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IDENTIFICATION OF COUNTERMEASURES TO REDUCE SEVERITY OF RURAL HIGHWAY CRASHES

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ABSTRACT

This report presents the details of an investigation aimed at finding potential countermeasures to enhance safety of rural highways by identifying critical factors contributing towards higher severity of crashes. Crash data from KARS (Kansas Accident Reporting System) database was analyzed and crash severity was modeled using several statistical modeling approaches. These approaches comprised of ordered choice (ordered probit and ordered logit) and loglinear models. The advantage of ordered choice models is that they are capable of distinguishing the differences between two ranked levels qualitatively, in this case, between two severity categories. A number of contributing factors, which could be categorized as driver related, environmental related, roadway related, vehicular and crash related were considered in the analysis process and critical ones were selected.

Results indicated that many driver related factors such as alcohol involvement, lack of seat belt usage, excessive speed, and driver ejection or being trapped due to the crash are contributory towards increased severity of crashes on rural highways. It also showed that the severities of single vehicle crashes are higher as compared to two- vehicle and animal-vehicle crashes. However, when two vehicles collide, head-on, angle, rear-end, and sideswipe collisions have higher propensity of resulting in higher severities. Roadway geometry related parameters such as curved and graded roads are also contributory towards increased crash severity in rural areas. In contrast, under wet road surface conditions, the probability of having a more severe crash is low. Driver cautiousness under such conditions resulting in reduced speeds might have led to this situation.

Significance of the lack of seat belt usage, alcohol involvement and excessive speed raises the need of strict laws and stronger enforcement against violators. On the other hand, the need of a well-organized agenda to educate the highway users is essential as it is not possible to increase seatbelt usage by enforcement alone. Improvement of roadway geometry and roadside environment at hazardous locations, provision of adequate safety features such as warning and regulatory signs, pavement markings, guardrails, etc. would be essential in improving the safety of rural highways. Improving emergency response time in rural areas would also help to reduce the severity of crashes, particularly fatalities, in rural areas.

ACKNOWLEDGEMENT

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1.0 INTRODUCTION

1.1 Background

In year 2002, about 42,815 people died due to highway crashes in the United States (*1*). About 60% of those fatalities occurred on rural highways, which account for over 75% of the total highway mileage in the USA. However, total vehicle miles traveled on rural highways only accounted for about 40% of total vehicle miles traveled in that year (*2*). In Kansas, the proportion of fatal crashes in rural areas as compared to urban areas is even higher than the national level. In fact, over 75% of total fatal crashes in Kansas highways occurred on rural highways in 2002. These rural highways accounted for 92% of total Kansas highway mileage on which, 53% of total travel occurred (*2*). Furthermore, out of 78,200 of total crashes occurred in that year, rural crashes accounted for only 36%. These figures indicate the important fact that rural highway crashes are more severe as compared to urban highway crashes and thus, safety of the users of these highways is one of the crucial issues in improving safety of the overall highway system.

Even though the above figures emphasize the need of improving safety in rural highway system, still rural highways are getting less attention. There are many reasons, which encumber the efforts in improving the safety of rural highways. One of the major challenges is the lack of enough funding and resources. In fact, while many states are allowed to use their funds in improving safety in any public roads, they are restricted to use them in improving certain rural highway systems. For example, out of $30 billion funds provided by FHWA to all states in fiscal year 2002, only $12.1 billion was utilized on rural highways, which is only 40% of the total amount. On the other hand, local municipal authorities are responsible for maintaining most of these rural highways and they might not be capable of investing large amounts of funds in improving these highways. In some cases, even if enough funds are available, it might be questionable due to the concern on cost effectiveness of investing large amounts of resources as these highways account for less traffic volumes as compared to urban highways (*3*).

In addition, safety of rural highway users becomes more vulnerable due to the delayed response from emergency services. For instance, in Kansas, the average emergency response time in urban areas is about 13 minutes, but the corresponding value for a rural highway crash is about 27 minutes, which is more than double that for urban highway crashes. This may be either due to difficulty in reaching the location or the unavailability of such services at near by places. In some instances, prompt response from emergency services may be hindered by poor communication facilities available in rural areas. In addition, in most of the cases, emergency services in rural areas rely on volunteers and thus they might not be able to provide a better service as skilled and paid staff. This may prevent the accident victims getting proper treatments before admitting to a hospital and eventually resulting in more severe injuries (*3*).

Timely availability of crash data is very important in planning and assessing highway safety programs. However, in some situations, regardless of whether the road is rural or urban, the time taken to upgrade the crash database is considerable and this would make more difficult in making informed decisions on potential highway safety solutions (*3*). On the other hand, the amount of research that has been carried out on rural highway safety is less compared to urban highways. The reason may again be due to lack of enough funds and low traffic volumes occurring on these highways. This may lead to lack of detailed information for highway agencies to work on improving safety features of these highways.

One way of addressing the highway safety issues related to rural highways is by trying to reduce the crash occurrences by implementing necessary countermeasures. The other way is trying to reduce the severity of crashes. However, these two methods could only be applied if relevant factors, which contribute towards the occurrence and increased severity of crashes, are known. Consequently, it is necessary to identify these contributing factors. Previous studies have indicated that these factors could mainly be categorized as driver, environmental, roadway and vehicular or crash related.

1.2 Objectives of the Study

Although numerous attempts have been made to address the highway safety issues through statistical analysis methods, comparatively fewer studies have been carried out on rural highways. Thus, the main objective of this study was to identify contributing factors that are likely to affect severity of rural highway crashes. Several statistical modeling approaches were made in this process and five types of contributing factors, driver, environmental, vehicular, highway and crash related, were considered. The statistical models used in this study comprised of ordered choice (logit and probit) and loglinear modeling structures. Once the critical factors were identified the next phase of this study was to identify necessary countermeasures to address those factors, which may be useful in reducing severities of rural highway crashes.

1.3 Outline of the Report

The first chapter of this report consists of an overview of the study including details about past studies on this area. The next chapter includes description about the methodology adopted in modeling crash severity with relevant contributing factors. This chapter also includes a description about the preliminary analysis of crash data and the selection of variables for the statistical models. Chapter 3 presents the results from preliminary analysis and statistical models and discussion about the results. The next chapter consists of details of suggested countermeasures and Chapter 5 consists of summary and conclusions of the study.

1.4 Literature Review

Many researchers have made attempts in developing the association between contributing factors towards highway crashes, namely highway user attributes, roadway related factors, environmental effects (i.e. bad weather, light condition, etc.) and vehicular related factors, and the propensity to be involved in a crash. Various statistical approaches have been utilized in this process. Shankar et al (*4*) have applied nested logit structure to successfully model the accident severity and relevant contributing factors. The factors comprised of driver related factors, roadway geometry and surface condition, environmental conditions, and collision type whether single vehicle, two-vehicle or multi-vehicle. The advantage of this method is that the effects of unobserved terms could be avoided as they are cancelled off in the estimation process. They have found that severities resulting from run-off-the-road crashes, angle crashes, truck-passenger car crashes, crashes with fixed objects and crashes occur on curved roads as high. In addition, driver attributes such as male drivers, lack of restrain system usage and alcohol involvement, tend to increase the severity of the crash. Abdel-Aty et al (*5*) have applied this nested logit structure to investigate the effect of lead vehicle's size on the rear-end crash configuration. They have calibrated different logit nests to estimate the probabilities of four rear-end crash configurations as a function of driver age and gender, vehicle type and maneuver, light condition, visibility of the driver and speed.

In another attempt by Ulfarsson et al (*6*) have applied the nested structure using multivariate multinomial logit models in modeling the effect of gender of the occupant on the severity of injuries they suffered in SUV, minivan, Pickup and passenger car crashes. They have considered 14 different driver-injury severity modeling structures for males and females in single and two vehicle crashes involving SUV, minivan and passenger cars.

As many influential factors in highway crashes are categorical or dichotomous variables many researchers have employed categorical data analysis approaches in their studies. A logistic regression modeling approach has been applied by Dissanayake et al (*7*) to investigate influential factors towards older drivers in highway crashes. All four types of influential factors, driver, environmental, vehicular and highway related, have been used in their attempt to model the injury severity. This logistic regression method has been applied by many researchers. Farmer et al. (*8*) have studied the rollover risk of cars and light trucks using logistic regression method while Krull et al (*9*) have applied this method to study injury effects of rollovers and events sequence in single vehicle crashes.

In almost all the crash reporting data bases, the crash severity is reported in three or more categories, fatal, incapacitating, property damage only, etc. and thus makes it possible of ordering the severity level from most severe to less severe. In other words, the severity, the response variable in the model, could be considered as an ordinal variable. This phenomenon has been applied to model the injury severity using both ordered probit and ordered logit models by O'Donnell et al (*10*). In this study, they have considered comparatively higher number of contributing factors, not like in many other studies, to model the injury severity. They have revealed that factors, such as alcohol involvement, lack of seatbelt usage, occupant being female and excessive speed are significant towards increased injury severities. According to their study, both ordered probit and ordered logit methods are found to produce similar outputs in modeling injury severity though the magnitudes of the estimations are different.

Khattak et al (*11*) have applied an ordered probit modeling approach in their study to investigate the relevant factors towards injury severities to older drivers. Khattak et al (*12*) have applied both ordered probit and binary probit modeling approaches in investigating risk factors in large truck rollovers and injury severity due to single vehicle crashes. In this approach, binary probit models have used to estimate rollover propensity of large trucks while ordered probit models have used to model the injury severity. This ordered probit modeling method has also been applied by Kockelman et al (*13*) in their study to investigate the contributing factors towards highway crashes in terms of injury severities sustained by drivers, and Ma et al (*14*) have applied this method to study the relationship between occupant injury severities and relevant contributing factors. The study Conducted by Duncan et al (15) to study the injury risk in truck-passenger car rear-end collisions is another application of the ordered probit modeling structure.

Kim et al (*16*) have applied log-linear models in their attempt to investigate the contribution of personal and behavioral factors towards injury severity in automobile crashes. They also have applied this method to study the effect of age, sex and vehicle type towards the driver being fault for the crash (*17*). Abdel-Aty et al (*18*) have applied the log-linear method in their study to reveal the effect of driver age on crash involvement. However, this method is less applicable in a situation where there is large number of explanatory variables (influential factors) in consideration due to the sophistication of interpreting the outcomes.

A negative binomial modeling approach has been applied by Shankar et al (*19*) to study the effect of roadway geometrics (horizontal and vertical alignments) and environmental factors such as weather and other seasonal effects. Miaou (*20*) has considered three modeling structures to evaluate the performance of Poisson and negative binomial regression models in studying the relationship between truck accidents and roadway geometric design.

A quasi-induced exposure method has been applied by Nikiforos et al *(21)* in their study to investigate casual factors for crashes in Southeastern low-volume rural roads. In this method, a ratio called relative accident involvement ratio (RAIR) has been derived to measure the crash propensity. The RAIR is the ratio between percentage of at-fault drivers per vehicles for a given set of highway characteristics to the percentage of not-at-fault drivers per vehicles for the same set of characteristics.

Once critical factors, which contribute towards high severity crashes in rural highways, were identified, the next objective of this study was to identify potential countermeasures to address those factors. This process was based on both knowledge on past studies and suggestions, which were made based on model outputs. Agent et al. (*22*) have developed a set of potential countermeasures to address fatalities in rural highways. In their study, the suggestion of countermeasures was based on detailed analysis of some selected fatal crashes on two lane rural highways in Kentucky but not based on any statistical analyses. The identified countermeasures mainly comprised of two categories, roadway related and non-roadway related countermeasures. The roadway related countermeasures included that are related to improvements to be made to the roadway geometry and roadside environment. Non-roadway related countermeasures were further divided into legislation, enforcement and education. In the second phase of this study, they have conducted a countermeasure effectiveness assessment to evaluate the effectiveness of the implemented countermeasures. According to this study, enactment of a mandatory seat belt law was the most potential countermeasure in reducing the fatalities in rural highways. As far as roadway related countermeasures are concerned, installation of centerline or shoulder rumble strips and the provision of chevron signs are the most effective countermeasures in reducing fatal crashes, according to the effectiveness study.

Washington et al. *(23)* have developed a Countermeasure Handbook, which includes potential countermeasures to address rural highway safety issues in their study to investigate fatal motor vehicle crashes on two lane rural highways in Georgia. In the first phase of this study they have evaluated some selected fatal crashes to study the nature of those crashes. In the second stage they have developed potential countermeasures through a technical approach. This approach was a combination of past knowledge of countermeasure effectiveness and new knowledge of engineering evaluation of some roadside countermeasures assessed for the selected fatal crashes. In this approach they have applied Bayesian techniques to asses the countermeasures. This handbook includes only countermeasures, which are related to engineering-based improvements to the highway system. In fact, it does not include any countermeasures related to legislation, enforcement or education/training though they might be crucial in addressing highway safety issues. The proposed countermeasures mainly comprised of, pavement marking, traffic signs, roadway and roadside improvements, lighting and regulations (speed enforcements).

Agent et al. *(24)* have developed accident reduction factors, which are associated with various types of highway improvements, to evaluate the effectiveness of countermeasures. The development of these reduction factors were based on information from surveys and review of literature on past studies. After evaluating data from survey and literature review, they have developed a set of general accident reduction factors.

The study carried out by Huang et al. *(25)* to identify severe crash factors and countermeasures provides set of countermeasures to address safety issues associated with crash factors, which have been identified as critical towards severe crashes in this study. Those factors includes, crashes at curved roadways, run-off-road crashes, crashes with utility poles and trees, head-on crashes, pedestrian and bicycle crashes, crashes occur in dark, and alcohol involvement. Thus, the suggested countermeasures are intended to reduce the occurrence of severe crashes associated with these factors. It comprise of both roadway related and non-roadway related countermeasures.

2.0 METHODOLOGY

2.1 Preliminary Analysis of Crash Data.

The crash data used in this study was extracted from the KARS (Kansas Accident Reporting System) database. The KARS consists of data for highway crashes occurred in all public roadways in Kansas and reported by the police officers. The total data set consisted of highway crash data for 1993 to 2002 and each record contained driver, vehicular, roadway, environmental related details and crash related details like crash type, time of occurrence, emergency response details, etc. In addition, each individual injury severity resulting from the crash has been categorized into five levels, namely, fatal, disabling/incapacitating, non-incapacitating, possible, and property damage only (no injury). Thus, the severity of a crash was identified according to the highest injury severity sustained by an involved person due to the crash. For instance, if there is at least one fatality resulting from a crash, then it is defined as a fatal crash and, when there is at least one incapacitating injury but no fatalities then it is classified as an incapacitating injury and so on.

Before going into much detailed analyses, a preliminary analysis of crash data was carried out to study the characteristics of rural highway crashes. In addition, since the total number of records in the database was high, it was necessary to select a subset of this database for statistical analysis and modeling, as it is not possible to use extremely large data sets due to the stability restrictions of the software used in this analysis. The separation of rural and urban highway crashes was based on the functional class of the highway on which the crash had occurred. Mainly, the frequency of annual crash occurrence was considered under various categories such as driver related, environmental related, vehicular related, highway related and other crash related factors in this analysis. In addition, crashes were categorized into three severity levels for simplification such as, fatal crashes, injury crashes (incapacitating, non-incapacitating and possible) and no-injury crashes. Results of this analysis are given in the tables in Appendix and further discussions on those results are given in Chapter 3 of this report.

2.2 Selection of the Data Sample

According to the preliminary analysis results, the trend of crash occurrence increased till 1998 and then showed some steady pattern (Fig. 3.1). The selection of data sample for modeling was based on these results and changes that have been made to the crash database (coding system) and variations in other characteristics over time. For example, all aspects of the transportation system including vehicles, attitudes of drivers, and knowledge of highway users could have been changed over a long period of time. By considering all these factors into account, data from 1998 to 2002 was selected for the purpose of statistical modeling. As the objective of this study was to focus on rural highway crashes, such records were extracted from the KARS database. Each crash record contained driver, vehicular, roadway, environmental related details and other crash related details like crash type, time of occurrence, emergency response details, etc.

