DETERMINANTS OF MOTOR VEHICLE FATALITIES AND FATALITY RATES: SOME PRELIMINARY FINDINGS FOR ILLINOIS

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ABSTRACT:

The statistics indicate that 1,400 fatalities and 150,000 injuries occurred per year in Illinois. 25 years of data starting from 1975 are complied and analyzed. It has been found that the fatality trend for Illinois is also comparable with the nationwide trend which indicates an overall decline in the number of motorway fatalities, while the Vehicle Miles Traveled (VMT) is constantly increasing. Traditionally, VMT is expected to be the most common predictor of fatalities and traffic accidents. The study is composed of three major tasks after a comprehensive literature survey. These are (i) data collection, compilation and database formation; (ii) identifying factors affecting fatality rates; and (iii) developing a statistical (time-series) forecasting model to predict future trends in fatalities in Illinois. This paper covers the progress in the two of the minor tasks, one in the second and the other in the third major tasks. The first part of the paper features the findings of the analysis that searches patterns among counties based on their socio-economic and demographic attributes. The findings suggested that the effect of socioeconomic and demographic factors on fatality rates were not statistically significant at 90% confidence level. Furthermore, the Illinois Department of Transportation's Division of Traffic Safety (IDOT-DOTS) administrative districts had some statistically significant differences on population-based fatality rate. However, pair-wise comparisons between socioeconomic and demographic variables did not provide distinct differences. The second part of the paper presents some of the initial findings of the analysis of effects of changes in policies relevant to traffic safety. Intervention analysis with univariate Box-Jenkins method is employed to identify whether a change in a particular policy had made an impact on the trends in fatalities and fatality rates in Illinois. The impact of raising the minimum age limit from 19 to 21, in 1982, for purchasing alcoholic products on the trend in the fatalities of the 16-21 year olds is analyzed. The results indicate that there has been a remarkable decrease in the fatalities of this age group after the change in the policy.

1. INTRODUCTION

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 US highways. The statistics for Illinois average about 1400 fatalities and 150,000 injuries per year. These alarming figures and costs associated with material loss and especially with loss of life or injuries attracted attention of public agencies to take precautions, to improve the safety of the roads and to educate drivers and individuals. Within the same context, extensive amount of research has been conducted up-to-date. Even a prompt review of the studies would reveal the major factors that affect the number of fatal accidents and fatality rates. These are: (i) driving habits; (ii) road-related; (iii) vehicle-related; and (iv) socioeconomic and demographic factors. Within each factor, several variables can be identified as being the most influential. Table 1 displays a plausible list.

Table 1. Factors that Affect Fatal Motorway Accidents

Factors	Influential Variables
Driver Factor	Age, Alcohol, Fatigue, Seat Belt Usage, Speed, Aggressiveness, Violation History
Road Factor	Posted Speed Limit, Roadside Safety Devices, Geometric Characteristics, Existence of Median and Barriers, Level of Pedestrian Traffic
Vehicle Factor	Vehicle Type, Safety Equipment (Airbag, ABS), Vehicle Defects, Age Of Vehicle
Socioeconomic and Demographic Factors	Income, Employment Levels, Poverty, Residential Density, Vehicle Ownership, Highway Network Density

Numerous cross-sectional studies have been conducted in varying scales and scopes in order to understand the relationships between factors and traffic accidents by combining several years of data and performing statistical analysis and constructing statistical models such as, (Blatt and Furman, 1998), (Doherty et al., 1998), (Ivan et al., 1999), (Arnold et al., 1997) and so forth. Another class of studies utilize time series techniques for identifying whether a change in a policy at a given time had an impact on accident rates, analyzing the relationships with other predictors by comparing the trends in the predictors and fatal accidents, and developing a statistical model for forecasting future fatality rates such as in (Chang and Paniati, 1990), (Voas et al., 1998), (Lane and Elias, 1994), (Rock, 1995), (Voas et al., 2000).

Every traffic accident especially fatal accident is a unique event which is caused or influenced by combinations of factors that may not be even observable. All of the studies above and the ones reviewed throughout this project, take a particular type of accident and try to identify the patterns in the observed attributes or analyze the changes in that type of accident under certain circumstances in time. Therefore, reaching such conclusions that can identify a set of factors as the causes of traffic accident fatalities and fatality rates is almost impossible. However, it is possible to distinguish traces of causation which would define the nature of more detailed analysis in future. By setting this as the principal goal of the study, the following objectives were established.

