in long-term futures are sought. At the regional level, decline on fatalities is not consistent. Since detailed information on fatalities and all factors causing fatalities was not available at regional and county level, a more rigorous analysis of future trends at the regional level could not be conducted.

7.3 General Remarks and Limitations of the Study

Few observations on fatality trends in areas where there is a large population concentration in Illinois seem to point out to the fact that these areas are major contributors to the decline in fatality in Illinois. The descriptive analysis, along with the correlation and regression analyses, was consistent in providing an insight into how various factors contribute to fatalities. The lower fatality rates obtained for Cook County, Champaign County and counties around Cook indicate that programs implemented in these areas have been effective in abating fatalities. These can also be implemented in other areas. As discussed earlier, some of these programs concern with better public awareness, education and better law enforcement. Table 7.1 provides a summary of such measures and what was perceived as their effectiveness in targeting those factors that are identified as the main determinants of motor vehicle fatalities and fatality rate in Illinois. While some of these measures are already in place in some areas in the State, they can be pursued on a more widespread level and with a better organization and effective implementation.

A major limitation of the study arose from lack of adequate data. The sources of data and limitations associated with data gathering was discussed in Section 4. This section presents an overview of limitation of the study and recommendations for future development to overcome these limitations.

Certain conclusions made on the distribution of fatality-causing factors across the State were based on fatality trends at the national level. Although in most part such trends may reflect Illinois data, more conclusive results can only be obtained when comprehensive information on Illinois fatal crashes is available. The information gathered for Illinois is primarily at the State level. Detailed information on local effects on fatalities was difficult to obtain. Furthermore, for certain areas, the information on specific causes of fatalities and statistics on fatalities was not comprehensive to obtain a meaningful statistical database.

A detailed analysis at the regional level requires data on societal, demographics, population distribution and driving habits that may be unique to a particular region. Lack of regional data on these factors imposes limitations on recommending measures that may be taken to reduce fatality risk specific to a region or county in Illinois. The multi-variable correlation and regression analyses were intended to obtain an insight into regional differences that may exist across the State to point to specific factors that may trigger higher fatality rates in some areas. These studies produced only a handful of factors that show significant differences across the State. However, the fact that many of these factors may be influenced by other regional and Statewide factors, the regression analysis results impose limitation on these analyses. For example, the correlation analysis found crashes involving alcohol-positive drivers a factor with some regional presence. However, there are several factors that may be present along with alcohol to influence fatalities one way or another. Two such factors are (1) the level of traffic law enforcement at the regional and local level; and (2) access to the emergency medical service facilities. The lack of adequate information on these factors limits the results of the study on the significance of alcohol in influencing fatalities. Areas where alcohol showed prominence are often associated with rural and less-populated areas. The level of traffic law enforcement in these areas, compared with urban areas, was not known. If the law enforcement level (in terms of patrol presence per specific area and population density) is uniform across the State, then the results of the correlation analyses on alcohol factor may be considered conclusive. Otherwise, one must incorporate the significance of these other factors to obtain more reliable results on regional difference in the alcohol consumption that may point to differences in fatality rates in certain regions within the State.

The development of hypotheses on fatalities was based on (1) the review of literature; and (2) study of fatality trends at the State and national levels. Information gathered from literature review generally reflected national trends. In addition conflicting results were reported on some factors. For example, reports on the significance of the 65 mph speed limit on fatalities were not unanimous. Studies that reported statistical hypothesis were very limited and touched upon specific factors rather than groups of factors. In this sense, there are limitations in the results of the hypotheses and hypotheses testing reported.

Table 7.1 Summary of Measures that Can be Taken to Control Fatalities.

Group	Factor	Enforcement Level	Measures
Driver	16-20 year age	State & Local	Limit on driving hours, graduation programs, limit on the number of people who can ride in a car with drivers under 18
	BAC level	State & Local	Educational programs, better law enforcement Especially in rural areas, better EMS access in rural areas
	Speeding	State & Local	More stringent penalties, better enforcement
Vehicle	Use of safety Equipment	State	Education, awareness, penalties
	Other factors	State & Local	Most factors in this group cannot be controlled Directly. Better law enforcement, education, and EMS availability should indirectly affect them to reduce fatalities
Environment/ Highway	Rural areas	Local	Better traffic law enforcement, better access to EMS, better signage and communication devices for emergency help
	Snowy day	local	Road closing in rural areas, informing public on Road closing, driving tips, frequent snow removals, deicing applications
	Day/night driving	Local	Night driving limitations for drivers under 18
	Crash Location	Local	control on drivers passing red lights (stiffer penalties, camera monitoring)
	Railroad Crossing	Local	Education programs, stiffer penalties
Demographics	EMS	Local	Better access to facilities, proper signage, installation of communication devices
	VMT	State	Factor cannot be directly controlled, measures taken to better enforce traffic law will indirectly control fatalities as pertain to this factor