In the data extraction process, the crash records related to more than two vehicles, pedestrians and trains were discarded from the selected data set. The reason is that the nature of these crashes is different from other types of crashes considered in this study and, their frequencies are comparatively much smaller. Eventually, after discarding missing data fields, the final data set comprised of 93,145 records. Although this may lead to the argument that the total sample size is too large, it was decided to continue with this dataset as this might lead to circumvent any biases resulting from smaller frequencies in some severity categories. On the other hand, large sample size would minimize errors caused by any assumptions made in the modeling process. For example, the normality assumption of the error distribution assumed in this study could be considered as reliable since the sample size is large. Part of the selected data sample was randomly selected and used for calibration of the model

2.3 Variable Selection

The review of past studies indicated that in most of the cases the attention has mainly been focused on studying safety issues related to a specific area, such as, a particular group of highway users (older or younger drivers, users of a particular vehicle type) or a particular crash type (single vehicle crashes, rear-end crashes) (5, 6, 7, 8). In such cases, number of variables (or contributing factors) considered has rather been limited. Instead, this study considered all of rural crashes and thereby tried to include many variables, as long as they are significant in making a difference in the outcome. On the other hand, the quality of the statistical model could be expected to a certain level as the number of variables increases.

The candidate factor selection process was based on both prior knowledge from previous studies and on the presumption that a particular factor would be significant towards the crash severity. Thus, the selected candidate vector of explanatory variables comprised many variables, some of which may or may not be critical in assessing the crash severity. The selected factors were categorized into driver-related, environmental-related, highway-related, vehicular-related and crash-related related factors such as emergency response time, time of the crash, crash type. Table 2.1 shows some important characteristics of the crash data utilized in the modeling process and the selected factors and their representation in the model are shown in Table 2.2.

It should be noted that, selection of some variables, which were believed to be important, was restricted by inadequate availability of data in the database. One such variable was the estimated travel speed of the vehicle at the time of the crash. However, many studies (4, 7, 10, 11) have identified the travel speed of the vehicle as a significant variable towards the severity of the crash. Thus, the posted speed limit at the location of the crash was considered instead of travel speed of the vehicle. However, this may lead to over-estimation or under-estimation of the corresponding parameter (generally under estimation). Based on limited amount of travel speed data, it was seen that, in about 62% of crashes the travel speed was at or above the posted speed limit. Thus, this assumption could be regarded as satisfactory. However, some other variables, such as initial impact point of the vehicle could not be considered in the modeling process due to the lack of detailed information related to those variables in the electronic database.

TABLE 2.1 Important Characteristics of Crash Data Used in Modeling

Factor		Crash Severity					Total	% *
		Fatal	Incapacitating	Non-incapacit-ating	Possible	No Injury		
Light Condition	Day Light	542	1,779	6,181	5,010	29,305	42,817	45.97
	Dark	465	1,095	4,199	3,126	41,443	50,328	54.03
Crash Type	Overturn	239	573	1,749	1,146	2,621	6,328	6.79
	Two-vehicle	498	1,097	3,437	3,022	17,882	25,936	27.84
	Animal-Vehicle	8	72	609	792	34,961	36,442	39.12
	Fixed Object	262	1,132	4,585	3,176	15,284	24,439	26.24
Location	Intersection	242	703	2,523	2,033	10,140	15,641	16.79
	Off the roadway	737	2,057	7,406	5,709	57,614	73,523	78.93
Roadway Related	Curve / grade	445	1,240	4,215	3,076	23,013	31,989	34.34
	Surface wet	127	458	2,014	1,716	13,149	17,464	18.75
	Interstate	68	433	1,193	807	7,041	9,542	10.24
	Arterial	510	1,253	3,574	2,906	27,516	35,759	38.39
	Collector	296	746	3,188	2,434	21,212	27,876	29.93
	Local	133	442	2,425	1,989	14,979	19,968	21.44
Speed (mph)**	1 - 26	7	32	172	224	2,849	3,284	3.53
	26 - 51	86	334	1,873	1,637	12,646	16,576	17.80
	51 - 76	914	2,508	8,335	6,275	55,253	73,285	78.68
Emergency Response Time (min)	<5	141	556	2,266	1,991	17,442	22,396	24.04
	5 -15	457	1,450	4,889	3,471	23,586	33,853	36.34
	15-60	383	829	2,996	2,502	26,041	32,751	35.16
	>60	26	39	223	169	3,635	4,092	4.39
Driver Related	Driver ejected/trapped	706	951	846	216	72	2791	3.00
	Seat belt not used	720	1,477	3665	2,138	7,536	15,536	16.68
	Driver at fault	852	2,332	7,568	5,203	24,470	40,425	43.40
	Alcohol /drug Involved	270	515	1,166	559	1,428	3,938	4.23
Total		1,007	2,874	10,380	8,136	70,748	93,145	100.00
Percentage		1.08	3.09	11.14	8.73	75.95	100.00	

** based on total number of crashes*
*** 1 mph = 1.6 kmph*

TABLE 2.2 Explanatory Variables Considered for Modeling Purpose

Variable	Mean	Description
ACC_TIME	-	Time of the crash in 24 hr clock
ALCOHOL	0.04	=1 if alcohol or drug involved, =0 otherwise
ANGLE_CR	0.11	=1 if two vehicles collide angle, =0 otherwise
ANM_VEH_CR	0.39	=1 if an animal-vehicle crash, =0 otherwise
ARTERIAL	0.38	=1 if occur on an arterial, =0 otherwise
BLACK_RD_TOP	0.72	=1 if occur on a black road surface, =0 otherwise
COLLECTOR	0.30	=1 if occur on a collector, =0 otherwise
DR_AT_FLT	0.43	=1 if at least one driver is at fault for the crash, =0 otherwise
DR_EJECT	0.03	=1 if at least one driver ejected due to the crash, =0 otherwise
DR_LICENSED	0.97	=1 if driver has a valid license, =0 otherwise
DR_MALE	0.57	=1 if the driver (both drivers in two-vehicle crashes) is male, =0 otherwise
DR_NO_STBLT	0.17	=1 if at least one driver not used safety equipments, =0 otherwise
DR_OLD	0.12	=1 if driver age (both drivers in two-vehicle crashes) is >55, =0 otherwise
DR_RESTRICT	0.45	=1 if at least one driver complied with restrictions =0, otherwise
DR_YOUNG	0.27	=1 if driver age (both drivers in two-vehicle crashes) is <25, =0 otherwise
HDON_CR	0.01	=1 if a head-on crash, =0 otherwise
INTERSTATE	0.10	=1 if occur on an interstate, =0 otherwise
INTR_SECN	0.17	=1 if occur at an intersection, =0 otherwise
LIGHT_CON	0.54	=1 if crash happens in dark or unlit conditions, =0 otherwise
LOCAL	0.21	=1 if occur on a local road, =0 otherwise
ON_RDWAY	0.21	=1 if occur on the roadway, =0 otherwise
PKTIME	0.12	=1 if occur during 6:45 to 9:00 am, =0 otherwise
RD_CUR_GRAD	0.34	=1 if roadway is not straight and level, =0 otherwise
RDCNT_MNT	0.02	=1 if occur at a construction or maintenance zone, =0 otherwise
REAR_END_CR	0.07	=1 if a rear-ended crash, =0 otherwise
RES_TIME	27	Emergency response time in minutes
RES_TIME_BINARY	0. 29	=1 if response time <= 5 minutes, =0 otherwise
ROLLOVER_CR	0.07	=1 if a rollover crash, =0 otherwise
SIDESWIPE_CR	0.04	=1 if a sideswipe crash, =0 otherwise
SNG_VEH_CR	0.33	=1 if a single vehicle crash, =0 otherwise
SPEED	55.12	Speed limit in mph*
TWO_VEH_CR	0.28	=1 if a two-vehicle crash, =0 otherwise
VEH_AT_FLT	0.02	=1 if at least one vehicle is at fault for the crash, =0 otherwise
VEH_AUTMBLE	0.94	=1 if at least one vehicle is an automobile, =0 otherwise
VEH_KS	0.86	=1 if vehicle (both vehicles in two-vehicle crashes) is registered in Kansas, =0 otherwise
VEH_MNR_STGT	0.72	=1 if vehicle (both vehicles in two-vehicle crashes) maneuver is straight before crash, =0 otherwise
WEEK_DAY	0.71	=1 if occur on a weekday, =0 otherwise
WET_RD_SURF	0.19	=1 if the road surface wet, =0 otherwise

*** 1 mph = 1.6 kmph*

2.4 Statistical Analysis

2.4.1 Loglinear Models

Initially, two types of statistical models were developed in this study, ordered logit and probit models and loglinear models. The first modeling approach was based on loglinear modeling structure. A loglinear model is capable of describing the interaction and association among a set of categorical variables *(18)*. However, according to Kim et al *(17)* when one variable is considered as a response or dependent variable, a logit model is more capable of describing the effect of set of independent variables (contributing factors) on the dependent variable, the injury severity in this case. The derivation of logit model from loglinear model is straightforward. However, when the number of explanatory variables or contributing factors is large, as the case in this study, this method becomes more sophisticated and the interpretation of results is not straightforward. Thus the explanation of this method and the interpretation of model outputs are omitted from this report.

2.4.2 Ordered Choice Models

As shown in the Table 2.2, most of the variables in this study are dichotomous variables, except speed, emergency response time and crash time. The dependent variable or the response variable in this case is the crash severity. When a variable can be ranked or ordered but the difference between two levels is unknown such a variable is called an ordinal variable. The response variable in this study, crash severity, can also be ordered as fatal, disabling/incapacitating, non-incapacitating, possible and no injury (PDO) and thus it can be considered as an ordinal response variable. Long (*26*) has discussed the applicability of ordered logit and probit models in analyzing this type of data. These ordered choice models are capable of capturing the qualitative difference between two ranked levels, in this case, between two crash severity levels (*12*).

The difference in ordered logit and ordered probit structures is the difference in distribution assumptions for the unobserved error term. In probit modeling process the error term is assumed to be normally distributed with mean 0 and variance 1 while for the logit model the logistic distribution is assumed with mean 0 and the variance of $p^2/3$, where p= 3.143. Although these methods are based on two different assumptions, they have been found to produce similar results (*10*).

The derivation of the ordered model is based on the measurement model (*26*),

$$y_i = m \qquad if\ \tau_{m-1} \le y^* < \tau_m \text{ for m = 1 to J} \tag{1}$$

where y* is the injury risk, which is an unobserved continuous variable called latent variable ranging from $-\infty$ to ∞, which is mapped to an observed variable *y*. The τ values are called thresholds or cut off points and the extreme categories at *m*=1 and *m*= J are defined by open-ended intervals with $\tau_0 = -\infty$ and $\tau_J = \infty$. According to the measurement model the variable y is thought of as providing incomplete information about an underlying y*.

Then the structural model can be considered as,

$$y^* = x_i \beta + \varepsilon_i \tag{2}$$

where x_i is a row of a vector of explanatory variables with a 1 in the first column for the intercept and the i th observation for x_k in the k+1 column. β is a vector of parameters to be estimated and ε_i is the error term which is assumed to be normally distributed. However, the KARS database does not comprise of any information on injury risk, *y** as it is unobserved, but it includes details on the variable *y*, which is observed at different levels of *y** at which, y =1 if there are no evident injuries, y =2 if the crash results only possible injuries, y=3 when the crash is non-incapacitating, y = 4 if it is a incapacitating crash and y=5 when crash is fatal. Thus, the measurement model can be illustrated as,

$$y_i \begin{cases} 1 \text{ (No injury)} & \text{if } \tau_0 = -\infty \le y^* < \tau_1 \\ 2 \text{ (Possible)} & \text{if } \tau_1 \le y^* < \tau_2 \\ 3 \text{ (Non-incapacitating)} & \text{if } \tau_2 \le y^* < \tau_3 \\ 4 \text{ (Incapacitating)} & \text{if } \tau_3 \le y^* < \tau_4 \\ 5 \text{ (Fatal)} & \text{if } \tau_4 \le y^* < \tau_5 = \infty \end{cases} \tag{3}$$

where the threshold values τ_1, τ_2, τ_3 and τ_4 are parameters to be estimated. According to the measurement model the probability that the ith victim of crash, suffer injury severity level of *m*

(m = 1 to 5) is the probability that the injury propensity y^* takes a value between two cut off points. That is,

$$\Pr(y_i = m|x_i) = F(\tau_m - x_i\beta) - F(\tau_{m-1} - x_i\beta) \quad (4)$$

where $F(x)$ is the cumulative distribution function of the unobserved error term ε_i evaluated at given x under the assumption that ε_i s are normally distributed with mean zero and constant variance as mentioned previously. For example, the probability that the victim *i* sustain fatal injury due to the crash is,

$$\Pr(y_i = 1 | x_i) = 1 - F(\tau_4 - x_i\beta) \quad (5)$$

It should be noted that to these probabilities be positive the thresholds values should satisfy the order, $\tau_1 < \tau_2 < \tau_3 < \tau_4$ (*27*) .

The estimation of these model parameters can be carried out through the method of maximum likelihood. The log likelihood, which is the logarithm of the likelihood function, can be written as,

$$\ln L(\beta, \tau | y, X) = \sum_{j=1}^{J} \sum_{y_i = j} \ln[F(\tau_j - x_i\beta) - F(\tau_{j-1} - x_i\beta)] \quad (6)$$

where β is the vector of parameters from the structural model, first column consisting of the intercept and τ is the vector of threshold parameters. The procedure consists of maximizing this equation using numerical methods. To make the model estimable either one threshold value, possibly $\tau_1$or the intercept is constrained to be some arbitrary value usually zero. The software used in this analysis assume the intercept $\beta_0=0$ and estimate the other parameters. For more details on parameter estimation of ordered models using maximum likelihood procedure reader is directed to *Regression Models for Categorical and Limited Dependent Variables* (*26*).

The partial change in the probability, that the i^{th} victim sustain injury severity m when a particular influential factor x_k changes, is very useful in interpreting model results. This is called marginal effect or partial change and can be depicted as,

$$\frac{\partial \Pr(y_i = m \mid x_i)}{\partial x_k} = \frac{\partial F(\tau_m - x_i\beta)}{\partial x_k} - \frac{\partial F(\tau_{m-1} - x_i\beta)}{\partial x_k} \qquad (7)$$

In other words, marginal effect is the slope of the probability curve relative to x_k holding all other variables constant. The usual practice is to maintain the other variables in their mean values while changing x_k (*26*). When there are many dichotomous variables, like in this study, the partial change in x_k becomes meaningless. Thus for binary variables, analysis is carried out by taking the difference between two probability outcomes (1 and 0) of x_k, while keeping other variables at their mean value (*26,27*).

The R^2 value, which is called Generalized Coefficient of Determination, is depicted as,

$$R^2 = 1 - \left\{ \frac{L(0)}{L(\hat{\beta})} \right\}^{\frac{2}{n}} \qquad (8)$$

and $$R^2_{\max} = 1 - \{L(0)\}^{[2/n]}$$

where $L(0)$ is the likelihood of the model which includes only intercept terms, $L(\hat{\beta})$ is the likelihood of the specified model with all the significant factors, and n is the sample size (*22*). However, according to Nagelkerke (*28*) this R^2 value achieves its maximum when it is equal to 0.75 for models with dichotomous variables, which is the case in this study, which contradicts with the original definition of the coefficient of determination that it should be in the range of 1 and 0. Thus, he proposed an adjusted value for R^2, called $\overline{R}^2$, which is defined as,

$$\overline{R}^2 = \frac{R^2}{R^2_{\max}} \qquad (9)$$

which has the maximum and minimum values of 0 and 1 respectively.