2. OBJECTIVES OF THE STUDY

- Develop both county and state level databases utilizing readily available data and external data sources;
- Describe fatalities and fatal crash patterns at the state level and county levels depending upon data availability;
- Identify and describe possible factors that may affect fatalities and fatality rates in Illinois;

- Analyze the variances in the fatal accident trend along with the factors having significant effects on fatality rates; and
- Develop a forecasting model for future trends in motorway fatalities, in an effort to provide assistance to policy development in reducing fatality rates in Illinois.

3. METHODOLOGICAL OVERVIEW

A major source of accident data is the Fatal Accident Reporting System (FARS). Starting from the year 1975, FARS presents the data in terms of a large number of variables at different levels: accident, vehicle, driver and personal. The database contains detailed information on the traffic crashes causing any fatalities in a 30 days time and is intended to provide detailed descriptive statistics at national and state level rather than to support experimental or quasi-experimental research. FARS data is built by two major data sources; field data collected by the law enforcement officers at scene of the accident and supplementary data from Secretary of State and medical agencies. The scale, scope, and the nature of the data collection sometimes impose reliability issues on some of the critical variables. Therefore, some of the information in FARS files may not be utilized. Furthermore, for analyzing the relationships with other variables that are relevant to whole population, region and/or highway network, data from external sources were needed such as: the Census Bureau, USDOT, Secretary of State, Illinois State Police and so forth. For an effective data collection and compilation, the data needs should be identified clearly and accurately. This requires a careful determination of the level of analysis.

The first major task of the methodology undertakes these issues. It covers the study of county level distributions of some of the essential variables throughout the state, and the search for an alternative way of grouping counties for a better understanding of regional characteristics pertaining to fatality patterns. This has been accomplished by utilizing the FARS data, provided by Illinois Department of Transportation's Division of Traffic Safety (IDOT-DOTS), for a three-year period from 1996 to 1998.

Another major task in data analysis is a comprehensive statistical analysis to determine the significance of each potential factor in motor vehicle fatalities and fatality rates in Illinois. Within this context, state and county level analyses were conducted. State level analyses included correlation analysis, hypothesis construction, and hypothesis testing by ANOVA and contingency table analysis, primarily, in an univariate context. County level analysis was carried out by multiple regression analysis.

Finally, a time-series analysis is needed for analyzing the trends and forecasting future fatalities and fatality rates. Univariate Box-Jenkins method with Auto-Regressive Integrated Moving Averages (ARIMA) is selected for the analysis. Figure 1 presents an overview of the process of this study.

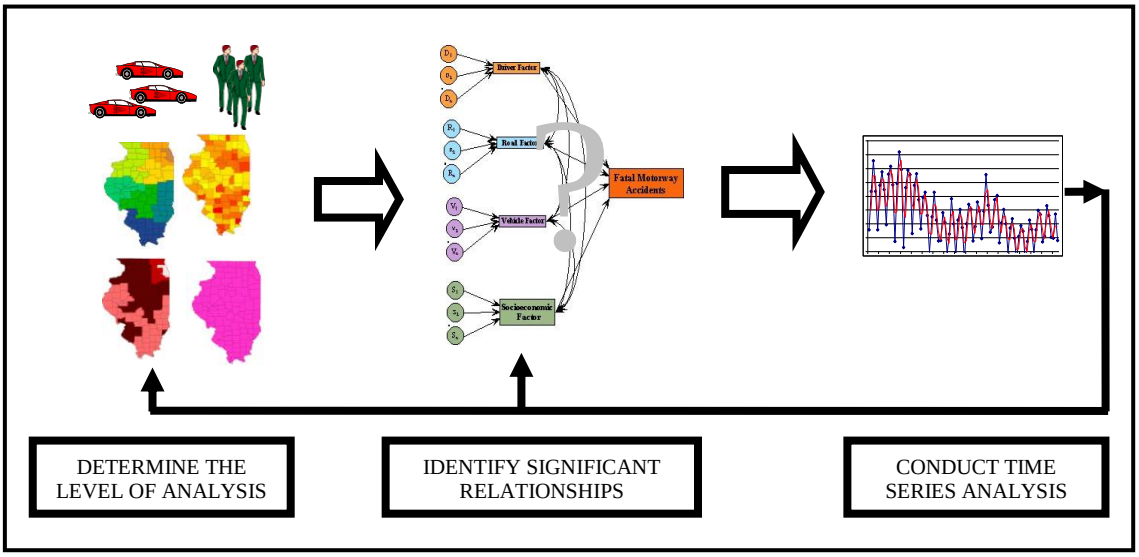

Figure 1. A Schematic Representation of the Methodology of the Study

4. GENERAL TRENDS IN FATALITIES AND FATALITY RATES AND THEIR DISTRIBUTION WITHIN ILLINOIS

In this section the preliminary findings of the study are presented. Traditionally, Vehicle Miles Traveled (VMT) is known as the most plausible predictor of traffic accidents and fatalities. Figure 2 displays the trends in annual fatalities and daily VMT's in the State of Illinois. The decline in fatalities, with an increasing VMT trend, initiated this research project which intended to identify more realistic determinants and factors to be considered for policy development. However, the trends in both variables indicated the contrary. The analysis of other variables besides VMT was needed.