A time series analysis to forecast future trends in fatalities in Illinois was also conducted. The analysis utilized quarterly data for some twenty years as provided by IDOT. The time series analysis relies on incremental differences observed from one period to next using auto-correlation results. The method works well when the influence by external factors is rather uniform and uninterrupted. Occurrence of specific events that may dramatically affect the output of the quantity will result in a higher level of uncertainty in the forecasts. In studying the trends in fatalities, one notices the prevalence of a rather large group of factors that directly or indirectly affect fatalities. In addition, the introduction of new traffic laws from time to time may shift the direction of one or more of such factors; and in tern may cause a sudden change in fatality. This change may dissipate over a short period of time in some cases. The time series analysis was primarily a uni-variable model and produced forecasts based on fatality trends without any input on other factors or events that may have triggered sudden changes in fatalities. Although the estimates are useful in identifying general fatality trends into future, their application will be limited. The results of this limited study can be used as a first step in identifying a specific number of factors that show prominence in affecting fatalities and use these, along with fatality data, to forecast more reliable estimates for the future. This would require implementation of a multi-variable time series analysis. The multi-variable time series analysis will only be possible when coincidental data on all factors affecting fatalities are available for a relative long period of time.

As described earlier, the significance of the implementation of a new law or regulation on changes in fatality trends was not considered in this study. To overcome this limitation, a separate study on fatalities needs to be conducted to investigate the level of effectiveness of a specific event (new laws) on changing fatality trends and the length of time over which such changes persist until they dissipate. Studies of this type will be very beneficial, especially at local levels, in developing comprehensive plans to reduce motor vehicle fatalities and estimating the cost associated with implementing such plans. Any such additional studies need to address and distinguish the difference in fatality trends for urban and rural roadways. Implementation of any plan to reduce fatalities must separately address the needs by these two groups of roadways.

8.0 CONCLUSIONS AND RECOMENDATIONS

The study reported herein was conducted for the purpose of identifying the determinants of motor vehicle fatalities in Illinois. The study utilized the State fatality data along with the national trends in fatality rates. The following is a list of main conclusions from this study.

- Factors affecting fatalities can be classified into four major groups; namely, driver, vehicle, environment/highway and demographics factors.
- A fatal crash is often a result of an interaction from several factors within the factor groups.
- In general, fatalities at the State level are on the decline based on data (up to 1999); however, at the local level this is not conclusive.
- Future estimates in fatality indicate a downward trend also; however, these estimates are subject to a large variation especially if estimates into a distant future are sought.
- At the local level, factors that show regional differences in affecting fatalities include BAC level, weather conditions, and rural versus urban driving.
- At the State level, factors that generally contribute significantly to fatalities, and are considered to be the main determinants of fatalities, include:

  1. BAC level
  2. Speeding
  3. Drivers in the 16-20-year age group
  4. Driving habits (night vs. day driving, and weekend vs. weekday driving).
  5. Rural versus urban driving
  6. Snowy and icy days
  7. Location of crashes in relation to the intersection
  8. Railroad crossing

- Several factors such as BAC level, speeding, etc. can be directly controlled through specific measures aimed at their control; while other factors such as age and VMT can only be controlled through indirect measures aimed to reduce fatalities in general.
- The regional differences in fatality rates can be attributed to differences in the level of law enforcement, education and awareness and accessibility to emergency medical service facilities.
- Measures that can be taken to help reduce fatalities can be decided based on their effectiveness at the local level; examples of such measures include better law

enforcement, patrol presence, limiting driving hours for 18 year-old and younger drivers, more frequent snow removal in rural areas, etc.

Major limitations of the study were due to lack of specific data for certain factors especially at the local level. To overcome these limitations, the following recommendations are made.

- Conduct a study exclusively aimed at identifying how a specific measure can reduce fatalities.

- Conduct more studies on regional and local trends on fatalities; develop a systematic method to compile local data for use in the study.

- Coordinate an effort with the State Police, IDOT Division of Traffic Safety, Secretary of State and local authorities in conducting a comprehensive study on fatality control at the local and State level. Include a limited number of factors in the study such that conclusive results can be obtained on the significance of these factors in affecting fatalities.

- Develop a more comprehensive time series analysis in order to forecast future fatality trends by incorporating the significance of fatality-causing factors, and events (including new laws and regulations) that may trigger sudden changes in traffic fatalities.