All the model estimations in this study were carried out by using SAS (Version 8) software *(29)*.

2.4.3 Model Estimation

When the number of variables is large, as in this study, the amount of time and resources for estimating the model is substantially high and sometimes leads to computational burdens. On the other hand, the candidate factor selection process was based on prior understandings but not on any statistical analysis. This raised the need for reducing the number of factors by eliminating non-significant variables. O'Dennell et al (*10*) have used the method of Schwarz Bayesian Information Criteria to accomplish this purpose. This method uses the backward elimination method, which applies the procedure that starts with all the candidate variables in the model and then eliminates one variable at a time by checking the significance of the likelihood ratio. They have further modified this method by only calculating the likelihood ratio for variables with asymptotic t-ratio close to zero to reduce the time consumption. However, even this method takes considerable time when analyzing large number of factors.

Instead of directly using this method, the methods of backward and stepwise selection, built-in facilities of the software (SAS) developed for this purpose, were used in this analysis (*29*). In the backward selection method, the model starts with all the variables and eliminates one variable at a time if the calculated residual chi-square value is non-significant at a given level of significance. In this analysis the level of significance considered was 95%. The stepwise selection method starts with only intercept term but no explanatory variables in the model and adds one variable at a time based on the significance of the residual chi-square test. Once a variable entered in to the model it is tested by backward selection method to make sure it is still significance over the variables already had in the model. Both these methods, stepwise and backward selection, were utilized in the parameter estimation procedure and provided the same results.

In addition to the backward and stepwise selection, the software also provides the capability to do forward selection. In this method, the model starts with no variables and adds one at a time based on the chi-square test results. The disadvantage of this method is that, once a variable is added into the model it is never removed from the model even if its overall effect is not significant. It should be noted that, even though the stepwise selection method used in this study was started with no variable at the beginning, it is also possible to start the model with some specified variables, which are to be kept in the model irrespective of the significance of the variables.

At the beginning of the modeling process, crash severity was modeled using both logit and probit modeling methods. The results showed that both methods were effective in predicting crash severity based on a given set of explanatory variables and thus, both methods seemed to be valid. However, further assessment of model results and model fitting information showed that the probit modeling method was more reliable and is better capable of predicting crash severity. Thus it was decided to proceed with probit method and only the results from probit modeling process are discussed in this report.

Initially, emergency response time was introduced to the model as a continuous variable and the corresponding parameter was estimated. However, the estimated parameter relevant to response time was found to be not explaining its effect correctly towards the crash severity. That is, the estimated parameter for this variable was negative, which explained the effect of emergency response time as, when the time taken to respond by emergency services is increasing the probability of having a more severe crash is decreasing. This seemed to be unreliable and unrealistic and thus, it was decided to introduce this variable into the model in a different manner. Preliminary analysis of crash data indicated that, in 95% of all type of crashes, the emergency services had responded within one hour and 97% of all injury crashes have been covered within one hour. However, there were some cases that the response time was more than even 20 hrs, but all of them were property damage only crashes. This situation may lead to some unreliable predictions. Thus it was decided to apply this variable as a dummy variable into the model to obtain a better explanation of its effect towards the crash severity. Several modeling efforts were carried out using different categories of the response time and the best was selected as shown in Table 2.2.

3.0 MODEL RESULTS AND DISCUSSION

3.1 Preliminary Analysis Results

Detailed results of the preliminary analysis are presented in the Appendix of this report. Figure 3.1 shows the overall (rural and urban) trend of crash occurrence in Kansas for the period of 1993 to 2002.

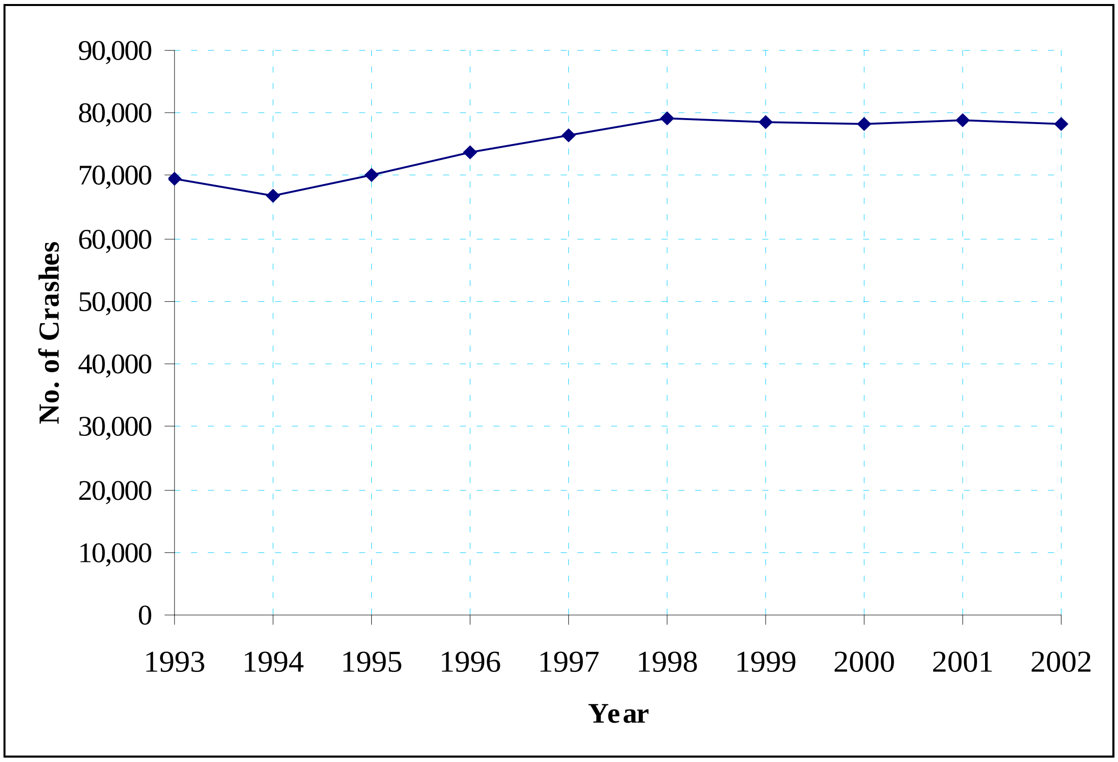

FIGURE 3.1 Trend of Crash Occurrence in Kansas from 1993 to 2002

It can be observed from the Figure 3.1 that the highway crash occurrence trend has been increasing from 1994 for up to 1998 and after that it shows some steady trend. However, the total number of crashes per year is still high, more than 75,000 per year. According to Figure 3.2, the occurrence of both rural and urban highway crashes have been increasing after 1994, but after 1998 rural crash occurrence shows a slight declining trend while number of urban crashes is increasing. This is much clear from the data in Table 1 of the Appendix, as the percentage of rural highway crashes has been declining from 1998.

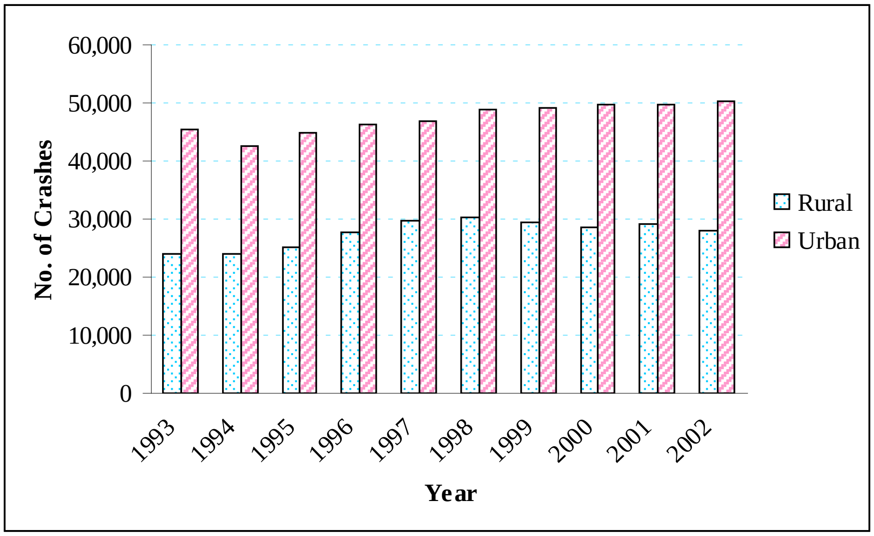

FIGURE 3.2 Distribution of Rural and Urban Highway Crash Occurrence in Kansas

However these figures are completely different for more severe crashes. In fact, as far as fatal crashes are concerned, rural highways accounts for substantially higher amount of fatalities compared to urban highways in Kansas. These numbers follows the same pattern as the average rural highway fatalities in the USA. According to Figure 3.3 and Figure 3.4, annually, rural highways account for 75% of total fatalities on average and, in some particular years, this is even higher than 75%. In addition, according to Figure 3.3, urban highway fatalities show slight declining trend after 1998 while rural highway fatalities are slightly increasing.

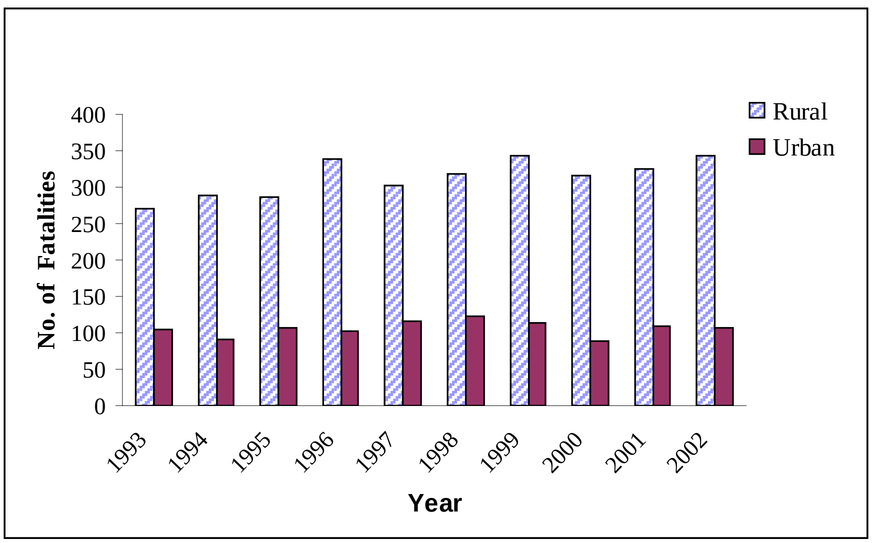

FIGURE 3.3 Distribution of Highway Fatalities in Kansas Rural and Urban Highways

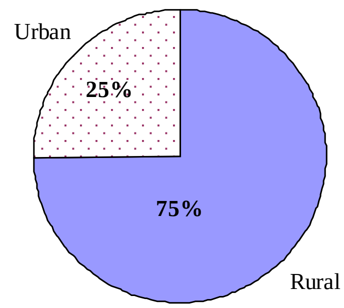

FIGURE 3.4 Average Annual Percentage of Fatalities in Rural and Urban Highways in Kansas

The above comparisons clearly indicate the fact that crashes occur on rural highways are more severe compared to urban highway crashes. Out of all four types of highway classes, interstate, arterial, collector and local roads, arterials and collectors account for comparatively higher number of fatalities. In addition, as shown in the Figure 3.5, number of fatalities that occur on arterials is substantially higher compared to other types. On average, annually 46% of fatalities occur on rural arterials in Kansas while collectors account for 30% of those crashes and local roads and interstates account for only about 17% and 7% crashes respectively.

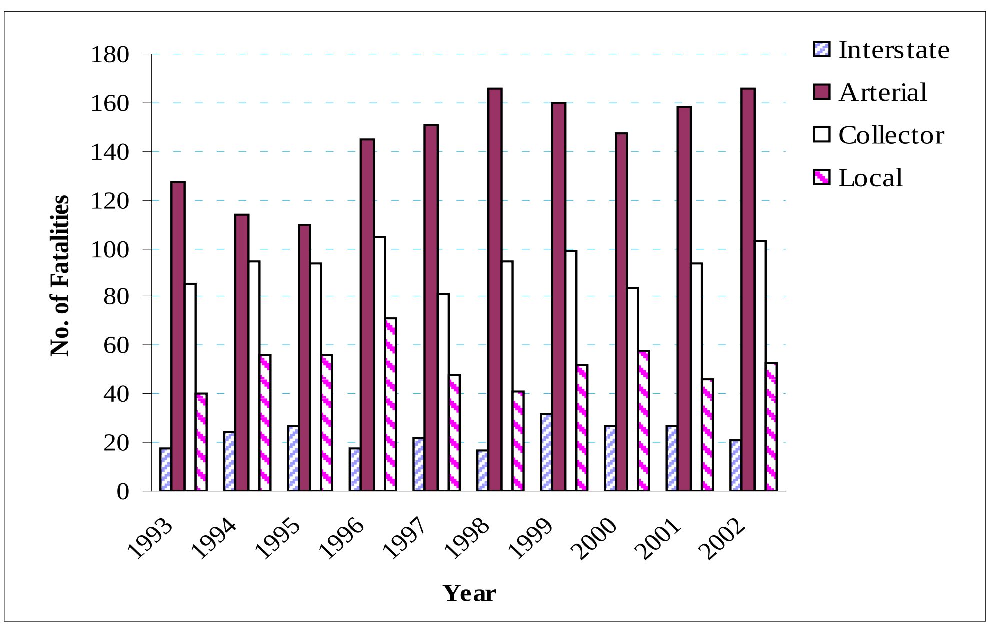

FIGURE 3.5 Yearly Distribution of Fatal Crashes on Different types of Rural Highway Classes

According to findings of many studies, the lack of seat belt usage is one of the critical contributing factors towards more severe injuries in highway crashes, especially for drivers *(11, 7)*. In the state of Kansas, out of total number of fatally injured drivers, about 61 % of those drivers on average are killed due to the lack of use of any safety features in each year. In addition, according to Figure 3.6, there is no declining trend in these fatalities even though many advanced safety features have been introduced.

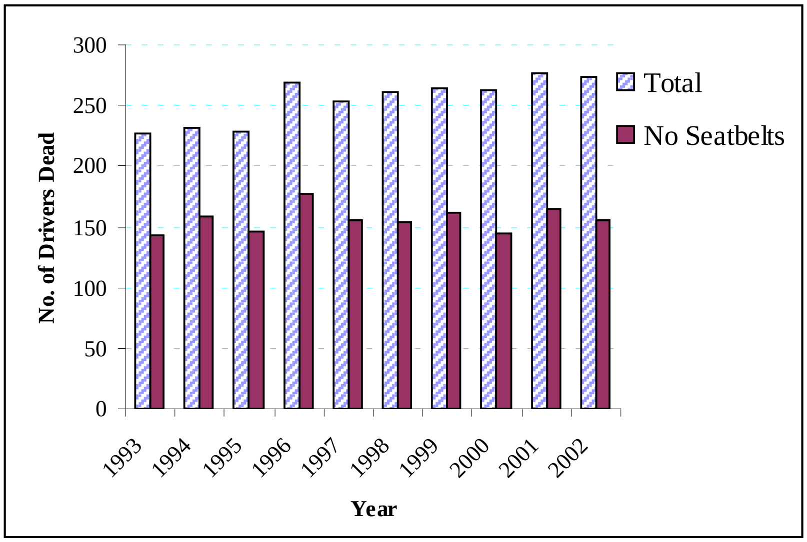

Figure 3.6 Driver Fatalities in Rural Highway Crashes by Seatbelt Usage in Kansas (1993 to 2002)

Another important characteristic of Kansas rural crashes is that very high percentage of drivers are killed due to ejection from the vehicle or being trapped in the vehicle due to the crash. As shown in the Figure 3.7, on average, about 74% of total driver fatalities occur due to the driver being ejected or trapped and this trend has been increasing from year 2000.