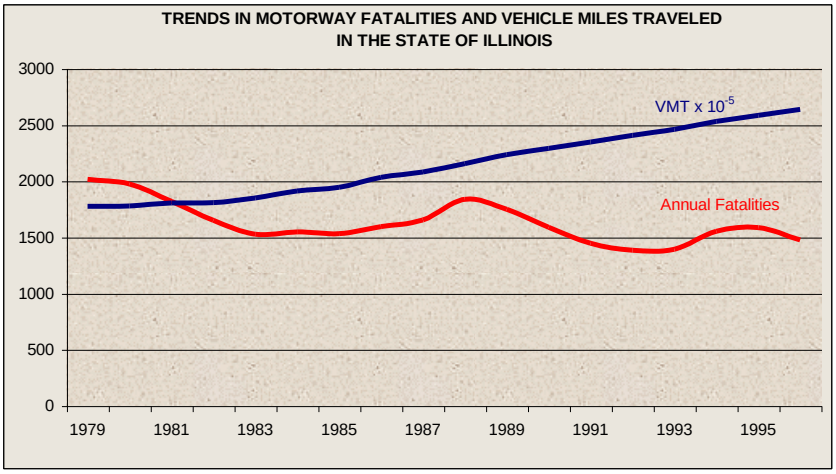

Figure 2. Trends In Fatalities and VMT in Illinois

In an effort to further investigate the fatality rates at local levels, a county level analysis of data was carried out. In some counties, the number of fatal accidents was found inadequate to conduct time series analysis. Figure 3 maps the distribution of average number of fatal accidents occurred between 1996 through 1998 at the county level in Illinois. This directed us to look for possible county aggregation schemes finer than the state level. The first alternative was IDOT-DOTS administrative districts. Figure 4 shows the boundaries of each district.

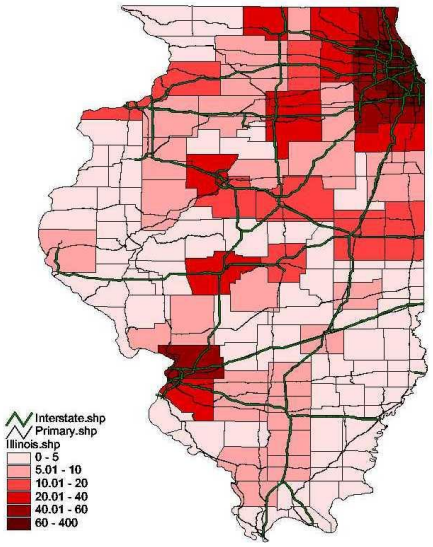

Figure 3. Distribution of Fatal Accidents to Counties in Illinois per Annum for the 1996-98 Period.

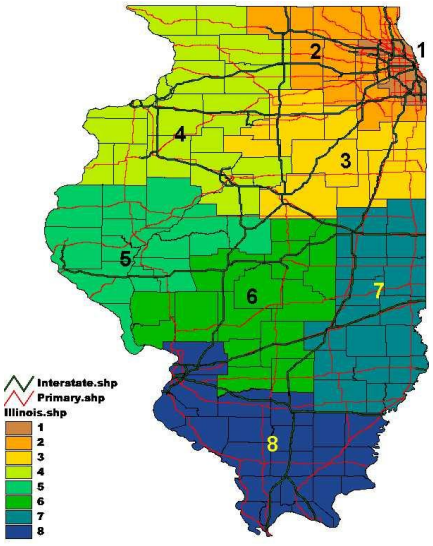

Figure 4. IDOT DOTS Administrative Districts

The number of fatal accidents and fatal accident rates and other relevant statistics are aggregated into IDOT Traffic Safety Division's administrative districts. The districts are then ranked. The statistics on fatalities and fatality rates along with rankings are provided in Table 2.