- Divided versus un-divided highways show differences in the statistics of fatal crashes. From the review of data, the fatality rate is less for un-divided highways. This can be attributed to the fact that divided highways have a heavier traffic volume. Since there was no specific VMT data in terms of divided versus un-divided highways, the specific conclusions on the role of type of highway on fatality rate cannot be made. And a such, more studies will be needed to ascertain whether divided versus un-divided highways can be considered as a determinant of motor vehicle fatalities in Illinois.

- The results obtained for the contribution of drivers in the 65-year-and-older category to motor vehicle fatalities were not conclusive. Additional studies will be needed to investigate the driving habits, VMT, and other attributes of this age group in affecting fatality rates, especially for those in the 85-year-and-older group.

Appendix-A
(List of Terms)

List of Terms

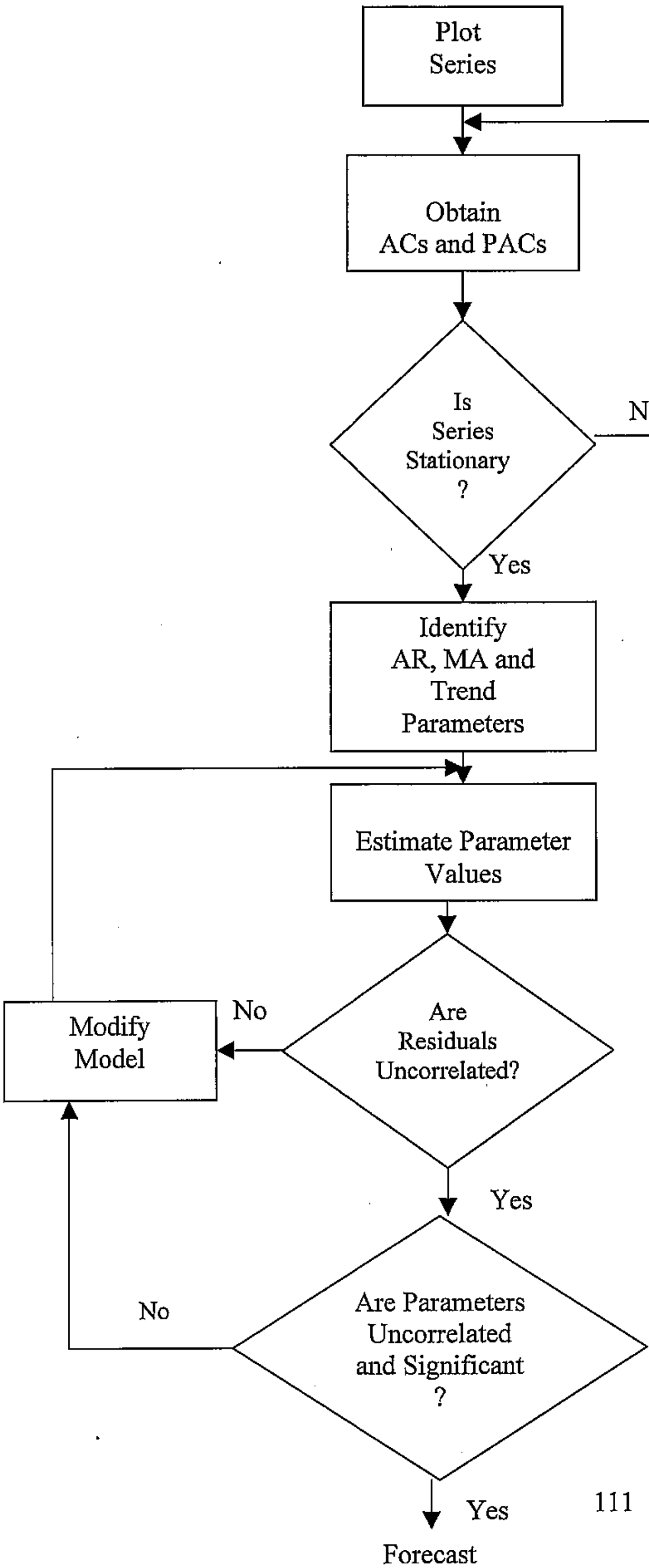
ACF	Autocorrelation function
ADT	Average daily traffic
ANOVA	Analysis of Variance
AR	Autoregressive
ARIMA	Autoregressive Integrated Moving Averages
AVMT	Average Vehicle Miles of Travel
BAC	Blood alcohol concentration
DVMT	Daily vehicle miles of travel
DUI	Driving under influence
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
IDOT	Illinois Department of Transportation
IIT	Illinois Institute of Technology
ITRC	Illinois Transportation Research Center
LMDA	Minimum legal drinking age
MA	Moving averages
NHTSA	National Highway Traffic safety Administration
NPTS	National Personal Transportation Survey
PAC	Partial autocorrelation
PACF	Partial autocorrelation function
RD	Regular differencing
SD	Seasonal differencing
SPSS	Statistical Package for Social Sciences
VMT	Vehicle miles of travel