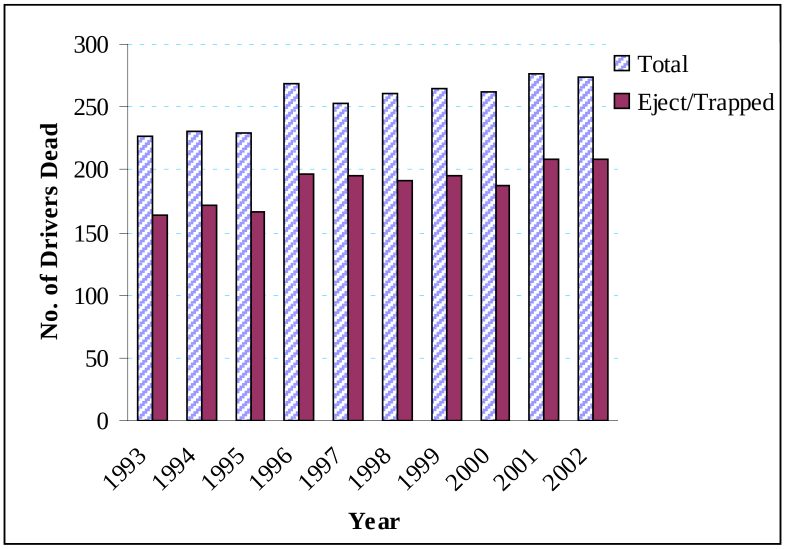

FIGURE 3.7 Driver Fatalities in Rural Highway Crashes by the Status of Driver being Ejected or Trapped (1993 to 2002)

About 34% of rural crashes are single vehicle crashes in Kansas and another 30% accounts for crashes, which involved two or more vehicles. In addition, about 33% of crashes occur due to the collision of vehicles with animals but in most of the cases these crashes are less severe as shown in the Table 8 of the Appendix. Annually, on average, about 50% of crashes occur under daylight conditions in rural highways while 82% of crashes occur when there are no adverse weather conditions. In addition, about 65% of crashes happened on straight and level roadways while in 79% of crashes roadway surface was dry. (Refer Table 4 to Table 7 in the Appendix for more details.)

3.2 Statistical Model Results

3.2.1 Model Fitting Information

The estimated adjusted R^2 value for the final model is found to be 0.38 from Table 3.1. Thus the model is capable of assessing 38% of the variation in crash severity explained by the contributing factors (explanatory variables).

Even though there is no generally accepted method for testing the accuracy of ordered multiple-choice models *(10)*, it is very important to check the prediction accuracy of the developed model. The software used in this study (SAS) produces predicted probabilities for each observation using the fitted model *(29)*. For example, it gives the probability of an observation being a fatal, incapacitating, etc. and the predicted overall severity of the observation is obtained based on the largest individual probability of each severity group. These predicted probabilities were obtained for the data sample, which had been separated from the original data set, using the fitted model. The overall predicted accuracy of the model is found to be 77.9 %. However, the prediction accuracies for different severity categories vary, i.e. fatal (33.6%), incapacitating (16.1%), non-incapacitating (11.5%), Possible (6.1%) and no injury (98.9%).

3.2.2 Model Results and Discussion

Estimated model coefficients using maximum likelihood method for the ordered probit model and the marginal effects are shown in Table 3.1. As the parameter estimation in ordered probit model assumes the injury risk and explanatory variables to be linearly related (equation 2), the interpretation of the parameters should be done accordingly. That is, a positive parameter indicates that the relevant variable has an increasing tendency towards the crash severity, while negative parameter indicates decreasing effect towards the severity. The interpretation of the marginal effects should be carried out based on the nature of the corresponding explanatory variable, i.e. whether it is continuous or binary. When the variable is continuous, a positive marginal effect means, that the probability of occurrence of that particular severity level increases by the magnitude of the particular marginal effect for a unit increase in the explanatory variable from its mean, while holding other variables on their means. For a binary variable, a positive marginal effect implies that, the probability of occurrence of a particular severity level increases by the corresponding magnitude of the marginal effect, when the level of the explanatory variable is changing from 0 to 1. However, it should be noted that, the idea of marginal effects becomes invalid for values of variables, which are very far from its mean.

The following sections consist of discussion on some important variables identified by using model outputs.

Driver Related Factors

The positive estimated parameter, with a statistically significant chi-square value (significant at 95 % confidence level), for the variable 'SPEED' indicates that, when the posted speed limit is increasing, the propensity of observing a more severe crash is also increased. This is in corroboration with findings of several past studies (*10, 7, 11*). This is reflected by positive marginal effects for fatal severity category. In fact, the probability of observing a fatal crash is increased by 0.004 for unit increase in speed from its mean value, while all the other variables remain at their means.

The estimated parameter for the variable related to the lack of driver seatbelt usage, (DR_NO_STBLT), is positive. This implies that, when at least one of the drivers involved in the crash does not use seatbelt, it is more likely to end up as a high severity crash. On the other hand, the model results show that, when the driver is ejected or trapped in the vehicle due to the crash, it would increase the probability of having a higher severe crash. In other words, according to the estimated marginal effects, when the driver is ejected or trapped due to the crash, the probability of having a fatal crash is increased by 0.21 and, when the driver does not use seatbelts, the probability of occurrence of a fatal crash is increased by 0.068.

When a male driver is involved, the severity of the resulting crash is going to be less, since the variable 'DR_MALE' has a negative estimated parameter. This could be due to the fact that, females are generally not much capable of bearing physical or mental trauma resulting in a crash (*10*). In addition, when an older driver (whose age is greater than 55 years) is involved in the crash, it is more likely to end up as a high severity crash compared to crashes, which involve younger drivers.

When at least one of the involved drivers is under the influence of alcohol or drugs, there is a higher probability of resulting in a higher severe crash, as the estimated parameter for variable 'ALCOHOL' is positive. In KARS database the alcohol involvement has been recorded as whether alcohol presented or alcohol contributed towards the crash based on the judgment made by the police officer. However, in some cases there might not be clear evidence available to make the decision whether alcohol contributed towards the crash or not. According to the Kansas

Department of transportation (KDOT), they have revised the rule by introducing the new definition for the alcohol involved crash in 1990 by taking into account both facts, alcohol present or alcohol contributed *(30)*, and thus this new definition was used in this study to define the alcohol involvement in crashes.

When the driver is at fault for the crash, it is more likely to be a high severity crash as model estimation results in a positive parameter for the variable DR_AT_FLT. These driver faults mainly include, failed to yield right of way, improper turning, passing or lane changing, under influence of drugs or alcohol, excessive speeding, disregarded traffic signals or signs, fell asleep or inattention, ill or medical condition. However, when the involved driver has a valid driver license the severity of the crash tend to be low compared to crashes which the involved driver doesn’t have a valid driving license.

<u>Crash Type</u>

The variable related to single vehicle crashes has a positive estimated parameter while variable, which represents two-vehicle crashes, is not significant in the model. Thus, single vehicle crashes tend to be more severe compared to two-vehicle and animal-vehicles crashes. This is indicated by having a positive estimated parameter for the variable related to rollover crashes and negative estimated parameter for the variable related to crashes that occur on the roadway. In other words, when the crash occurs off the roadway, there is a higher chance of resulting in higher severities. However, in the case of two-vehicle crashes, head-on collisions, angle collisions, rear-ended collisions and sideswipe collisions tend to be resulting in higher severities, as model estimates give positive parameters for the variables related to those collision types. Crashes related to animals (animal-vehicle crashes) tend to be less severe in nature. As mentioned in section 3.1, significant amount (over 30%) of rural crashes accounts for animal-vehicle crashes, but most of them are less severe.

<u>Roadway Related Factors</u>

The variable related with the roadway geometry (RDCUR_GRAD) results in a positive parameter. This implies that, if a crash occurs on a roadway, which is not level and straight, the severity of the crash can be expected to be high. In rural highways, drivers might tend to speed up due to the encouraging environment provided by higher allowable speed limits and low traffic volumes occur on those highways compared to urban highways. These higher speeds may reduce the driver's ability to control the vehicle at sharp bends and eventually pulling the vehicle off the roadway resulting more severe crashes. The severity would be even higher when there are fixed objects exists very near to the road way like trees, advertising and utility poles, etc. On the other hand, those low traffic volume conditions might encourage drivers to overtake the vehicle at upgrade road segments and this would result in very dangerous head-on crashes with opposing vehicles.

According to the model results, the probability of having high severity crashes on interstate and local roadways are low as compared to arterials and collectors. On local roads, this may be due to the fact that there are fewer vehicular interactions with other vehicles. On interstates, better highway attributes and physical features combined with more uniform speeds might lead to this situation.

Environmental Factors

The variable related to roadway surface condition, on which the crash occurred, has a negative estimated parameter. That means, when a crash occurs on a slippery road surface (under snowy or bad weather conditions) the severity of the crash is going to be less, compared to crashes that occur on dry road surfaces. Drivers might be paying more attention when driving under severe weather conditions and tend to reduce their speeds, which may lead to reduce the possibility of incurring a crash with increased severity. On the other hand, under these conditions emergency response time might be a critical factor towards the severity of the crash, because in these situations (in bad weather conditions) there is a tendency for having a delayed response from emergency services (*4*). However, in this study emergency response time was controlled in the model, which might indicate the real effects of light condition and weather condition and thus resulting in more reliable estimations.

Vehicular Factors

When the maneuver of the vehicle before the crash is straight and following the road, the probability of having a more severe crash is increased, as the variable 'VEH_MN_STGT' has a positive estimated parameter. The comparison of straight maneuver of the vehicle was made with other types of maneuvers, such as right or left turning, U-turning, overtaking, changing lanes, merging.

According to parameter estimations, when the vehicle (both vehicles in the case of two-vehicle crashes) is registered in the state of Kansas, chance of having a more severe crash is less. This variable was selected with the intention of assessing the effect of driver familiarity with the surrounding. In other words, unfamiliar, out-of-state drivers are more likely to be more seriously injured than in-state drivers.

Emergency Response Time

When the emergency response time is less than 5 minutes, the tendency of having a more severe crash is decreased compared to longer response times, as the model output shows a positive parameter for this variable. However, it should be noted that, there was no hard-and-fast rule in defining this threshold value of 5 minutes. In fact, even though this cut-off value of 5 minutes was come up with the data used in this study, it might be possible to have another threshold value under a different set of conditions. Therefore, a more general interpretation, saying that - longer the emergency response time is higher the probability of having a more severe crash - would be more appropriate. This is confirmed by the marginal probability estimations as the probability of having a fatal crash is decreased by 0.005 when the response time is less than 5 minutes compared to delayed response times.

TABLE 3.1 Maximum Likelihood Estimation of Parameters and Marginal Effects

Factor	Estimated Parameter	Chi-Square Statistic	Marginal Effects				
			Fatal	Incapa-citating	Non-Incapacitating	Possible	No Injury
ACC_TIME	NS	NS	-	-	-	-	-
ALCOHOL	0.180	331.21	0.0488	-0.0019	-0.0187	-0.0078	-0.0204
ANGLE_CR	0.438	695.42	0.1069	-0.0087	-0.0411	-0.0161	-0.0410
ANM_VEH_CR	-0.244	201.50	-0.0976	-0.0637	-0.0598	-0.0172	0.2383
ARTERIAL	NS	NS	-	-	-	-	-
BLACK_RD_TOP	NS	NS	-	-	-	-	-
COLLECTOR	NS	NS	-	-	-	-	-
DR_AT_FLT	0.151	639.95	0.0359	-0.0004	-0.0136	-0.0059	-0.0159
DR_EJECT	0.813	4877.86	0.2135	-0.0276	-0.0735	-0.0262	-0.0862
DR_LICENSED	-0.058	24.45	-0.0138	0.0003	0.0053	0.0023	0.0060
DR_MALE	-0.073	214.97	-0.0174	0.0002	0.0066	0.0029	0.0078
DR_NO_STBLT	0.283	2269.40	0.0684	-0.0037	-0.0263	-0.0107	-0.0277
DR_OLD	0.033	16.09	0.0077	-0.0001	-0.0029	-0.0013	-0.0035
DR_RESTRICT	NS	NS	-	-	-	-	-
DR_YOUNG	NS	NS	-	-	-	-	-
HDON_CR	0.751	1076.58	0.1853	-0.0289	-0.0709	-0.0250	-0.0605
INTERSTATE	-0.068	60.54	-0.0160	-0.0001	0.0060	0.0027	0.0074
INTR_SECN	0.064	26.64	0.0152	-0.0003	-0.0058	-0.0025	-0.0067
LIGHT_CON	NS	NS	-	-	-	-	-
LOCAL	-0.048	47.92	-0.0114	0.0000	0.0043	0.0019	0.0052
ON_RDWAY	-0.070	32.89	-0.0165	0.0000	0.0062	0.0028	0.0076
PKTIME	-0.026	11.29	-0.0061	0.0000	0.0023	0.0010	0.0027
RDCNT_MNT	-0.040	6.56	-0.0094	0.0000	0.0035	0.0016	0.0043
RDCUR_GRAD	0.029	33.33	0.0069	-0.0001	-0.0026	-0.0011	-0.0031
REAR_END_CR	0.339	399.00	0.0824	-0.0059	-0.0317	-0.0126	-0.0323
RES_TIME_BINARY	-0.023	17.06	-0.0054	0.0000	0.0020	0.0009	0.0024
ROLLOVER_CR	0.165	399.34	0.0396	-0.0015	-0.0152	-0.0063	-0.0166
SIDESWIPE_CR	0.184	92.37	0.0443	-0.0020	-0.0170	-0.0070	-0.0183
SNG_VEH_CR	0.380	582.08	0.0911	-0.0033	-0.0347	-0.0146	-0.0386
SPEED	0.016	986.86	0.0038	0.0000	-0.0014	-0.0006	-0.0017
TWO_VEH_CR	NS	NS	-	-	-	-	-
VEH_AT_FLT	NS	NS	-	-	-	-	-
VEH_AUTMBLE	NS	NS	-	-	-	-	-
VEH_KS	-0.043	38.95	-0.0103	0.0001	0.0039	0.0017	0.0046
VEH_MNR_STGT	0.064	108.60	0.0151	0.0000	-0.0057	-0.0025	-0.0069
WEEK_DAY	NS	NS	-	-	-	-	-
WET_RD_SURF	-0.123	387.43	-0.0290	-0.0003	0.0109	0.0049	0.0135
τ_1	-1.473	332.81					
τ_2	-0.529	43.97					
τ_3	0.519	42.30					
τ_4	0.966	146.55					
R^2	0.308						
Adjusted R^2	0.382						

NS - *Variables are not significant*
- *Not applicable*

4.0 COUNTERMEASURE IDENTIFICATION

4.1 Background

The identification of countermeasures should be done based on critical factors, which were identified through statistical analyses and described in the previous chapter. In fact, the countermeasure identification is the addressing of those critical factors. One important fact, which should be considered in the countermeasure analysis, is the reliability and effectiveness of proposed countermeasures. In other words, any suggested countermeasure should make sense that it is going to address the relevant contributing factor/s effectively, not only in terms of reducing the severity of crashes but also in terms of cost effectiveness. However, though these factors are considered during the countermeasure identification process, it is not possible to assure that those are going to be 100% effective. The reason is that, a particular countermeasure could be successful under a given set of conditions but there is a possibility that it would fail in a different circumstance. In addition, since the suggestions are made based on probability, there is a chance that a particular countermeasure of being unsuccessful. Thus, it is important to evaluate the effectiveness of the countermeasures after the implementation, at least for some selected locations.