Table 2. IDOT-DOTS Administrative Districts Fatal Accident Occurrence and Fatality Rate Rankings

ATTRIBUTES	DISTRICTS								STATE
	1	2	3	4	5	6	7	8	
Fatal Crashes	384	283	98	120	42	106	77	161	1270
Total Fatalities	422	315	105	135	50	119	87	186	1420
VMT (Millions)	90.60	68.20	15.77	25.14	8.40	18.72	15.92	27.52	270.28
Fatal Crashes per Highway Mile	0.034	0.016	0.007	0.005	0.003	0.005	0.004	0.008	0.009
Fatal Crashes per Million VMT	4.23	4.15	6.22	4.76	5.00	5.64	4.84	5.85	4.70
Fatal Crashes per 100,000 Residents	7.5	11.1	21.0	13.2	13.5	16.9	14.7	17.3	11.1
Fatalities per Highway Mile	0.037	0.018	0.007	0.006	0.003	0.006	0.005	0.009	0.010
Fatalities per Million VMT	4.7	4.6	6.7	5.4	5.9	6.3	5.5	6.7	5.3
Fatalities per 100,000 Residents	8.3	12.3	22.5	14.9	16.0	19.0	16.6	19.9	12.4
RANKINGS									
Fatal Crashes	1	2	6	4	8	5	7	3	-
Total Fatalities	1	2	6	4	8	5	7	3	-
Fatal Crashes per Highway Mile	1	2	4	6	8	5	7	3	-
Fatal Crashes per Million VMT	7	8	1	6	4	3	5	2	-
Fatal Crashes per 100,000 Residents	8	7	1	6	5	3	4	2	-
Fatalities per Highway Mile	1	2	4	5	8	6	7	3	-
Fatalities per Million VMT	7	8	2	6	4	3	5	1	-
Fatalities per 100,000 Residents	8	7	1	6	5	3	4	2	-

Cook County (District 1) and its surrounding counties (District 2) ranked very high in the number of fatal accidents; but when the rates were calculated these counties had the lowest ranks. The Northeastern Illinois, except the Chicago Metropolitan Area, Central Illinois, and Southern Illinois seemed to have higher fatal accident and fatality rates.

The analysis of variance (ANOVA) provided that districts differ from each other on population-based fatality rate. Pair-wise comparisons among the districts indicated that statistically significant differences exist between the district pairs 3-4, 3-5, and 5-8. Further analysis of the differences among the districts, summarized in Table 3, did not provide distinct patterns of the socioeconomic and demographic characteristics.

Table 3. Detailed Comparison of Districts

	Mean Fatality Rate for 100,000 Residents								
Districts	1	2	3	4	5	6	7	8	Significantly Different Variables
	8.3	15.4	23.9	15.8	14.1	19.8	17.7	21.0	
1*									
2									-
3		-							-
4		-	+						-
5		-	+	-					Median Income
6		-	-	-	-				-
7		-	-	-	-	-			-
8		-	-	-	+	-	-		Unemployment

* District 1 is the Cook County and has not been included in ANOVA
\+ Indicates statistically significant fatality rate between the districts

Different fatality rates and a set of the most prominent socioeconomic and demographic variables that may influence fatal accident rates were mapped in order to investigate geographical similarities and distinct aggregation schemes. This would help further investigating the effect of socio-economic factors by analyzing the differences in fatalities and fatality rates among these new zones. Figures 5 to 8 display some of the variables considered. However, within a multivariate context, this mapping exercise did not provide a particular scheme for aggregation.