Appendix-B
(Time Series Analysis)

Box-Jenkins Time Series Analysis

The Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) technique (Box-Jenkins, 1994) is used in this research to investigate future trends in fatalities in Illinois. Fatality data available at the State level was used in this analysis. The method required selection of a time interval and development of a data matrix representing fatality data at each interval. The data received from IDOT is quarterly and covers the period 1975-1996. And as such, the time interval used in the analysis is 1/4 of a year. The software SPSS Trends (SPSS, 1999) was used for the analysis. This analysis constitutes a uni-variable forecasting method. The ARIMA model building is based on statistical analysis of historical data. The data provides the necessary information for selection of a particular model which will be suitable for forecasting. Upon selection of the model, a set of values for the parameters that describe the model is determined. Usually, this is done by trial and error. This is then followed by a statistical test performed to investigate the validity of the model in predicting reliable estimates for future occurrences of the quantity (Hoff, 1983).

The model building process is usually an iterative approach as shown in Fig. B.1 (Hoff, 1983). Two types of ARIMA models are often used. These are: (1) non-seasonal; and (2) seasonal models. A combination of the two is also possible and has been used. A non-seasonal model is designated by ARIMA (p,d,q), where p and q are model parameters and d is the number of differencing needed to obtain a stationary series. The seasonal model is denoted with ARIMA (sp, sd, sq), in which sp and sq are the series parameters and sd is the differencing. All these parameters are often obtained by trial and error. There are several methods via which various models (with various parameters) can be compared in terms of efficiency, reliability and stability. Combined non-seasonal and seasonal models are designated with ARIMA $(p,d,q)(sp,sd,sq)$. The selection of a robust ARIMA model requires a trial and error procedure (see Fig. B.1). The process starts by tentatively selecting one or two models comparing teir respective autocorrelation functions (ACF) and partial autocorrelation functions (PACF).



Nomenclature:
AC: autocorrelation
AR: autoregressive
MA: moving averages
PAC: partial autocorrelation

Fig. B.1 General ARIMA Model Process.

To identify the moving average (MA) and auto-regressive (AR) trends, several different models are selected and compared with a pre-determined theoretical autocorrelation function. The predetermined function is often a type that has been proven to provide a parsimonious and statistically adequate representation of data. The estimate of a definite number of parameters will be needed to build a model for forecasting. For example, if only one parameter (say θ_1) is selected, using the moving average, i.e., MA(1) model, the estimate for fatalities Z_t at period t is

$$Z_t = (1 - \theta_1 B)\, a_t \qquad \text{(B.1)}$$

In which a_t represents the random error at period t; and B is a constant. With this model, one must find an accurate estimate for θ_1 by using the available data. As it is evident from Eq. B.1, the estimate for fatality depends on the random error a_t. The estimate Z_t can be written in terms of this error at period t-1, t-2, etc. Using the autoregressive model with only one parameter ϕ_1, the AR(1) will be represented by

$$Z_t = C - \phi_1 Z_{t-1} + a_t \qquad \text{(B.2)}$$

In which C is a constant and Z_{t-1} is the fatality estimate at the period t-1.

Suppose ϕ_1 at time t-1 is known. However, since a_t at t-1 is not known, one can only obtain an estimate for Z_t as oppose to the actual Z_t. Denoting this estimate as $\hat{Z}_t$, one can write

$$\hat{Z}_t = \mu(1-\phi_1) - \phi_1 Z_{t-1} \qquad \text{(B.3)}$$

where μ is a constant. Notice that in this model, the estimate at the period t depends on the estimate for Z at the previous period, i.e., t-1. The difference between Z_t and $\hat{Z}_t$ is known as the residual. The residual follows a random process known as "random shock." Furthermore, this difference is shown to be proportional with a_t. In fact

$$Z_t - \hat{Z}_t = a_t \qquad \text{(B.4)}$$

As described in Hoff (1983), the residuals can be used as a measure to verify the validity of the estimates obtained from the model. Usually, the sum of squares of the residuals is used for this purpose. A small value for the sum of squares is an indication of better results from the model. As described later in this section, several models for forecasting fatalities in the future were tried. For example when a model such as ARIMA (2,0,0)(0,1,2) was used, the program SSPS yielded a sum of squares of residuals equal to 117209.36. Changing the model parameters, one obtained different sums of squares. For example with ARIMA (1,0,0)(0,1,1), the sum of squares of the residuals was 127632.07; whereas, with ARIMA (1,0,0)(0,1,2), the sum of squares of residuals was 134070.62. As is evident, the model represented by ARIMA (1,0,0)(0,1,2) had the lowest sum of squares for the residuals and, as such, offered a better fit.