Although the proposed countermeasures are effective and reliable, it does not make the sense that it is going to be applicable at each and every location. For instance, adding a new lane in to a rural two-lane undivided highway would be very effective in reducing head-on crashes but this solution would not be applicable if the relevant agencies are unable to provide sufficient funds to implement this countermeasure. In fact, as commonly noticeable, the major challenge in improving the rural highway safety is the lack of enough funding and thus, the suggested countermeasures should suit the financial situation of relevant authorities. In addition, the proposals, especially the enactment or revision of rules and regulations, should be compatible with the existing state and national system of transportation acts and regulations.

Because of the challenges due to the scarcity of resources in improving rural highway system, the relevant authorities have to have a proper planning and management system to utilize the available funds optimally. In this context, they need to deploy short-term plans to address warranted issues that need immediate treatments as well as some long-term plans to improve the whole system. Usually those long-term plans are more time consuming and expensive and they might consists of countermeasures such as, construction of new highways, widening of existing roadways and bridges, installation of advanced equipments (traffic signals, etc.), legislation while short-term plans consists of countermeasures such as, installing rumble strips, adding pavement markings and installing signs, improving clear zones.

The availability of funding for those expensive plans may become uncertain as it may be dominated by the economic situation of the country. On the other hand, in most of the cases, rural highways are getting secondary attention in fund allocation. However, the need for improving of rural highway safety has a higher importance. In this situation, the short-term plans, in fact low-cost countermeasures become important though they might not be capable of addressing the whole issue of rural highway safety. Thus, the major emphasis in this study was made on those low-cost countermeasures while focusing on some long-term countermeasures as well to make the countermeasure plan comprehensive.

The suggested countermeasures could be mainly categorized as roadway related and non-roadway related countermeasures. Non-roadway related countermeasures include legislation and enforcement of law and educating highway users through education and training programs. Roadway related countermeasures deals with the warranted improvements in roadway geometry and environment. It should be noted that, the addressing of each and every identified contributing factor was not necessary as some of those factors are interrelated and thus addressing of one factor would be effective on another factor as well. For example, countermeasures, that would help to increase the number of seatbelt users, would eventually help to reduce the possibility of ejecting the driver due to the crash. In addition, the improvements made to roadway and roadside geometry may address the safety issues associated with arterials and collectors. Table 4.1 shows the possible countermeasures, which could potentially address the identified contributing factors in rural highway crashes.

TABLE 4.1 Suggested Countermeasures for Relevant Contributing Factors

Contributing Factor	Countermeasures
Alcohol and Drug Involvement	Enact stronger alcohol laws Increase the level of enforcement Establish proper education and training programs to educate drivers
Lack of Seatbelt Usage	Revise existing seatbelt laws / Increase the level of enforcement Conduct proper education programs to educate the drivers Introduce new technologies to enforce drivers to wear seatbelts before moving the vehicle
Head-on Crashes	Install centerline rumble strips and provide raised medians Provide or upgrade centerline pavement marks Provide sufficient lane width Provide adequate warning and regulatory signs Provide no passing zones at locations with inadequate sight distance Provide alternate passing zones Provide exclusive left turning lanes at intersections Widen the pavement width
Roadway Geometry (not level and straight)	Lower the regulatory/posted speed limits Improve sight distance by maintaining adequate clear zones Add or upgrade centerline and edge line pavement markings Provide advance warning signs with advisory speeds Provide object markers Provide post delineators and chevron alignment signs at sharp curves Install or upgrade guard rails Improve longitudinal shoulder (widen and pave) Modify super-elevation or cross slope at sharp horizontal curves Modify geometric alignment at horizontal and vertical curves Remove or relocate fixed objects which exist very closer to the shoulder Flatten side slopes Provide skid-resistant pavement surfaces Provide a spiral transition

Table 4.1 contd…

Contributing Factor	Countermeasures
Excessive Speed	Educate people about the danger of high speed Increase the law enforcement against over speeding Reduce regulatory speed limits at hazardous locations Provide adequate warning and regulatory signs
Intersections	Provide adequate warning signs with regulatory speed limits Provide regulatory signs especially at un-signalized intersections Improve sight distance by providing adequate clear zones Install traffic signals at warranted un-signalized intersections Provide or upgrade pavement markings Provide exclusive turning lanes (especially for left turn) Provide adequate lane width
Single Vehicle Crashes (run-off-the-road and rollover crashes)	Install rumble strips (centerline and edge line) Remove, relocate or convert (to breakaway) fixed objects Lower the regulatory speed limits Install or upgrade guard rails Provide object markers Provide post delineators and chevron alignment signs at sharp horizontal curves and narrow roadway sections Add or upgrade centerline and edge line pavement markings Modify super-elevation or cross slope at sharp horizontal curves Modify geometric alignment at horizontal and vertical curves Provide adequate clear zones Flatten side slopes
Delayed Response from Emergency Services	Enhance the potential capacity of emergency services Provide or improve mobile emergency medical units Improve communication facilities in rural areas

4.2 Details of Selected Countermeasures

As previously mentioned, the suggested countermeasures depicted in the Table 4.1 can be divided in to two categories as roadway related and non-roadway related countermeasures. Some contributing factors could be addressed through non-roadway related countermeasures or roadway related countermeasures alone while some factors have to be addressed through both types of countermeasures.

4.2.1 Non-roadway Related Countermeasures

This category usually consists of legislation, enforcement and education/training. This can be further divided into different sub categories such as, prevention of alcohol or drug involvement, increase in seatbelt usage, prevention of high speeding, etc depending on the area of application. The following sections comprise of brief discussion on those countermeasures based on the area of application. It should be noted that perhaps some of those countermeasures may have been already implemented in Kansas but may not be very active in rural areas. Sometimes, this may be due to the lack of enough resources. For example, although a state has strong law enforcements, it is not going to be effective in rural areas if the state lacks enough officers to deploy in rural highways as those highways may be getting the secondary attention due to low traffic volumes occupied on rural highways. Therefore, if these countermeasures are to be effective in improving rural highway safety, more emphasis has to be made on rural areas.

Countermeasures to prevent driving under influence of alcohol or drugs

Alcohol involvement in highway crashes has a great importance regardless of whether the crash occurs on a rural or urban highway due to risk of resulting in high severity crashes. Unlike some other contributing factors, this factor could be addressed successfully only if the drivers understand the real danger of driving under influence and refrain from it, though some strong law enforcement steps would help to lower the number of influenced drivers up to some extent. Thus, proper educational and training programs are essential to achieve this objective. These programs should be well organized and oriented to educate the people about harmful effects of driving under influence. On the other hand, people can be encouraged to attend those programs by making the participation mandatory. One way of achieving this could be the legislating of a new regulation in to the driver license issuance procedure that, each candidate must attend certain number of such programs before applying for a driving license, especially for youngsters. This could be further enhanced by adding the requirement of maintaining a routing attendance to training and educating programs for drivers who are younger than a certain age, whom have been identified as the most vulnerable group.

On the other hand, legislation and enforcement also play a vital role in reducing the driving under influence. Possible enforcement and law enactment steps would include;

a) Introduce sobriety checkpoints so that enforcement officers can stop suspected vehicles and check whether the drivers are under influence of alcohol or drugs
b) Apply zero tolerance laws for younger drivers
c) Increase the penalties for offenders (increase the fine, extend the imprisonment period, increase the driver license suspension period or suspend promptly, etc.)
d) Reduce the legal limit for Blood Alcohol Concentration (BAC)
e) Apply mandatory alcohol impairment testing for drivers who involve in injury crashes

It should be noted here that, as far as Kansas is concerned, it has already applied most of above rules and regulations and also it has well-organized training and educating programs. In addition, the Kansas Department of Transportation has a separate institution called Drunk Driving Prevention Office to deal with this issue *(29)*. This would make the things much easy for the state of Kansas in implementing these countermeasures as it is already having a good background in addressing the issue of driving under influence of alcohol and drugs.

<u>Countermeasures to address lack of seatbelt usage</u>

According to the report of 2001 Seat Belt Summit, the most effective way to increase the use of seatbelts substantially is by applying strong law enforcements *(30)*. However, out of 50 states in the United States, only 21 states and District of Columbia and Puerto Rico have enacted primary seatbelt laws while other states have secondary laws including the state of Kansas and the state of New Hampshire does not have any seatbelt laws in active *(31)*. In addition, according to the Kansas Survey of Adult Seatbelt Usage in 2003, the seatbelt usage rate in Kansas was only 64%, which is far below the US rate of 79% as depicted in Table 4.2. Another important fact that can be observed from those data is that, the seatbelt use rate in rural arterials and collectors are very low compared to rural interstates and this reflects the findings of this study as collectors and arterials are more lethal than interstates.

Table 4.2 Comparison of Kansas Safety Belt Usage Rates

Kansas Adult Observational Safety Belt Usage Rates (%) (Driver/Front Outboard Passenger)						
Year	1999	2000	2001	2002	2003	2004
KS Rate (age 14+)	63	61	60	61	64	68
US Rate	67	71	73	75	79	
Kansas Safety Belt Usage Rates by Road Types (%)						
Year	1999	2000	2001	2002	2003	2004
Rural Interstate(ie.. I-70)	68	78	77	70	79	80
Rural Principle Arterials and Minor Arterials (ie..undivided US or K Hwys)	55	60	58	60	63	69
Rural Major & Minor Collectors (county roads)	47	47	50	52	53	59
Urban Interstate (ie..I-435)	70	68	69	70	72	74
Urban Freeways, Expressways, Minor Arterials (ie..divided US or K roads)	54	51	57	59	59	65
Urban Collectors (ie..city streets)	48	42	53	56	56	60

These facts make the important point that the revision of the existing secondary seatbelt laws, in fact enactment of primary seatbelt law, would be essential in improving the rate of safety belt users. On the other hand, many studies have revealed that change of secondary laws to primary laws has made substantial improvements in the rate of seatbelt usage in many states *(30)*. In addition, the penalty should be increased for seatbelt law violators. This may include increasing of fine, suspension of driving license after certain number of offenses, increased penalty for other violations if found to be violating the seatbelt law concurrently and may be even imprisonment is possible after several violations. In addition, some statewide programs could be frequently conducted to check and catch the violators.

In some cases people may have the wrong idea that violation of seatbelt law is not a serious offense. This could only be corrected by educating them through proper education and training programs while maintaining a strong law enforcement program. These programs should cover as many highway users and areas as possible and the information should be easily accessible to the public. Further, these programs would be more effective if they conducted under a separate institution such as Kansas Safety Belt Education Office.

Countermeasures to reduce over-speeding

Over-speeding is one of the major causes in many severe highway crashes. This may be more of a concern in rural highways due to the encouraging environment for speeding created by low traffic volumes and higher allowable speed limits in those highways. Thus, it is necessary to revise the allowable speed limits especially at locations where roadway geometry is hazardous. In fact the allowable speed limits need to be reduced at locations such as, sharp horizontal bends and vertical curves where sight distance is limited, locations with slippery road surfaces, road segments with narrow lanes, etc, un-signalized intersections, etc. On the other hand strong enforcement and increased penalty for speeding drivers would force drivers to drive under allowable speed limits. In addition, drivers should be educated about the danger associated with high speed driving. For example, the perception-reaction plus braking distance is substantially increased when the speed is increased by one mile per hour at higher speeds and this would reduce the ability of the driver to evade a crash. On the other hand, higher speeds increase the impact due to the crash. Again this requires well-organized and proper education and training programs.

Improve the capacity of emergency services

The lack of prompt respond from emergency medical services is a one of the serious issue in improving rural highway safety. One major reason for this may be due to unavailability of such facilities at near by locations and thus it would take considerable time to reach the location. In some cases, even though emergency services are available in the area they might not be able to respond quickly due to the insufficient availability of resources, vehicles, equipments and trained staff. Another reason may be the difficulties in communication in those areas. For example, the communication between control station and emergency vehicles might be hampered by dead spots, areas where the messages cannot be heard *(32)*.

Therefore, the first and foremost step in implementing this countermeasure would be to strengthen the capacity of available emergency service stations by providing enough resources. In addition they should be equipped with more powerful communication facilities such as satellite communication systems. In a case of bad weather or the ground vehicles can not reach the location promptly, those facilities should be able to provide alternative transport such as helicopters or small aircrafts which are equipped with all necessary facilities. In the second phase, provision of more emergency units in rural areas may be possible. These units may comprise of mobile emergency units with adequate facilities.

4.2.2 Roadway Related Countermeasures

Install rumble strips (edge or centerline rumble strips)

Installation of rumble strips on the shoulder has found to be an effective countermeasure in reducing run-off-the road (including both ways of the roadway) crashes especially in rural highway crashes *(33)*. Rumble strips are made by creating undulations on the pavement and they are usually installed at edge or centerline of the pavement in longitudinal direction of the roadway. These rumble strips are capable of alerting the driver that he or she is going to run off the roadway by the noise and the vibration created when the tires move on rumble strips.

It should be noted that, there are some issues associated with the installation of rumble strips. The major issue is the complaints made by both drivers and nearby residents about the noise. However, as far as rural areas are concerned, they are not very densely populated and thus this is not going to be a big issue. However, if this issue arises, then it should be considered in implementing this countermeasure.

Maintain adequate clear zones

Adequate sight distance is very important for drivers to drive safely, especially at sharp horizontal curves and un-signalized intersections. As far as rural highways are concerned, most of the time the roadside is occupied by lot of trees and bushes and this may lead to obstruct the driver’s sight. On the other hand, adequate clear zones help in reducing run-off-the-road crashes as well. For example, when a driver runs off the road over the shoulder and if the road way has been designed with adequate clear zones having recommended side slopes , then the driver has enough time and distance to get back the vehicle in to the pavement without hitting with a fixed object or overturning. In addition providing proper sight triangles at un-signalized intersections helps in reducing crashes at intersections. The guidelines and design concepts for clear zones are provided with MUTCD *(34)*.

Remove or relocate fixed objects which exists very closer to the roadway

This can also be considered as a part of the improving clear zones. However, the intention of implementation of this is to reduce crashes with fixed objects. These fixed objects may be trees, utility poles, advertising boards, etc which exists very closer to the roadway which are commonly noticeable in rural areas. In the case of utility poles and advertising boards, replacement has to be done while natural objects like trees have to be removed if they cause any danger.

Provide adequate warning and regulatory signs

The purpose of a warning sign is to alert the driver about an oncoming unexpected road conditions such as rail road crossings, un-signalized intersections, sharp bends, etc. while regulatory signs are used to enforce the motorists, for example, stop signs, regulatory speed limit signs, etc. The installation of warning signs adequately would effectively help in reducing highway crashes especially in rural areas. For example, the rural highways have the nature of rapidly changing geometries such as sharp curves, vertical alignments, etc and, if the driver is already informed about the change in the road conditions, then the driver has enough time to adjust the speed of the vehicle to safely traverse the situation. Sometimes, these warning signs may be provided with advisory speeds, especially at sharp horizontal curves or steep down hill road segments, so that the vehicle can be handled safely. On the other hand, regulatory signs enforce the driver to drive under the given conditions so that the driver will be able to traverse a certain roadway segment safely. For instance, at an un-signalized intersection, the driver is forced to stop before crossing it by stop sign which would help the driver to cross the intersection without colliding with cross through vehicles.

It should be noted that, providing too much of warning signs or improper installation may again cause confusions and eventually becomes useless. For instance, when there are too many warning signs then driver get confused and tend to neglect them or when the signs can not be clearly visible, this countermeasure becomes useless. Therefore, instillation should be according to the guidelines provided with the MUTCD *(34)*.