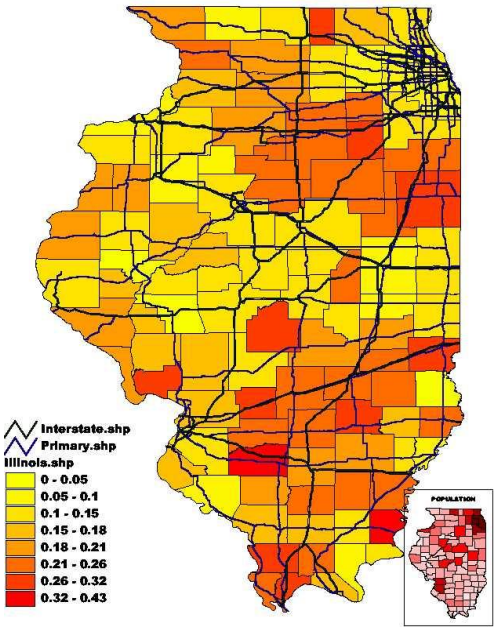

Figure 5. Distribution of Population Based Fatality Rate in Illinois

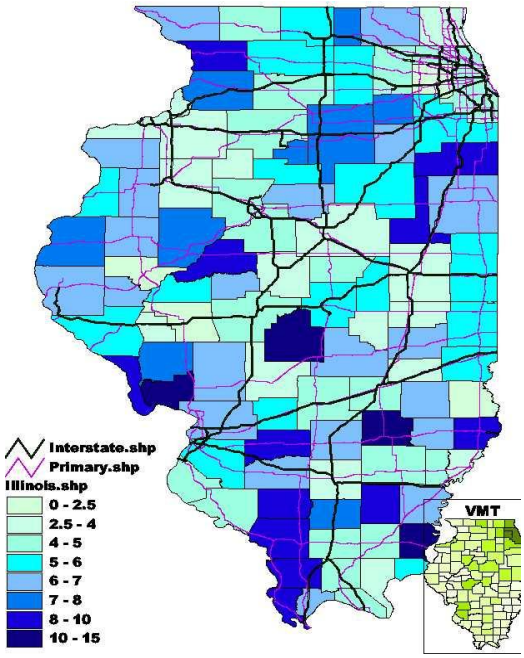

Figure 6. Distribution of VMT Based Fatality Rate in Illinois

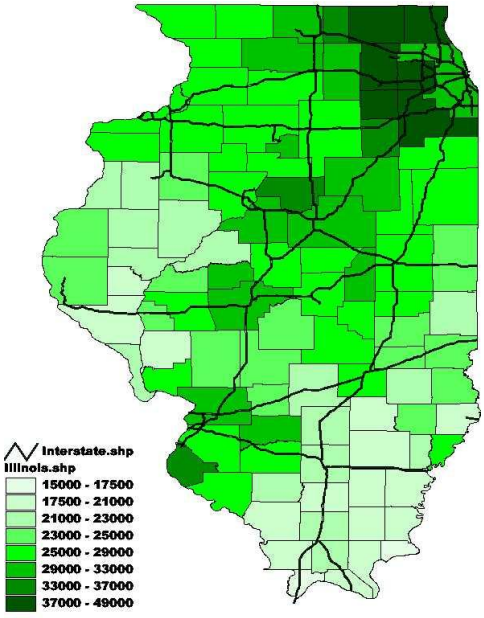

Figure 7. Distribution of Median Income in Illinois

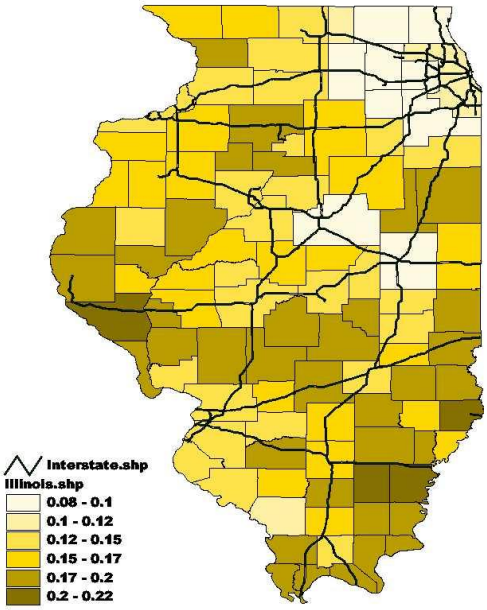

Figure 8. Distribution of Population of Persons Older than 65

In order to examine the regional effects in more detail, counties were also grouped together, statistically, based on their scores on several socio-economic and demographical factors. The scores on level of median income, population density, highway-network mileage, unemployment levels, and percentage of the population older than 65 were used to create socioeconomically and demographically distinct ensembles of counties. Three clustering schemes were developed with 4, 5 and, 6 clusters utilizing clustering algorithms in cluster analysis. Figure 9 displays the first two sets of the ensembles. The differences among the clusters on the number of fatal accidents, population-based fatality rate, and VMT-based fatality rate were analyzed by ANOVA where significant differences would indicate that socio-economic and demographic attributes affect fatalities and fatality rates. Table 4 summarizes the results.