Model Verification

The stability and robustness of the ARIMA estimates can be verified by examining several identities. These are:

- Correlation coefficients between ARIMA model parameters (θ_i, and ϕ_i)
- Redundancies in ARIMA coefficients in mixed AR and MA models.
- Residual variance.
- *t*-values
- Checking for instability.
- Diagnosing checking by examining ACF and PACF residuals.

These are explained below.

Correlation Coefficients between ARIMA Parameters -- A desirable condition among the ARIMA model parameters is statistical independence. These parameters were introduced in the MA models as θ_i and in the AR model as ϕ_i. The program SPSS computes a matrix of correlation coefficients for these parameters. The program designates the AR parameters as AR1, AR2, ... (instead of ϕ_i), and the MA parameters as SMA1, SMA2, ...(instead of θ_i). Initial values for these parameters must be assumed and entered into the program. Final values originate from estimation and by trial and error. The coefficients appearing in the correlation matrix represent the degree of dependence of parameters on one another. Coefficients equal to and close to ±1 indicate a perfect (or nearly perfect) correlation; whereas, zero or nearly zero coefficients indicate statistical independence. When coefficients approach ±0.9 and higher, the forecast results are unstable, which indicate unreliable results. This is to say that when correlation coefficients are high, a small change in one parameter will also cause changes (of the same magnitude) in all other "correlated" parameters. This change will have a little effect on the sum of the squares of the residuals and will alter any improvement in the forecast estimates. Thus in such cases, new ARIMA models (by trying different p, q, and d values) must be developed to improve the results.

In the models developed for forecasting fatalities in Illinois, one AR parameter and two MA parameters were used. The correlation matrix computed by SPSS appears in Table B.1. As seen in the table, correlation coefficients were small enough to assume that parameters are statistically independent. This condition resulted in stable and reliable forecast estimates.

Table B.1 Correlation Coefficients among ARIMA Model Parameters.

	AR1	SMA1	SMA2
AR1	1.000	0.1276	-0.1662
SMA1	0.1276	1.000	-0.4236
SMA2	-0.166	-0.4236	1.00

Coefficient Redundancy-- When mixed AR and MA ARIMA models are used, a problem with the redundancy of model coefficients may become prevalent; and thus causing unreliable results. Redundancy means that ARIMA model coefficients are selected such that AR and MA models produce Z_t estimates that are equal to a_t values. As a result, the residual value a_t will become a "white noise" process. The white noise process has a constant unbounded autocorrelation function. When this condition prevails, the forecast results are not stable nor reliable because no improvement in the sum of squares of the residuals will be obtained as iterations advance. To demonstrate coefficient redundancy, consider a model represented by ARIMA (1, 0, 1) with ϕ_1 = 0.4 and θ_1 = 0.4. Notice that when the two models (i.e., AR and MA) are set equal, the following equation is obtained.

$$(1 - 0.4 B) Z_t = (1 - 0.4 B) a_t$$

This results in $Z_t = a_t$, which is an indication of redundancy in the model. To check the redundancy, one can examine the program output to determine whether new iterations change the sum of the squares of the residuals. The models used for fatalities in Illinois were examined and none of the models selected had any problem with the redundancy.

Residual Variance – As expected, ARIMA models (no matter how properly constructed) will not fit the data closely. This means that ARIMA estimates are subject to uncertainties. The variation in the results (known as statistical noise) cannot be totally eliminated. The estimated residuals a_t (i.e. the random shocks) are a good estimate of this noise. When different ARIMA models are compared, with all other conditions being equal, the model with the smallest a_t is the most desirable one. In the selected models used for forecasting fatalities in Illinois, the smallest variance obtained was 1422.62. The model corresponding to this variance was ultimately used for fatality forecasting.