<u>Provide or upgrade pavement markings</u>

Pavement markings are the signs that are marked on the pavement to direct drivers and to control the traffic flows. In rural highways the most important and common type of pavement markings are centerline and edge line pavement markings. Edge line markings are provided to delineate the outside of the lane and centerline markers separate the two-way traffic streams. Edge lines are intended to guide the driver to prevent the vehicle running off the roadway and thus effective in preventing run-off-the-road crashes, which are common in rural highways. The intention of providing centerline markers is to guide the driver to prevent the vehicle crossing into the oncoming traffic, which would cause head-on crashes. The provision of pavement markings should be in accordance with the guide lines provided in MUTCD *(34)*.

<u>Provide object markers</u>

The purpose of providing object markers is to alert the driver about obstructions within or adjacent to the roadway and eventually prevent the vehicle from hitting with fixed objects. Thus, this would be very effective in rural highways as, single vehicle crashes are more dangerous in those highways. This countermeasure is more useful during night time when the visibility is poor and the markings should be according to the requirements given in MUTCD *(34)*.

<u>Provide post delineators and Chevron alignment signs at sharp horizontal curves and narrow roadway sections</u>

Post delineators are useful at locations where there are unexpected or confusing roadway alignments such as at sharp horizontal curves and lane reduction transitions. Basically, chevron alignment signs are provided at sharp horizontal curves to alert and guide the driver about the sudden change in horizontal alignment of the roadway. The purpose of providing these signs is to assist the driver to keep the vehicle on the roadway and eventually preventing run-off-the-road crashes. Installation of post delineators and chevron signs should follow the directions given in MUTCD *(34)*.

Modify superelevation or cross slope at sharp horizontal curves

The horizontal curves should be superelevated across the curve to facilitate the vehicle to transverse the curve without running out of the roadway due to the centrifugal forces. This is more important in roadways with higher allowable speed limits such as minor arterials and collectors. This countermeasure is applicable at existing horizontal curves where the superelevation is not adequate. Consequently the intention of this countermeasure is to reduce run-off-the-road crashes.

Modify geometric alignment at horizontal and vertical curves

Horizontal curves may become dangerous due to the improper alignment of the curve. In some cases, improper alignment of vertical curves obstructs adequate sight distance for drivers. The modification of the curve may include, flattening of horizontal curve, shaving of the crest of vertical curve.

Install or upgrade Guardrails

One of the most commonly applicable countermeasures to prevent run-off-the-road crashes is installing of guardrails. These guard rails are placed adjacent to the roadway at locations such as side slopes are very steep and not traversable, road side obstacles exists such as trees and some other vulnerable roadside features exist such as ponds, lakes, etc. These guardrails should be designed and installed according to MUTCD *(34)* guidelines so that those guardrails would not cause any direct hazard and impacts.

The above countermeasures usually do not require any new constructions or large investments. Thus, those can be considered as low cost countermeasures and are especially applicable for rural highways. However, there are some other general countermeasures as well, which would be applicable in improving rural highway safety. These countermeasures may include, widening of existing lanes including bridges, adding new lanes in to the existing roadways, installing traffic signals at un-signalized warranted intersections. Since these countermeasures are more expensive and time consuming they may be considered as long-term plans. Thus, these countermeasures need to be further evaluated before implementing which is beyond the scope of this study.

5.0 SUMMARY AND CONCLUSIONS

Statistical models, ordered choice (probit and logit) and loglinear models were applied to identify critical contributing factors towards more severe crashes in rural highways. Since the interpretation of results from loglinear models is more sophisticated, only the results from ordered probit model were presented in this report. Different types of contributing factors, driver related, environmental related, roadway related, vehicular related and crash-related factors, were considered in the study. Crash data from KARS database was used in this analysis. Based on the outputs from statistical models countermeasures were identified to address the identified contributing factors. These countermeasures consist of both roadway and non-roadway related countermeasures.

One of the important findings in this study is that higher injury risk for drivers who do not use safety equipments at the time of crash. Since Kansas has secondary seat belt law, this finding might shed light on the need for revisiting the existing law and push forward towards the primary seat belt law. On the other hand, when the driver ejects from the vehicle the injury risk is increasing. It is important to note that, when the driver does not wear any seat belt the probability of ejecting might be high and thus the driver is in a more vulnerable situation.

Factors such as alcohol or drug involvement, travel speed, faulty drivers, seat belt violation, driver being ejected or trapped, and adverse roadway geometry seem to increase the severity of rural highway crashes. In addition, single vehicle crashes are more severe and head-on crashes cause more severe injuries in the case of two vehicle crashes. When the arrival of emergency services is delayed, the probability of sustaining more severe injuries is high.

Most of the findings of this study are consistent with previous studies. The reason for getting negative effects towards crash severity under adverse weather and light conditions may be due to the fact that drivers are more careful and tend to reduce their speeds when driving under extreme conditions. However, this makes an interesting point to go for further studies to investigate this finding in more details.

It should be noted that, the data used in this analysis were based on police reports and thus the accuracy of the findings is subjected to the accuracy of the data used. Especially in the case of seat belt usage, the accuracy of data is questionable since not everybody may accept the truth and in some situations driver might be already out of the vehicle when police officers arrive at the scene. However, some higher degree of accuracy could be expected in data relevant to diver age and gender, environmental conditions, roadway conditions, location of the crash, crash type, etc.

The countermeasures were suggested with the intention of addressing the identified critical factors. Those countermeasures include both, countermeasures from literature survey on past studies and suggestions based on model outputs. The major emphasis was made on low-cost countermeasures in this process even though some countermeasures were also suggested. The suggested countermeasures are mainly twofold, roadway related and non-roadway related. Non-roadway countermeasures are basically legislation, enforcement and education/training. Some of those countermeasures are; Enact strong alcohol laws, Increase the level of enforcement, Establish proper education and training programs to educate drivers, Revise existing seatbelt laws, Lower the regulatory speed limits, Enhance the potential capacity/efficiency of emergency services.

The roadway related countermeasures deal with necessary improvements in the roadway geometry and environment. They also comprise of new construction of lanes and highways as well. The major roadway related countermeasures are; Install rumble strips, Maintain adequate clear zones, Provide adequate warning and regulatory signs, Provide or upgrade pavement markings, Modify geometric alignment at horizontal and vertical curves, Install or upgrade Guardrails, Widening of existing lanes including bridges, Adding new lanes in to the existing roadways, Install traffic signals at un-signalized warranted intersections.

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APPENDIX

TABLE 1 Trend of Crash Occurrence in Rural and Urban Areas in Kansas (1993-2002)

Year	Rural			Urban		Grand Total
	Severity	Total	% on Grand Total	Total	% on Grand Total	
2002	Fatal	343	76.39	106	23.61	449
	Injury	6,198	33.53	12,286	66.47	18,484
	No Injury	21,397	36.10	37,870	63.90	59,267
	Total	27,938	35.73	50,262	64.27	78,200
2001	Fatal	325	75.06	108	24.94	433
	Injury	6,422	33.21	12,918	66.79	19,340
	No Injury	22,267	37.74	36,730	62.26	58,997
	Total	29,014	36.83	49,756	63.17	78,770
2000	Fatal	316	78.02	89	21.98	405
	Injury	6,339	32.52	13,153	67.48	19,492
	No Injury	21,864	37.53	36,395	62.47	58,259
	Total	28,519	36.49	49,637	63.51	78,156
1999	Fatal	343	75.05	114	24.95	457
	Injury	6,643	32.86	13,576	67.14	20,219
	No Injury	22,574	38.96	35,361	61.04	57,935
	Total	29,560	37.60	49,051	62.40	78,611
1998	Fatal	319	72.34	122	27.66	441
	Injury	6,897	33.52	13,680	66.48	20,577
	No Injury	23,118	39.84	34,916	60.16	58,034
	Total	30,334	38.37	48,718	61.63	79,052
1997	Fatal	302	72.08	117	27.92	419
	Injury	7,038	33.90	13,723	66.10	20,761
	No Injury	22,296	40.24	33,110	59.76	55,406
	Total	29,636	38.70	46,950	61.30	76,586
1996	Fatal	339	76.70	103	23.30	442
	Injury	6,881	33.48	13,670	66.52	20,551
	No Injury	20,364	38.55	32,461	61.45	52,825
	Total	27,584	37.37	46,234	62.63	73,818
1995	Fatal	287	72.84	107	27.16	394
	Injury	6,475	31.88	13,836	68.12	20,311
	No Injury	18,506	37.40	30,981	62.60	49,487
	Total	25,268	36.00	44,924	64.00	70,192
1994	Fatal	289	75.85	92	24.15	381
	Injury	6,441	32.06	13,648	67.94	20,089
	No Injury	17,331	37.43	28,967	62.57	46,298
	Total	24,061	36.04	42,707	63.96	66,768
1993	Fatal	270	72.00	105	28.00	375
	Injury	6,173	30.97	13,759	69.03	19,932
	No Injury	17,588	35.70	31,675	64.30	49,263
	Total	24,031	34.54	45,539	65.46	69,570

TABLE 2 Annual Crash Occurrence on Rural Highways based on Severity and Roadway Function Class

Year	Injury Severity	Roadway Function Class						Total	% *
		Interstate	Principal Arterial	Monor Arterial	Major Collector	Monor Collector	Local		
2002	Fatal	21	107	59	96	7	53	343	1.23
	Injury	591	1,293	890	1,538	177	1,709	6,198	22.18
	No Injury	1,729	4,695	3,293	5,458	550	5,672	21,397	76.59
	Total	2,341	6,095	4,242	7,092	734	7,434	27,938	100.00
	% **	8.38	21.82	15.18	25.38	2.63	26.61	100.00	
2001	Fatal	27	96	62	83	11	46	325	1.12
	Injury	610	1,302	927	1,733	212	1,638	6,422	22.13
	No Injury	1,907	4,876	3,427	5,711	526	5,820	22,267	76.75
	Total	2,544	6,274	4,416	7,527	749	7,504	29,014	100.00
	% **	8.77	21.62	15.22	25.94	2.58	25.86	100.00	
2000	Fatal	27	100	47	77	7	58	316	1.11
	Injury	640	1,310	922	1,756	186	1,525	6,339	22.23
	No Injury	1,840	4,480	3,472	5,916	515	5,641	21,864	76.66
	Total	2,507	5,890	4,441	7,749	708	7,224	28,519	100.00
	% **	8.79	20.65	15.57	27.17	2.48	25.33	100.00	
1999	Fatal	32	104	56	92	7	52	343	1.16
	Injury	652	1,381	949	1,785	202	1,674	6,643	22.47
	No Injury	1,921	4,692	3,523	6,137	577	5,724	22,574	76.37
	Total	2,605	6,177	4,528	8,014	786	7,450	29,560	100.00
	% **	8.81	20.90	15.32	27.11	2.66	25.20	100.00	
1998	Fatal	17	112	54	84	11	41	319	1.05
	Injury	690	1,416	990	1,918	220	1,663	6,897	22.74
	No Injury	2,102	4,940	3,571	6,176	615	5,714	23,118	76.21
	Total	2,809	6,468	4,615	8,178	846	7,418	30,334	100.00
	% **	9.26	21.32	15.21	26.96	2.79	24.45	100.00	
1997	Fatal	22	89	62	72	9	48	302	1.02
	Injury	622	1,434	1,003	2,017	266	1,696	7,038	23.75
	No Injury	1,968	4,591	3,446	6,125	617	5,549	22,296	75.23
	Total	2,612	6,114	4,511	8,214	892	7,293	29,636	100.00
	% **	8.81	20.63	15.22	27.72	3.01	24.61	100.00	
1996	Fatal	18	91	54	88	17	71	339	1.23
	Injury	587	1,345	944	1,985	265	1,755	6,881	24.95
	No Injury	1,626	3,850	3,097	5,880	566	5,345	20,364	73.83
	Total	2,231	5,286	4,095	7,953	848	7,171	27,584	100.00
	% **	8.09	19.16	14.85	28.83	3.07	26.00	100.00	
1995	Fatal	27	66	44	85	9	56	287	1.14
	Injury	533	1,166	838	1,961	237	1,740	6,475	25.63
	No Injury	1,468	3,551	2,641	5,246	592	5,008	18,506	73.24
	Total	2,028	4,783	3,523	7,292	838	6,804	25,268	100.00
	% **	8.03	18.93	13.94	28.86	3.32	26.93	100.00	
1994	Fatal	24	70	44	88	7	56	289	1.20
	Injury	493	1,125	824	1,904	252	1,843	6,441	26.77
	No Injury	1,354	3,354	2,432	4,946	515	4,730	17,331	72.03
	Total	1,871	4,549	3,300	6,938	774	6,629	24,061	100.00
	% **	7.78	18.91	13.72	28.84	3.22	27.55	100.00	
1993	Fatal	18	86	41	80	5	40	270	1.12
	Injury	585	1,161	858	1,645	212	1,712	6,173	25.69
	No Injury	1,723	3,268	2,455	4,354	408	5,380	17,588	73.19
	Total	2,326	4,515	3,354	6,079	625	7,132	24,031	100.00
	% **	9.68	18.79	13.96	25.30	2.60	29.68	100.00	

* *based on injury severity level*

** *based on roadway function class*

TABLE 3 Annual Crash Occurrence on Kansas Rural Highways based on Crash Location

	Location	Injury Severity	Year									
			1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
ON ROADWAY	Non-Intersection	Fatal	152	170	173	208	171	185	198	177	176	200
		Injury	3,399	3423	3503	3782	4016	4188	3633	3560	3551	3514
		No Injury	11,805	11934	12691	14559	16184	17114	16483	15783	16172	15664
		Total	15,356	15,527	16,367	18,549	20,371	21,487	20,314	19,520	19,899	19,378
		%	63.90	64.53	64.77	67.25	68.74	70.83	68.72	68.45	68.58	69.36
	Intersection	Fatal	45	44	47	62	64	58	75	61	69	65
		Injury	1034	1052	1103	1260	1291	1280	1358	1230	1157	1027
		No Injury	2188	1888	2118	2279	2533	2635	2643	2571	2334	1938
		Total	3,267	2,984	3,268	3,601	3,888	3,973	4,076	3,862	3,560	3,030
		%	13.59	12.40	12.93	13.05	13.12	13.10	13.79	13.54	12.27	10.85
	Intersection-related	Fatal	11	5	2	5	13	9	10	8	10	6
		Injury	433	495	531	452	503	467	402	373	446	400
		No Injury	1007	1010	1212	1038	1113	1138	1015	1014	1169	1223
		Total	1,451	1,510	1,745	1,495	1,629	1,614	1,427	1,395	1,625	1,629
		%	6.04	6.28	6.91	5.42	5.50	5.32	4.83	4.89	5.60	5.83
	Parking lot or Driveway Access	Fatal	4	6	5	7	3	8	9	6	3	3
		Injury	264	267	226	117	197	178	164	189	253	242
		No Injury	1073	1005	855	646	824	910	831	802	918	929
		Total	1,341	1,278	1,086	770	1,024	1,096	1,004	997	1,174	1,174
		%	5.58	5.31	4.30	2.79	3.46	3.61	3.40	3.50	4.05	4.20
	Interchange Area	Fatal	0	3	5	0	2	2	3	7	5	3
		Injury	46	62	61	57	77	82	89	89	83	109
		No Injury	109	132	131	108	189	207	215	258	235	263
		Total	155	197	197	165	268	291	307	354	323	375
		%	0.65	0.82	0.78	0.60	0.90	0.96	1.04	1.24	1.11	1.34
	On Crossover	Fatal	0	1	0	0	0	1	1	0	0	0
		Injury	9	4	10	3	3	5	7	4	4	2
		No Injury	12	19	11	7	14	12	12	7	18	6
		Total	21	24	21	10	17	18	20	11	22	8
		%	0.09	0.10	0.08	0.04	0.06	0.06	0.07	0.04	0.08	0.03
OFF ROADWAY	Roadside (Including Shoulder)	Fatal	56	57	50	52	45	49	42	51	57	60
		Injury	890	1080	965	1150	891	637	937	820	816	816
		No Injury	1202	1258	1290	1567	1307	979	1243	1283	1217	1254
		Total	2,148	2,395	2,305	2,769	2,243	1,665	2,222	2,154	2,090	2,130
		%	8.94	9.95	9.12	10.04	7.57	5.49	7.52	7.55	7.20	7.62
	Median	Fatal	2	0	1	3	1	1	1	4	3	4
		Injury	65	40	42	44	54	53	39	68	106	81
		No Injury	98	51	64	63	82	92	81	100	168	104
		Total	165	91	107	110	137	146	121	172	277	189
		%	0.69	0.38	0.42	0.40	0.46	0.48	0.41	0.60	0.95	0.68
	Parking lot, Rest Area Trafficway	Fatal	0	0	0	0	1	0	0	0	1	0
		Injury	0	0	12	14	1	2	5	1	2	2
		No Injury	0	0	97	86	29	10	23	6	8	2
		Total	0	0	109	100	31	12	28	7	11	4
		%	0.00	0.00	0.43	0.36	0.10	0.04	0.09	0.02	0.04	0.01
	Unknown	Fatal	0	3	4	2	2	6	4	2	1	2
		Injury	33	18	22	2	5	5	9	5	4	5
		No Injury	94	34	37	11	21	21	27	40	28	14
		Total	127	55	63	15	28	32	40	47	33	21
		%	0.53	0.23	0.25	0.05	0.09	0.11	0.14	0.16	0.11	0.08
	Grand Total		24,031	24,061	25,268	27,584	29,636	30,334	29,559	28,519	29,014	27,938