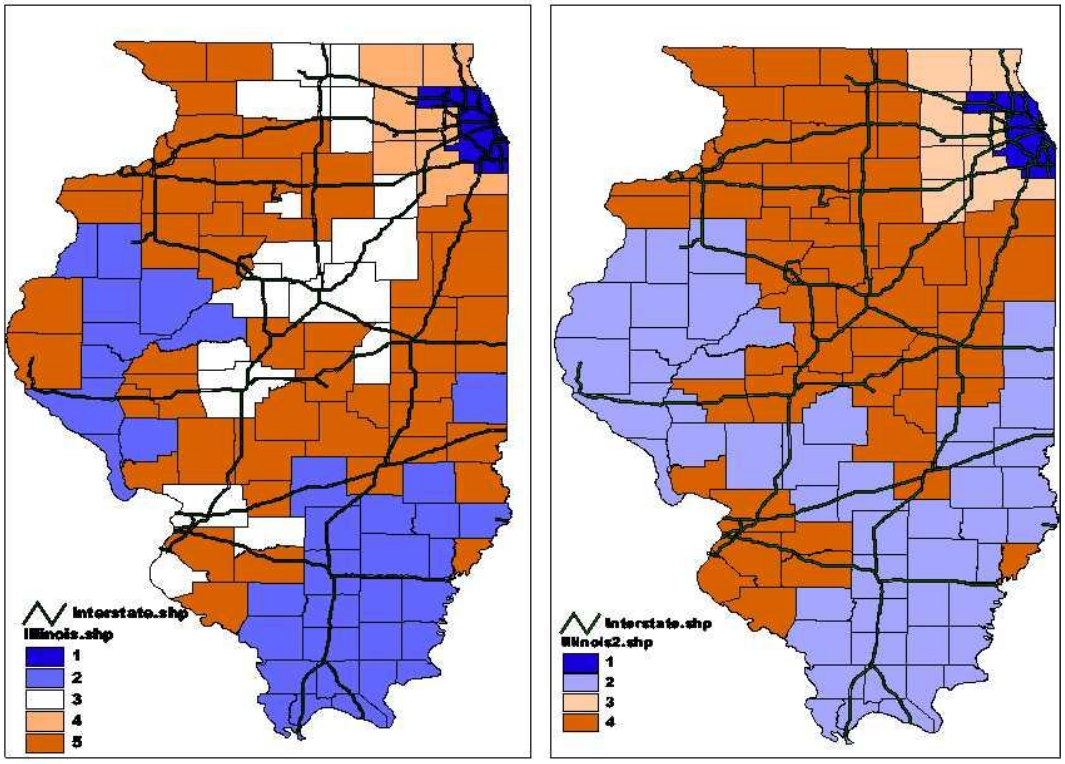

Figure 9. Ensembles with 5 and 4 Clusters

The clusters were found to have statistically significant differences only on the number of fatal accidents. Furthermore, the results of non-significant differences indicated that the effect of socio-economic and demographic factors on fatality rates were not observable at county level.

Table 4. ANOVA Summary for Different Clustering Schemes

Schemes	FATLCRSH		FATRATE		VMTFTRAT	
	F	Sig.	F	Sig.	F	Sig.
6 Clusters	30.68	0.000	1.159	0.334	1.635	0.172
5 Clusters	34.27	0.000	0.525	0.213	2.110	0.104
4 Clusters	39.53	0.000	0.801	0.452	1.266	0.286
Districts	12.22	0.000	2.986	0.010	1.169	0.330

* Cook County appears as a separate cluster and not included in ANOVA

5. ANALYSIS OF THE IMPACT OF POLICY CHANGES ON FATALITIES

The third major task of the project was building a forecasting model for studying the trends in fatalities and fatality rates and the one of the early stages of this task is to analyze the trends in fatalities and fatality rates. For that purpose, the trend in the number of fatalities in the last 25 years was plotted and the behavior of the trend was studied. The plot of fatalities against time in Figure 10, indicates an overall decline, while peaking at 2126 in 1977, there were 1456 fatalities in 1999. During the study period, an average of 1675 people died in motorway crashes in each year.

The annual fatality trend has a fluctuating pattern with an increasing frequency and decreasing amplitude. 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 broken line in Figure 10 represents the overall pattern. The remaining plots also display similar characteristics. Note that the "Injuries" plot only indicates number of injuries in "fatal" motorway crashes.