***t*-value** – The *t*-value is another statistic that can be used to examine the robustness of the ARIMA estimates. An approximate *t*-value is obtained for the ARIMA model parameters AR1, AR2, … and SMA1, SMA2, … The equation used in SPSS is

$$t = \frac{\text{(Estimated Parameter)} - \text{(Hypothesized Value of the Parameter)}}{\text{(Estimated Standard error of the Parameter)}}$$

Since a parameter (such as AR1) is obtained based on the input data, there is a statistical variation in it. The standard error of the expected value of the parameter is $\frac{s}{\sqrt{n}}$ in which s = the standard deviation and n = the number of samples. When the absolute value of t is less than 2.0, the confidence level on the estimated parameter is not favorable. New ARIMA models must then be tried. Table B.2 provides a summary of the t–values for the model that was eventually used by IIT for time-series analysis of fatalities in Illinois. As seen in the table, these values were all larger than 2.0.

Table B.2 *t*-values for the Model Parameters.

Parameter	*t*-value
AR1	4.5166
SMA1	3.6247
SMA2	2.4991

Checking ARIMA Parameters for Stationary and Invertibility -- In ARIMA models, the AR parameters are checked to determine whether they satisfy the following inequalities.

$$|\phi_2| < 1$$
$$\phi_2 + \phi_1 < 1$$
$$\phi_2 - \phi_1 < 1$$

It is noted that when p is taken as zero, i.e., in the ARIMA (0,d,q) model, the series will always be stationary resulting in reliable forecast estimates. The model used for fatality estimates was ARIMA (1, 0, 0) (0, 1, 2). With $|\phi_i| < 0.4536$, stability is satisfied.

Invertibility - Invertibility implies that the MA parameters must satisfy conditions given in Table B.3.

Table B.3 Conditions for Invertibility.

Model type	Invertible condition
ARIMA (p, d, 0)	Always invertible
ARIMA (p, d, 1)	$\lvert\theta_1\rvert < 1$
ARIMA (p, d, 2)	$\lvert\theta_2\rvert < 1$ $\theta_2 + \theta_1 < 1$ $\theta_2 - \theta_1 < 1$

A noninvertible ARIMA model implies that weights placed on any past two observations do not decline as we move further into the past. Thus to obtain an invertible model, larger weights must be applied to more recent observations. For example, in an ARIMA model, the following series is used in MA.

$$Zt = C - \theta_1 Z_{t-1} - \theta_1^2 Z_{t-2} - \theta_1^3 Z_{t-3} \ldots - \theta_1^k Z_{t-k}.$$

Now consider the following two scenarios with θ_1=2 and θ_2=0.6.

Weights with θ_1=2

k	θ_1^k
1	$\theta_1 = (2)^1$
2	$\theta_1^2 = (2)^2$
3	$\theta_1^3 = (2)^3$

Weights with $\theta_1 = 0.6$

k	θ_1^k
1	$\theta_1 = 0.6$
2	$\theta_1^2 = 0.36$
3	$\theta_1^2 = 0.216$

Notice that with $\theta_1 = 0.6$, the weights decline as we move into previous observations. This is a desirable condition for invertibility. This shows that when $\theta < 1$ more weight is given on recent values. In the selected model, two parameters, as given below, were used.

$$\theta_1 = 0.4115$$
$$\theta_2 = 0.2840$$

Examining the conditions in Table B.3, one obtains

$| \theta_2 | = 0.2840 < 1$
$\theta_2 + \theta_1 = 0.6955 < 1$
$\theta_2 - \theta_1 = - 0.5885 < 1$

These showed that the model complied with the invertibility requirement.

Diagnostic checking -- The success of the Box-Jenkins uni-variable method depends on a right combination of the AR and MA models that would result in (1) independent AR and MA parameters (i.e., θ_I and ϕ_I); and (2) smallest possible value for the sum of the residuals. However, with a small number of trials on selecting various combinations of the AR and MA models, one may not exactly know whether a minimum value for the sum of squares of the residuals has been obtained. Furthermore, as discussed earlier, if correlation coefficients among MA and AR parameters are large, there is an indication that the random shock (a_t) is approaching a white noise pattern. This condition is not desirable. At times, however, one may not easily recognize, or decide, whether correlation coefficients are large. In situations like this, diagnostics checking is conducted to determine the adequacy of the model selected.