TABLE 4 Annual Crash Occurrence on Kansas Rural Highways based on Roadway Geometry

Roadway Character	Injury Severity	Year									
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Straight & Level	Fatal	154	164	164	205	166	170	187	183	179	209
	Injury	3,651	3785	3755	4092	4183	4129	4061	3741	3931	3804
	No Injury	11,277	11271	12083	13355	14815	15552	15246	14711	15242	14649
	Total	15,082	15,220	16,002	17,652	19,164	19,851	19,494	18,635	19,352	18,662
	% **	62.76	63.26	63.33	63.99	64.66	65.44	65.95	65.34	66.70	66.80
Straight on Grade	Fatal	65	73	60	75	73	70	87	72	79	64
	Injury	1,421	1454	1458	1526	1607	1488	1369	1447	1324	1275
	No Injury	3,802	3540	3744	4300	4562	4656	4463	4352	4361	4120
	Total	5,288	5,067	5,262	5,901	6,242	6,214	5,919	5,871	5,764	5,459
	% **	22.00	21.06	20.82	21.39	21.06	20.49	20.03	20.59	19.87	19.54
Straight at Hillcrest	Fatal	8	7	11	10	13	11	10	5	6	12
	Injury	201	222	241	253	236	248	213	219	232	216
	No Injury	502	553	586	618	660	659	650	646	606	595
	Total	711	782	838	881	909	918	873	870	844	823
	% **	2.96	3.25	3.32	3.19	3.07	3.03	2.95	3.05	2.91	2.95
Curved & Level	Fatal	26	25	30	24	27	38	25	25	33	32
	Injury	400	489	464	480	506	505	490	455	512	475
	No Injury	843	835	912	921	1021	1021	1053	1023	999	979
	Total	1,269	1,349	1,406	1,425	1,554	1,564	1,568	1,503	1,544	1,486
	% **	5.28	5.61	5.56	5.17	5.24	5.16	5.30	5.27	5.32	5.32
Curved on Grade	Fatal	14	18	15	19	16	24	26	25	22	22
	Injury	344	331	371	384	364	393	412	374	346	356
	No Injury	642	644	627	693	736	780	748	714	750	749
	Total	1,000	993	1,013	1,096	1,116	1,197	1,186	1,113	1,118	1,127
	% **	4.16	4.13	4.01	3.97	3.77	3.95	4.01	3.90	3.85	4.03
Curved at Hillcrest	Fatal	0	0	3	4	2	2	2	1	3	2
	Injury	27	22	39	27	24	27	24	26	29	22
	No Injury	36	42	60	56	63	62	37	35	48	52
	Total	63	64	102	87	89	91	63	62	80	76
	% **	0.26	0.27	0.40	0.32	0.30	0.30	0.21	0.22	0.28	0.27
Unknown	Fatal	3	2	4	2	5	4	6	5	3	2
	Injury	129	138	147	119	118	107	74	77	48	50
	No Injury	486	446	494	421	439	388	375	383	261	253
	Total	618	586	645	542	562	499	455	465	312	305
	% **	2.57	2.44	2.55	1.96	1.90	1.65	1.54	1.63	1.08	1.09
Total		24,031	24,061	25,268	27,584	29,636	30,334	29,558	28,519	29,014	27,938

TABLE 5 Annual Crash Occurrence on Kansas Rural Highways based on Roadway Surface Condition

Roadway Surface Condition	Injury Severity	Year									
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Dry	Fatal	212	251	248	280	235	258	299	269	279	307
	Injury	4,508	5188	4948	5459	5402	5310	5459	5095	5214	5025
	No Injury	12,470	13945	14025	16195	17281	18043	18688	17423	18261	17366
	Total	17,190	19,384	19,221	21,934	22,918	23,611	24,446	22,787	23,754	22,698
	%	71.53	80.56	76.07	79.52	77.33	77.84	82.71	79.90	81.87	81.24
Wet	Fatal	37	25	23	36	28	29	27	22	26	23
	Injury	766	611	712	713	753	828	662	580	610	515
	No Injury	2127	1663	1924	2127	2189	2735	2212	1918	1966	1833
	Total	2,930	2,299	2,659	2,876	2,970	3,592	2,901	2,520	2,602	2,371
	%	12.19	9.55	10.52	10.43	10.02	11.84	9.81	8.84	8.97	8.49
Snow or Slush	Fatal	5	0	0	5	9	6	4	7	3	2
	Injury	235	151	139	117	224	92	145	145	99	137
	No Injury	884	522	532	441	834	414	485	634	396	584
	Total	1,124	673	671	563	1,067	512	634	786	498	723
	%	4.68	2.80	2.66	2.04	3.60	1.69	2.14	2.76	1.72	2.59
Ice or Snow Packed	Fatal	13	10	10	7	24	18	7	13	11	7
	Injury	508	338	492	396	505	506	243	396	376	419
	No Injury	1574	835	1528	1113	1520	1464	772	1494	1303	1295
	Total	2,095	1,183	2,030	1,516	2,049	1,988	1,022	1,903	1,690	1,721
	%	8.72	4.92	8.03	5.50	6.91	6.55	3.46	6.67	5.82	6.16
Mud, Dirt or Sand	Fatal	3	1	3	7	3	3	2	2	4	3
	Injury	96	89	84	104	91	98	86	82	83	75
	No Injury	269	175	208	200	214	238	228	190	211	179
	Total	368	265	295	311	308	339	316	274	298	257
	%	1.53	1.10	1.17	1.13	1.04	1.12	1.07	0.96	1.03	0.92
Derbris (Oil,etc)	Fatal	0	0	0	0	0	0	0	0	0	0
	Injury	4	1	0	3	4	6	6	6	4	2
	No Injury	9	3	5	7	11	2	9	7	10	8
	Total	13	4	5	10	15	8	15	13	14	10
	%	0.05	0.02	0.02	0.04	0.05	0.03	0.05	0.05	0.05	0.04
Unknown	Fatal	0	2	3	4	3	5	4	3	2	1
	Injury	56	63	100	89	59	57	42	35	36	25
	No Injury	255	188	284	281	247	222	178	198	120	132
	Total	311	253	387	374	309	284	224	236	158	158
	%	1.29	1.05	1.53	1.36	1.04	0.94	0.76	0.83	0.54	0.57
Total		24,031	24,061	25,268	27,584	29,636	30,334	29,558	28,519	29,014	27,938

TABLE 6 Annual Crash Occurrence on Kansas Rural Highways based on Light condition at the time of the Crash

Light Condition	Injury Severity	Year									
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Day Light	Fatal	160	157	146	180	192	182	185	164	157	192
	Injury	3,620	3,756	3,833	4,123	4,160	4,234	4,068	3,826	3,844	3,691
	No Injury	8,691	8,166	8,705	9,243	10,318	10,590	10,063	9,956	9,873	9,431
	Total	12,471	12,079	12,684	13,546	14,670	15,006	14,316	13,946	13,874	13,314
	% *	51.90	50.20	50.20	49.11	49.50	49.47	48.43	48.90	47.82	47.66
Dawn	Fatal	2	3	4	5	6	11	4	6	7	12
	Injury	124	139	155	167	174	142	179	156	185	145
	No Injury	704	770	935	1,029	1,148	1,174	1,214	1,105	1,262	1,150
	Total	830	912	1,094	1,201	1,328	1,327	1,397	1,267	1,454	1,307
	% *	3.45	3.79	4.33	4.35	4.48	4.37	4.73	4.44	5.01	4.68
Dusk	Fatal	11	8	11	10	5	9	11	9	14	12
	Injury	165	195	208	190	243	178	158	155	166	178
	No Injury	639	704	720	875	1,044	1,035	957	908	856	827
	Total	815	907	939	1,075	1,292	1,222	1,126	1,072	1,036	1,017
	% *	3.39	3.77	3.72	3.90	4.36	4.03	3.81	3.76	3.57	3.64
Dark, Street Lights On	Fatal	7	11	17	18	11	10	9	18	20	14
	Injury	353	375	381	370	416	411	382	368	417	405
	No Injury	1,332	1,193	1,443	1,522	1,637	1,868	1,678	1,759	1,931	1,808
	Total	1,692	1,579	1,841	1,910	2,064	2,289	2,069	2,145	2,368	2,227
	% *	7.04	6.56	7.29	6.92	6.96	7.55	7.00	7.52	8.16	7.97
Dark, no Street Lights	Fatal	86	107	108	120	87	106	129	114	123	112
	Injury	1,867	1,932	1,796	1,947	1,996	1,905	1,833	1,818	1,789	1,758
	No Injury	5,965	6,324	6,386	7,411	7,914	8,272	8,503	7,984	8,204	8,074
	Total	7,918	8,363	8,290	9,478	9,997	10,283	10,465	9,916	10,116	9,944
	% *	32.95	34.76	32.81	34.36	33.73	33.90	35.40	34.77	34.87	35.59
Unknown	Fatal	4	3	1	6	1	1	5	5	4	1
	Injury	44	44	102	84	49	27	23	16	21	21
	No Injury	257	173	317	284	235	179	159	152	141	107
	Total	305	220	420	374	285	207	187	173	166	129
	% *	1.27	0.91	1.66	1.36	0.96	0.68	0.63	0.61	0.57	0.46
Grand Total		24,031	24,060	25,268	27,584	29,636	30,334	29,560	28,519	29,014	27,938

TABLE 7 Annual Crash Occurrence on Kansas Rural Highways based on Weather condition at the time of the Crash

Weather Condition	Injury Severity	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
No Adverse Conditions	F	227	255	251	290	246	270	297	272	283	296
	I	4,858	5382	5133	5634	5663	5507	5605	5291	5397	5161
	N	13,644	14560	14740	16741	18094	18802	19285	18364	19019	17903
	Total	18,729	20,197	20,124	22,665	24,003	24,579	25,187	23,927	24,699	23,360
	Percentage	77.94	83.94	79.64	82.17	80.99	81.03	85.21	83.90	85.13	83.61
Rain	F	26	16	19	22	22	23	22	17	21	17
	I	639	475	599	616	659	848	582	477	530	474
	N	1,695	1221	1543	1750	1805	2553	1820	1531	1657	1571
	Total	2,360	1,712	2,161	2,388	2,486	3,424	2,424	2,025	2,208	2,062
	Percentage	9.82	7.12	8.55	8.66	8.39	11.29	8.20	7.10	7.61	7.38
Sleet	F	3	2	1	0	1	1	2	1	0	1
	I	126	71	36	35	59	62	40	31	52	47
	N	388	207	112	101	180	190	156	142	177	180
	Total	517	280	149	136	240	253	198	174	229	228
	Percentage	2.15	1.16	0.59	0.49	0.81	0.83	0.67	0.61	0.79	0.82
Snow	F	6	1	7	10	17	8	5	8	4	10
	I	282	189	338	227	396	178	181	303	156	284
	N	1,035	594	1132	714	1394	675	588	1111	585	1090
	Total	1,323	784	1,477	951	1,807	861	774	1,422	745	1,384
	Percentage	5.51	3.26	5.85	3.45	6.10	2.84	2.62	4.99	2.57	4.95
Fog	F	5	7	2	7	5	6	6	5	6	8
	I	103	152	128	128	81	116	60	58	143	80
	N	332	398	379	412	271	373	245	233	426	259
	Total	440	557	509	547	357	495	311	296	575	347
	Percentage	1.83	2.31	2.01	1.98	1.20	1.63	1.05	1.04	1.98	1.24
Other	F	3	4	4	8	8	6	4	7	7	8
	I	69	99	146	175	120	136	132	150	103	127
	N	140	141	297	395	318	289	271	306	254	275
	Total	212	244	447	578	446	431	407	463	364	410
	Percentage	0.88	1.01	1.77	2.10	1.50	1.42	1.38	1.62	1.25	1.47
Unknown	F	0	4	3	2	3	5	7	6	4	3
	I	96	73	95	66	60	50	43	29	41	25
	N	354	210	303	251	234	236	209	177	149	119
	Total	450	287	401	319	297	291	259	212	194	147
	Percentage	1.87	1.19	1.59	1.16	1.00	0.96	0.88	0.74	0.67	0.53
Grand Total		24,031	24,061	25,268	27,584	29,636	30,334	29,560	28,519	29,014	27,938

TABLE 8 Annual Crash Occurrence on Kansas Rural Highways based on Type of Collision