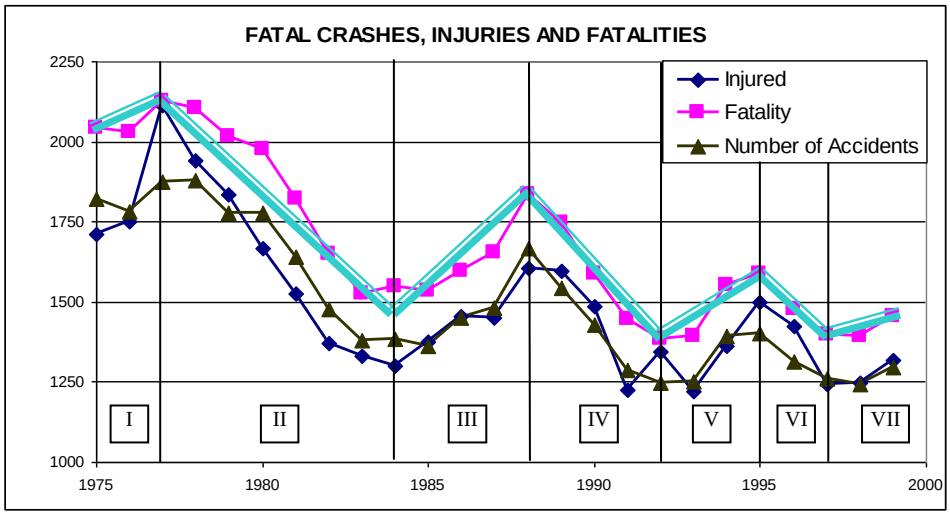

Figure 10. Trends in the Number of Fatal Accidents, Fatalities and Injuries

One of the first steps in analyzing a trend was to search for significant changes after an important date for the concept under study. For that purpose, the study period was divided into seven periods in which the trend is either increasing or decreasing, and important dates of policy changes relevant to traffic safety were obtained, see Table 5. Each segment of the trend is discussed acknowledging these important events.

Table 5. Important Events and Dates for Traffic Safety in Illinois

Periods	Trend	Years	Descriptions
Period I	Increase	1973	19-20 year-olds are allowed to purchase beer and wine
		1974	Maximum speed limit was reduced to 55 mph.
Period II	Decrease	1980	Legal drinking age is established as 21 for all types of alcoholic beverages
		1982	Legal BAC was established as 0.10 & penalties were toughened
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

Period I (1975-1977)

The first period covers the first three years of FARS analysis period where a slight increase in fatalities (less than 5%) was observed, however, the mean is the highest. During this period, there were no significant changes in the policy regarding to traffic safety.

Period II (1977-1984)

During the second 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. These changes seem contributing to the decline in the fatalities, however, this claim must be studied in detail in order to draw more reliable conclusions. This period also corresponds to the time of 1979 oil crisis. In order to better contemplate the impact of this period, daily VMT in Illinois is plotted against time in Figure 11. Starting from 1977, VMT showed some decline and started to pick up in 1980 and 1977 VMT level was reached 1983. While the decline in fatalities can be associated with the change in the VMT, the behavioral aspects specific to that period might be more influential such as limiting non-mandatory trips, driving at slower speeds for saving fuel.

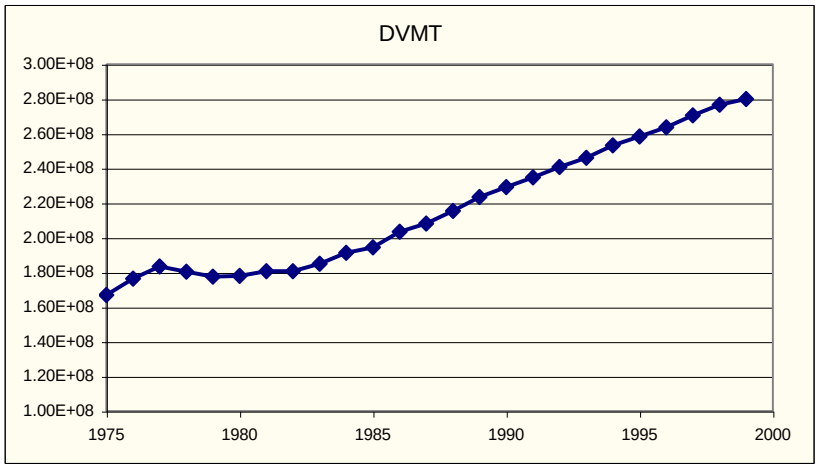

Figure 11. Trends in Daily Vehicle Miles Traveled in Illinois

Period III (1984-1988)

This mid-eighties period witnessed a prominent increase in fatalities slightly lower than 25%. The changes made in the policies in this period intended to improve traffic safety except raising maximum speed limit to 65mph on rural Interstate highways in 1987. The increase in fatalities can be linked to the raise in the posted speeds, however, when the fatality plot was broken by road functional class, it has been seen that the slight increase in the fatalities in the Interstate highways was not comparable to the increase observed in the total fatality plot during this period (Mohammadi et al., 2002).

Period IV (1988-1992)

Throughout the fourth period, fatality numbers showed a decline of approximately more than 25%. The list of important policies for traffic safety does not contain an important policy change leaving this decline trend unexplained with policy impacts.

Period V (1992-1995)

During the fifth period, fatalities increased by nearly 15% while there has no important change in the law and policy until at the end of the period.