Use of Residual ACF and PACF Values in Diagnostics Checking -- This is the main analytical tool in the diagnostic checking. The idea is to compute the autocorrelation function (ACF) and partial autocorrelation functions (PACF) for the residuals. If the residuals show a pattern, this is an indication that a_t is approaching the white noise; and the model needs to be revised. In this connection, one must avoid the condition where the ACF and PACF of the error series (i.e., the residuals) are significantly different from zero. The Box-Ljung Q-statistic (also called the modified Box-Pierce statistic) is used as a common test for this condition. In essence, this is a Chi-square test for identifying whether the test statistic is significant. The significance means that the residuals are different from zero -- an undesirable condition that requires that an appropriate revision on the selected model be made. The program SPSS provides for a convenient way of conducting this test and the diagnostic checking.

```
MODEL:   MOD_4.
Variable:   ERR_1          Missing cases:   60      Valid cases:   84

Autocorrelations:    ERR_1    Error for FATALITY from ARIMA, MOD_1 CON

     Auto-  Stand.
Lag  Corr.    Err. -1   -.75   -.5 -.25    0    .25   .5    .75    1    Box-Ljung  Prob.
                   □⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩□
  1  -.062   .107                 .   *⇔    .                         .340   .560
  2   .097   .107                 .    ⇔** .                         1.162   .559
  3   .032   .106                 .    ⇔*   .                        1.251   .741
  4   .045   .105                 .    ⇔*   .                        1.436   .838
  5   .107   .105                 .    ⇔** .                         2.491   .778
  6   .255   .104                 .    ⇔***.*                        8.525   .202
  7   .008   .103                 .    *    .                        8.530   .288
  8   .058   .103                 .    ⇔*   .                        8.849   .355
  9  -.090   .102                 . **⇔     .                        9.623   .382
 10   .003   .101                 .    *    .                        9.624   .474
 11  -.026   .101                 .   *⇔    .                        9.689   .559
 12  -.128   .100                 .***⇔     .                       11.322   .502
 13  -.039   .099                 .   *⇔    .                       11.475   .571
 14  -.239   .098                *.***⇔     .                       17.377   .237
 15   .023   .098                 .    *    .                       17.431   .294
 16  -.064   .097                 .   *⇔    .                       17.859   .332

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  144     Computable first lags:  83

Partial Autocorrelations:    ERR_1   Error for FATALITY from ARIMA, MOD_1 CON

   Pr-Aut- Stand.
Lag  Corr.    Err. -1   -.75   -.5 -.25    0    .25   .5    .75    1
                   □⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩⇧⇩⇩⇩⇩□
  1  -.062   .109                 .   *⇔    .
  2   .093   .109                 .    ⇔** .
  3   .043   .109                 .    ⇔*   .
  4   .041   .109                 .    ⇔*   .
  5   .107   .109                 .    ⇔** .
  6   .267   .109                 .    ⇔***.*
  7   .030   .109                 .    ⇔*   .
  8   .010   .109                 .    *    .
  9  -.121   .109                 . **⇔     .
 10  -.062   .109                 .   *⇔    .
 11  -.090   .109                 . **⇔     .
 12  -.231   .109                *.***⇔     .
 13  -.099   .109                 . **⇔     .
 14  -.270   .109                *.***⇔     .
 15   .036   .109                 .    ⇔*   .
 16   .017   .109                 .    *    .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  144     Computable first lags:  83
```

Fig. B.2 Sample ARIMA Analysis Program Output

Figure B.2 presents a sample of computer print-out from the SPSS program for the ARIMA model selected for forecasting fatalities in Illinois. As seen in the figure, ACF and PACF values are plotted for lags from 1 to 16. Each lag represents one time period difference between records. The ACF and PACF values appear to be randomly distributed. Only a few scattered correlation coefficients exceeded the 95% confidence limits. These appear as dotted lines on the plots in Fig. B.2. Furthermore, the Box-Ljung statistics (Chi-square test results) for the ACF values was not statistically significant at any leg. This indicated that the autocorrelation values were not significantly different from zero. This further indicated that the selected model offered a favorable fit for the available data.