Crash Type	Injury Severity	Year									
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Collision with Other Motor vehivle	F	137	116	117	152	151	148	164	155	143	151
	I	2272	2194	2340	2424	2518	2495	2398	2206	2175	2048
	N	5358	4787	5323	5371	5903	5968	5569	5433	5345	5034
	Total	7,767	7,097	7,780	7,947	8,572	8,611	8,131	7,794	7,663	7,233
	Percentage	32.32	29.50	30.79	28.81	28.92	28.39	27.51	27.33	26.41	25.89
Collision with Parked Motor vehivle	F	1	1	4	1	1	4	2	3	3	4
	I	88	80	77	78	79	69	75	68	67	57
	N	1238	1042	1076	1160	1207	1331	1248	1198	1338	1159
	Total	1,327	1,123	1,157	1,239	1,287	1,404	1,325	1,269	1,408	1,220
	Percentage	5.52	4.67	4.58	4.49	4.34	4.63	4.48	4.45	4.85	4.37
Overturned	F	45	75	66	80	51	66	73	54	60	86
	I	1231	1448	1391	1485	835	768	802	929	844	1635
	N	1170	1138	1151	1201	708	642	620	673	683	1328
	Total	2,446	2,661	2,608	2,766	1,594	1,476	1,495	1,656	1,587	3,049
	Percentage	10.18	11.06	10.32	10.03	5.38	4.87	5.06	5.81	5.47	10.91
Collision with Fixed Object	F	68	71	70	76	68	70	74	80	99	72
	I	1897	2053	2028	2152	2914	2808	2681	2522	2685	1905
	N	3443	3154	3579	3649	4749	4723	4426	4543	4463	4104
	Total	5,408	5,278	5,677	5,877	7,731	7,601	7,181	7,145	7,247	6,081
	Percentage	22.50	21.94	22.47	21.31	26.09	25.06	24.29	25.05	24.98	21.77
Collision with Other Object	F	1	3	2	2	0	3	1	2	0	2
	I	78	77	72	32	42	29	33	32	18	18
	N	345	242	270	198	196	205	213	218	204	219
	Total	424	322	344	232	238	237	247	252	222	239
	Percentage	1.76	1.34	1.36	0.84	0.80	0.78	0.84	0.88	0.77	0.86
Collision with Animal	F	0	2	2	5	6	3	1	3	3	2
	I	222	226	242	342	331	416	374	368	407	325
	N	5424	6418	6503	8117	8809	9539	9824	9158	9664	8896
	Total	5,646	6,646	6,747	8,464	9,146	9,958	10,199	9,529	10,074	9,223
	Percentage	23.49	27.62	26.70	30.68	30.86	32.83	34.50	33.41	34.72	33.01
Collision with Pedestrian	F	10	8	9	6	8	12	15	8	6	11
	I	120	120	111	129	93	79	90	63	74	63
	N	4	7	5	2	4	2	0	2	3	3
	Total	134	135	125	137	105	93	105	73	83	77
	Percentage	0.56	0.56	0.49	0.50	0.35	0.31	0.36	0.26	0.29	0.28
Collision with Railway Train	F	5	10	10	10	10	7	8	6	4	8
	I	29	23	29	26	25	19	26	13	15	20
	N	33	28	33	31	32	18	20	13	19	10
	Total	67	61	72	67	67	44	54	32	38	38
	Percentage	0.28	0.25	0.28	0.24	0.23	0.15	0.18	0.11	0.13	0.14
Collision with Pedecycle	F	1	0	3	2	2	3	3	0	1	2
	I	63	71	59	53	61	55	43	42	39	34
	N	4	7	8	5	6	3	4	1	2	4
	Total	68	78	70	60	69	61	50	43	42	40
	Percentage	0.28	0.32	0.28	0.22	0.23	0.20	0.17	0.15	0.14	0.14
Other Non-collision	F	2	3	4	5	4	3	1	5	6	5
	I	165	147	117	157	133	153	115	87	93	93
	N	529	489	529	619	667	670	632	583	530	623
	Total	696	639	650	781	804	826	748	675	629	721
	Percentage	2.90	2.66	2.57	2.83	2.71	2.72	2.53	2.37	2.17	2.58
Unknown	F	0	0	0	0	1	0	1	0	0	0
	I	8	2	9	3	7	6	6	9	5	0
	N	40	19	29	11	15	17	18	42	16	17
	Total	48	21	38	14	23	23	25	51	21	17
	Percentage	0.20	0.09	0.15	0.05	0.08	0.08	0.08	0.18	0.07	0.06
Grand Total		24,031	24,061	25,268	27,584	29,636	30,334	29,560	28,519	29,014	27,938

TABLE 9 Alcohol and Drug Involvement in Kansas Rural Highway Crashes

Year		Total Crashes				Alcohol and Drug Involved Crashes				
		Severity				*	Severity			
		F	I	N	Total		F	I	N	Total
1993	No. of Crashes	270	6,173	17,588	24,031	No. of Crashes	55	715	504	1,274
	%	1.12	25.69	73.19	100.00	%	20.37	11.58	2.87	5.30
1994	No. of Crashes	289	6,441	17,331	24,061	No. of Crashes	79	844	491	1,414
	%	1.20	26.77	72.03	100.00	%	27.34	13.10	2.83	5.88
1995	No. of Crashes	287	6,475	18,506	25,268	No. of Crashes	78	758	536	1,372
	%	1.14	25.63	73.24	100.00	%	27.18	11.71	2.90	5.43
1996	No. of Crashes	339	6,881	20,364	27,584	No. of Crashes	95	812	556	1,463
	%	1.23	24.95	73.83	100.00	%	28.02	11.80	2.73	5.30
1997	No. of Crashes	302	7,038	22,296	29,636	No. of Crashes	55	781	528	1,364
	%	1.02	23.75	75.23	100.00	%	18.21	11.10	2.37	4.60
1998	No. of Crashes	319	6,897	23,118	30,334	No. of Crashes	64	751	553	1,368
	%	1.05	22.74	76.21	100.00	%	20.06	10.89	2.39	4.51
1999	No. of Crashes	343	6,643	22,574	29,560	No. of Crashes	83	725	542	1,350
	%	1.16	22.47	76.37	100.00	%	24.20	10.91	2.40	4.57
2000	No. of Crashes	316	6,339	21,864	28,519	No. of Crashes	83	790	544	1,417
	%	1.11	22.23	76.66	100.00	%	26.27	12.46	2.49	4.97
2001	No. of Crashes	325	6,422	22,267	29,014	No. of Crashes	92	803	566	1,461
	%	1.12	22.13	76.75	100.00	%	28.31	12.50	2.54	5.04
2002	No. of Crashes	343	6,198	21,397	27,938	No. of Crashes	107	724	548	1,379
	%	1.23	22.18	76.59	100.00	%	31.20	11.68	2.56	4.94

* Percentage base on total number of crashes in each injury severity
e.g. % of fatalities in 2002 due to alcohol and drug involvement = (107/343)*100 = 31.2 %

TABLE 10 Driver Injury Severities based on Safety Belt Use in Kansas Rural Highway Crashes

Year	Safety Equipment Used	Injury Severity			Total	%
		Fatal	Injury	No Injury		
1993	Non used	143	2,043	4,001	6,187	19.29
	Shoulder and Lap belt	40	2,899	16,233	19,172	59.77
	Lapbelt only	0	161	744	905	2.82
	Passive system(airbag)	0	10	36	46	0.14
	Other	6	130	20	156	0.49
	Unknown	38	695	4,879	5,612	17.49
	Total	227	5,938	25,913	32,078	100.00
1994	Non used	158	2,332	3,672	6,162	19.61
	Shoulder and Lap belt	38	2,979	16,205	19,222	61.18
	Lapbelt only	2	159	620	781	2.49
	Passive system(airbag)	2	13	37	52	0.17
	Other	2	86	10	98	0.31
	Unknown	29	718	4,355	5,102	16.24
	Total	231	6,287	24,899	31,417	100.00
1995	Non used	146	2,207	3,830	6,183	18.53
	Shoulder & Lap belt	46	3,172	17,732	20,950	62.80
	Lapbelt only	1	135	697	833	2.50
	Shoulder only		8	20	28	0.08
	Passive system(airbag)	1	29	48	78	0.23
	Other	1	92	67	160	0.48
	Unknown	34	670	4,425	5,129	15.37
	Total	229	6,313	26,819	33,361	100.00
1996	Non used	177	2,361	3,767	6,305	17.57
	Shoulder & Lap belt	46	3,472	19,691	23,209	64.68
	Lapbelt only	1	125	606	732	2.04
	Shoulder only	0	9	25	34	0.09
	Passive system(airbag)	7	57	45	109	0.30
	Other	2	106	288	396	
	Unknown	36	726	4,338	5,100	14.21
	Total	269	6,856	28,760	35,885	100.00
1997	Non used	155	2,269	3,825	6,249	16.19
	Shoulder & Lap belt	61	3,665	21,321	25,047	64.89
	Lapbelt only	0	121	585	706	1.83
	Shoulder only	2	15	42	59	0.15
	Passive system(airbag)	4	76	100	180	0.47
	Other	4	134	537	675	1.75
	Unknown	27	744	4,910	5,681	14.72
	Total	253	7,024	31,320	38,597	100.00

Table 10 Contd…

Year	Safety Equipment Used	Injury Severity			Total	%
		Fatal	Injury	No Injury		
1998	Non used	154	2243	3900	6297	15.99
	Shoulder & Lap belt	63	3713	22845	26621	67.58
	Lapbelt only	1	108	484	593	1.51
	Shoulder only	2	13	17	32	0.08
	Passive system(airbag)	9	84	99	192	0.49
	Other	1	67	20	88	0.22
	Unknown	31	691	4845	5567	14.13
	Total	261	6919	32210	39390	100.00
1999	Non used	161	2000	3274	5435	14.29
	Shoulder & Lap belt	64	3781	22758	26603	69.93
	Lapbelt only	0	32	7	39	0.10
	Shoulder only	0	18	19	37	0.10
	Passive system(airbag)	3	82	117	202	0.53
	Other	4	148	411	563	1.48
	Unknown	33	621	4508	5162	13.57
	Total	265	6682	31095	38042	100.00
2000	Non used	145	1798	2772	4715	12.86
	Shoulder & Lap belt	60	3693	22519	26272	71.67
	Lapbelt only	2	34	6	42	0.11
	Shoulder only	1	13	22	36	0.10
	Passive system(airbag)	11	85	100	196	0.53
	Other	6	139	368	513	1.40
	Unknown	37	587	4260	4884	13.32
	Total	262	6349	30047	36658	100.00
2001	Non used	165	1714	2412	4291	11.58
	Shoulder & Lap belt	64	3773	23651	27488	74.16
	Lapbelt only	1	30	6	37	0.10
	Shoulder only	1	11	17	29	0.08
	Passive system(airbag)	11	87	119	217	0.59
	Other	6	127	322	455	1.23
	Unknown	29	595	3923	4547	12.27
	Total	277	6337	30450	37064	100.00
2002	Non used	155	1620	2159	3934	11.07
	Shoulder & Lap belt	64	3732	23094	26890	75.70
	Lapbelt only	2	31	9	42	0.12
	Shoulder only	0	10	10	20	0.06
	Passive system(airbag)	12	105	118	235	0.66
	Other	5	122	290	417	1.17
	Unknown	36	602	3347	3985	11.22
	Total	274	6222	29027	35523	100.00

TABLE 11 Driver Injury Severities based on Gender of the Driver in Kansas Rural Highway Crashes

Year	Gender	Injury Severity			Total	%
		Fatal	Injury	No Injury		
1993	Female	53	2,306	8,368	10,727	33.44
	Male	174	3,629	17,050	20,853	65.01
	Unknown	0	3	495	498	1.55
	Total	227	5,938	25,913	32,078	100.00
1994	Female	67	2,504	8,308	10,879	34.63
	Male	164	3,782	16,148	20,094	63.96
	Unknown	0	2	443	445	1.42
	Total	231	6,288	24,899	31,418	100.00
1995	Female	62	2,592	9,101	11,755	35.24
	Male	167	3,715	17,240	21,122	63.31
	Unknown	0	6	478	484	1.45
	Total	229	6,313	26,819	33,361	100.00
1996	Female	84	2,877	10,019	12,980	36.17
	Male	184	3,974	18,261	22,419	62.47
	Unknown	1	5	480	486	1.35
	Total	269	6,856	28,760	35,885	100.00
1997	Female	80	2,945	10,694	13,719	35.54
	Male	173	4,071	20,034	24,278	62.90
	Unknown	0	8	592	600	1.55
	Total	253	7,024	31,320	38,597	100.00
1998	Female	84	2,832	11,030	13,946	35.40
	Male	176	4,079	20,571	24,826	63.03
	Unknown	1	8	609	618	1.57
	Total	261	6,919	32,210	39,390	100.00
1999	Female	80	2,798	10,803	13,681	35.96
	Male	185	3,880	19,738	23,803	62.57
	Unknown	0	4	554	558	1.47
	Total	265	6,682	31,095	38,042	100.00
2000	Female	74	2,659	10,377	13,110	35.76
	Male	188	3,686	19,063	22,937	62.57
	Unknown	0	4	607	611	1.67
	Total	262	6,349	30,047	36,658	100.00
2001	Female	79	2,566	10,654	13,299	35.88
	Male	198	3,761	19,168	23,127	62.40
	Unknown	0	10	629	639	1.72
	Total	277	6,337	30,451	37,065	100.00
2002	Female	82	2,606	10,385	13,073	36.80
	Male	192	3,613	18,094	21,899	61.65
	Unknown	0	3	548	551	1.55
	Total	274	6,222	29,027	35,523	100.00

TABLE 12 Driver Injury Severities in Rural Highway Crashes based on whether Driver being Ejected or Trapped due to the Crash

Year	Eject / Trapped	Injury Severity			Total	%
		Fatal	Injury	No Injury		
1993	Not Ejected/Trapped	49	4,599	22,546	27,194	84.77
	Ejected / Trapped	164	574	20	758	2.36
	Unknown	14	765	3,347	4,126	12.86
	Total	227	5,938	25,913	32,078	100.00
1994	Not Ejected/Trapped	48	4,925	22,485	27,458	87.40
	Ejected / Trapped	172	605	16	793	2.52
	Unknown	11	757	2,398	3,166	10.08
	Total	231	6,287	24,899	31,417	100.00
1995	Not Ejected/Trapped	52	5,142	23,403	28,597	85.72
	Ejected / Trapped	167	597	28	792	2.37
	Unknown	10	574	3,388	3,972	11.91
	Total	229	6,313	26,819	33,361	100.00
1996	Not Ejected/Trapped	60	5,563	25,172	30,795	85.82
	Ejected / Trapped	197	652	25	874	2.44
	Unknown	12	641	3,563	4,216	11.75
	Total	269	6,856	28,760	35,885	100.00
1997	Not Ejected/Trapped	47	5,680	25,103	30,830	79.88
	Ejected / Trapped	195	643	35	873	2.26
	Unknown	11	701	6,182	6,894	17.86
	Total	253	7,024	31,320	38,597	100.00
1998	Not Ejected/Trapped	56	5,646	26,346	32,048	81.36
	Ejected / Trapped	191	637	22	850	2.16
	Unknown	14	636	5,842	6,492	16.48
	Total	261	6,919	32,210	39,390	100.00
1999	Not Ejected/Trapped	56	5,454	25,370	30,880	81.17
	Ejected / Trapped	195	635	33	863	2.27
	Unknown	14	593	5,692	6,299	16.56
	Total	265	6,682	31,095	38,042	100.00
2000	Not Ejected/Trapped	60	5,099	24,245	29,404	80.21
	Ejected / Trapped	187	620	15	822	2.24
	Unknown	15	630	5,787	6,432	17.55
	Total	262	6,349	30,047	36,658	100.00
2001	Not Ejected/Trapped	55	5,063	25,164	30,282	81.70
	Ejected / Trapped	208	575	21	804	2.17
	Unknown	14	699	5,265	5,978	16.13
	Total	277	6,337	30,450	37,064	100.00
2002	Not Ejected/Trapped	58	4,998	24,222	29,278	82.42
	Ejected / Trapped	208	647	31	886	2.49
	Unknown	8	577	4,774	5,359	15.09
	Total	274	6,222	29,027	35,523	100.00

TABLE 13 Emergency Response Time for Rural Highway Crashes in Kansas

Time Taken to Respond (minutes)	Fatal Crashes	Cumulative %	Injury Crashes	Cumulative %	No-Injury Crashes	Cumulative %	Total	%	Cumulative % of Total
0 - 60	1426	97.60	29622	97.81	100841	94.62	131889	95.35	95.35
60 - 120	26	99.38	393	99.11	2401	96.88	2820	2.04	97.39
120 - 180	3	99.59	70	99.34	679	97.51	752	0.54	97.94
180 - 240	0	99.59	24	99.42	363	97.85	387	0.28	98.22
240 - 300	0	99.59	14	99.47	245	98.08	259	0.19	98.40
300 - 360	0	99.59	8	99.49	179	98.25	187	0.14	98.54
360 - 420	0	99.59	15	99.54	155	98.40	170	0.12	98.66
420 - 480	1	99.66	8	99.57	132	98.52	141	0.10	98.76
480 - 540	0	99.66	5	99.59	157	98.67	162	0.12	98.88
540 - 600	1	99.73	18	99.65	140	98.80	159	0.11	99.00
>600	4	100.00	107	100.00	1278	100.00	1389	1.00	100.00
Total	1461		30284		106570		138315		

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