Period VI (1995-1997)

Zero tolerance law for drivers under 21 and raises in speed limits on some of the Interstate highways and freeways in 1995 may not seem to cause a 12% decline in total fatalities. Although these changes may affect the fatalities on Interstate highways and fatalities among the young drivers their effect are expected to cancel each other. Furthermore, Mohammadi, et al. (2002) shows that decline in fatalities was observed for all driver age groups.

Period VII (1997-1999)

There was a slight increase (less than 5%) in fatalities during this period. A decline due to reduction of legal BAC to 0.08 might be expected. This was also supported by Voas et al., (2000) which studied the several months after the enactment of the Illinois 0.08 Law. However, Mohammadi et al., (2002) shoes that the impact of the policy was diminished later.

The exercise of searching for a policy impact on the total fatalities did not perform well as might expected. The main reason is that a policy usually targets a specific type of fatal accident such as accidents involving young drivers, drivers with high BAC levels, and so forth, therefore, its impact may not be reflected in total figures. In order to observe such impacts the trends of such special type of accidents and/or involvement of drivers have to be analyzed similarly

Analysis of Traffic Safety Policy Impacts for the Targeted Population

In this section the impacts of a policy change on the motorway fatalities of the targeted portion of the drivers is analyzed in order to establish a baseline for further analysis. The first important change seemed to be the raising the minimum legal age for purchasing alcoholic products in 1980 from 19 to 21. The effect of this policy might be a reduction in total fatalities and in the fatalities of this particular age group. The impact of this change was analyzed by the Intervention ARIMA method (Box-Jenkins, 1976) where the trend of the monthly fatalities of the 16-20 year old drivers was taken into consideration before and five years after 1980. First, a statistical model was built for forecasting fatalities on the basis of historical observations using quarterly fatalities for age 16-20 from 1975 to 1980. Fatalities of the group for the period of 1981-1985 were forecasted by this model. Then, the actual fatalities were compared with forecasted fatalities. The projection period was selected as 5 years since the ARIMA models start to produce larger errors for medium and long-range forecasts. Figure 12 shows graphical representation of these series. The actual fatalities were always less than the forecasted values except 3 out of 20 quarters. It can be concluded that due to the change in the policy resulted in significant reductions in the fatalities of the 16-20 year olds, therefore, the policy had a positive impact on traffic safety.

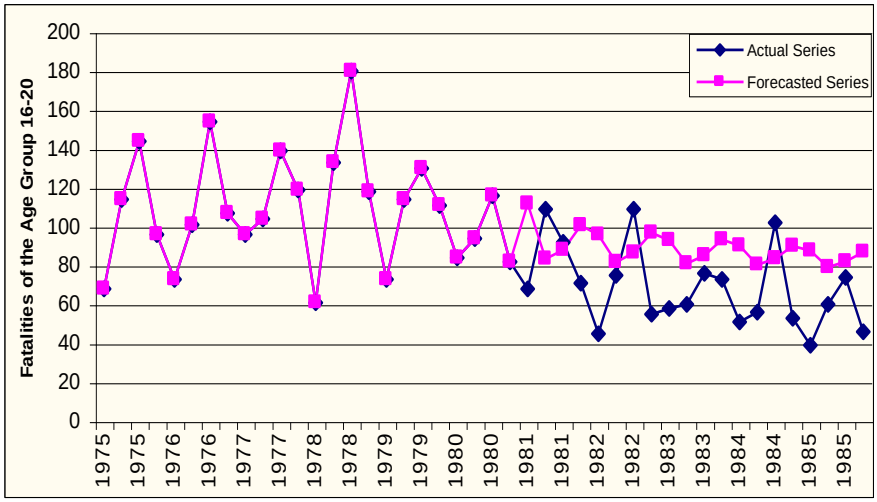

Figure 12. Actual vs. Projected Trends in Fatalities for 16-20 Year Olds

7. CONCLUSIONS

This paper presents findings at two different stages of the project named Determinants Of Motor Vehicle Fatalities And Fatality Rates In Illinois. Based on the findings discussed in the paper, the following conclusions can be drawn:

- Despite an increase in VMT in both Illinois and the nation, accident rate is on a decline.
- The highest number of fatalities occurs in Chicagoland Metropolitan Area, Cook County and neighboring counties.
- Northeastern Illinois, excluding Chicagoland Metropolitan Area, Central and Southern Illinois have the highest fatality rates.
- The effect of socio-economic and demographic factors was not statistically significant at county level analysis.
- The trend in number of fatalities is in decline with a fluctuating pattern with an increasing frequency and decreasing amplitude.
- 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 impact of policy changes on fatalities can not be reliably observed by analyzing the total annual trends.
- Impacts of policy changes are observable when the analysis focuses on the target group of the policy and its time of initiation.

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