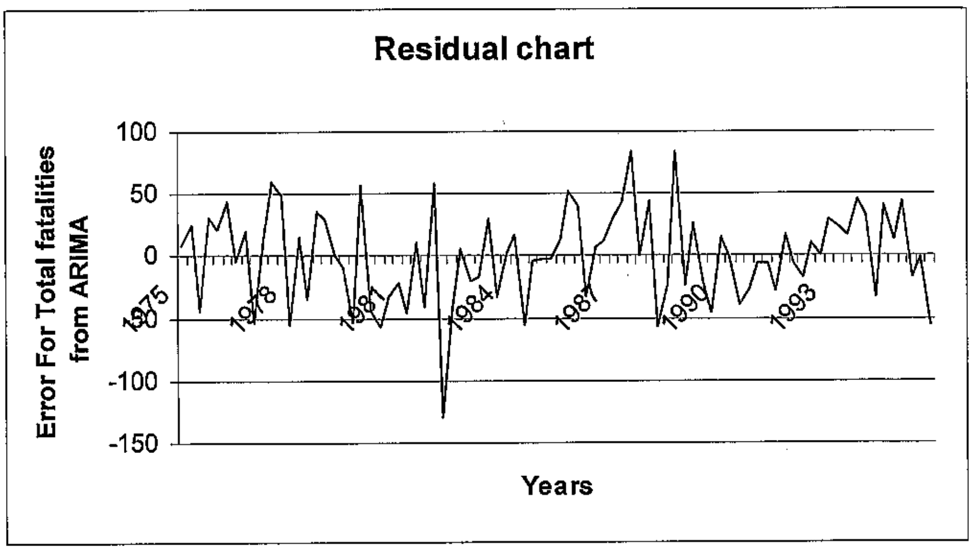


Fig. B.3 Plot of the Residual variance

Residual Plot -- Figure B.3 presents a plot of the variance of the residuals for the fatality data over the entire period of analysis. In a robust model, the residuals will not show any dramatic change in the variance. A visual examination of this plot is helpful in identifying where an unusually large value (compared with the rest of the values in the plot) occurs. As seen in Fig. B.3, the residual shows no pattern although there might be some "outliers." This is usually the result of a sudden change in certain condition at a particular time, which may produce a change in variance. To handle this situation, one may consider interpolating the values in periods where unusual results are observed. However, as it is evident from Fig. B.3, the selected model for fatality analysis shows a consistent pattern for the entire period of analysis.

Over-fitting -- In certain cases, one may wish to include additional MA and AR parameters (i.e., θ_1 and ϕ_1) in the model to further improve the forecast results. This is called "over-fitting." However, it is not recommended to add parameters to the AR and

MA models simultaneously; since this may further increase the model redundancy. In all models tried, over-fitting was proved to be ineffective to improve the forecast fatalities.

The models tested for fatality forecasting are summarized in Table B.4. For each model, all the aforementioned tests were conducted. The sleeted model is designated as model 1 and has the lowest sum of the squares of the residuals. Furthermore, for this model, the *t*-values of all model parameters are outside of the critical range. Models labeled by 5 and 6 have a smaller standard error; however, they have *t*-values that are within the critical range. In all test categories, Model 1 was proved to be superior and was used to generate forecast fatality results.

Table B.5 Comparing Various ARIMA Models Used in the Time-series Analysis.

No.	Model	Standard error	Sum of Square	Residual variance	*t*-ratio	Coefficients
1	**Selected model ARIMA (1,0,0) (0,1,2)**	37.71	117209.26	1422.62	AR1 = 4.51 SMA1 = 3.62 SMA2 = 2.49	AR1 = 0.45 SMA1 = 0.41 SMA2 = 0.28
2	**ARIMA (1,0,0) (0,1,1)**	39.5	127632.07	1561.01	AR1 = 4.5 SMA1 = 3.35	AR1 = 0.46 SMA1 = 0.36
3	**ARIMA(1,0,0) (0,1,0)**	40.4	134070.62	1632.52	AR1 = 3.26	AR1 = 0.34
4	**ARIMA(1,0,0) (0,2,1)**	42.56	156124.69	1811.62	AR1 = 3.47 SMA1 = 2.58	AR1 = 0.37 SMA1 = 0.95
5	**ARIMA(2,0,0) (0,1,2)**	37.56	114727.21	1410.95	AR1 = 3.51 AR2 = 1.33 SMA1 = 3.79 SMA2 = 2.26	AR1 = 0.39 AR2 = 0.15 SMA1 = 0.44 SMA2 = 0.26
6	**ARIMA(1,0,0) (0,1,3)**	37.49	114658.79	1406.11	AR1 = 3.81 SMA1 =2.934 SMA2 = 2.06 SMA3 = 1.12	AR1 = 0.40 SMA1 =0.35 SMA2 = 0.25 SMA3 = 0.14
7	**ARIMA(0,0,0) (0,1,2)**	41.79	144554.3	1746.82	SMA1 = 2.63 SMA2 = 3.00	SMA1 = 0.29 SMA2 = 0.33
8	**ARIMA(1,0,0) (0,0,2)**	50.56	226571.08	2557.2	AR1 = 2.44 SMA1 = -9.79 SMA2 = -4.47	AR1 = -0.26 SMA1 = -1.01 SMA2 = -0.48
9	**ARIMA(1,0,0) (0,2,2)**	44.34	162983.4	1966.43	AR1 =2.817 SMA1 = 3.04 SMA2 = 0.70	AR1 =0.30 SMA1 = 0.81 SMA2 = 0.11

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