TRAFFIC ACCIDENT SEVERITY ANALYSIS ON NH-163 USING LIMDEP MODEL

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***Abstract* — In this paper, a brief practical review is presented on the statistical evidence showing the model indicate that factors such as location of the crash, time of occurrence of the accident, the vehicles involved in the accidents as well as the maneuver of collisions are the four most important attributes that are found to be consistently significant. For example, the accidents occurring in day light are resulting in lower injury severity level than accidents occurring at night time. It has also been observed that accidents occurring near intersections are relatively less severe than accident occurring on roadway segments. Lorry's and unknown vehicles (in hit and run accidents) have been identified as accused vehicle in more cases than motorcycles & autos. Results also indicating that all the single vehicle collision are less severe than crashes involving SUVs and cars. Pedestrians, motorcycles, bicycle and autos are observed to sustain higher levels of injury severity than other users. Analysis of crash maneuver also shows that hit and run type of accident is very high and often results in higher levels of severities than even a head-on collision.**

***Keywords*—Accidents, severity, ranga reddy, NH-163, probit Modeling,**

1. Introduction

Throughout the world, the growth of the transport system has been and continues to be a key element in economic development. Increase in gross national product is associated with greater movement of people and goods and greater investment in both vehicles and transport infrastructure. In the developing world, current trends in population growth, industrialization and urbanization are causing heavy pressure on the transport network in general and on road network in particular. Most unwanted side-effect of this growth in traffic is growing numbers of deaths and injuries from road traffic accidents resulting in enormous cost in terms of lost productivity of the society. This also includes personal losses due to injuries (or fatalities) in traffic accidents as the victims must deal with pain and suffering, medical costs, wage loss, and vehicle repair costs. As a result traffic safety issues had attracted much attention of traffic engineers and planners to do effective research and get better understanding of the problem that provides the framework against which effective policies and counter-measures could be developed.

Traffic safety is a major concern because of the economic and social costs of traffic crashes. The impact that traffic accidents have on society is significant. Individuals injured (or killed) in traffic accidents must deal with pain and suffering, medical costs, wage loss, and vehicle repair costs. For society as a whole, traffic accidents result in enormous costs in terms of lost productivity and property damage. It is assumed that there is total 2% loss of GDP only due to road accident in India. Clearly, efforts to improve our understanding of the factors that influence accident severity are warranted. So the common practice in transportation engineering is a thorough study of traffic accidents and gets an understanding of the factor affecting them. Severity of injury sustained by victim involved in crashes is of considerable interest to policy makers & safety engineers. The relationship between the injury severity of traffic crashes and factors such as driver and passenger characteristics, vehicle type, and traffic and geometric conditions has attracted much attention. Better understanding of this relationship is necessary and very important for improving vehicle and roadway designs such that severe injuries can be reduced. Numerous studies have applied statistical models for crash injury severity study.

Recent years have witnessed rapid motorization, urbanization, industrialization, migration and other changes related to globalization and economic policies of successive governments in India. An accompanying effect of these changes is the increasing road crashes and deaths due to lack of safety policies and program.

The total number of accidents reported by Ministry of road transport and highways in the year 2012 were 4,84,704 of which 1,06,591 or 22.0% of total accidents were fatal; the number of persons killed in the accidents were 1,19,860 (i.e. an average of one fatality per 4.0 accidents) and the number of persons injured at 5,23,193 exceeded total number of accidents (4,84,704) in 2012. The proportion of fatal accidents in the total road accidents has consistently increased since 2001 as reflected in Table-1.1 The severity of road accidents measured in terms of persons killed per 100 accidents is observed to have increased from less than 20 in 2001 to 24.7 in 2012. India has a rural road network of over 3,300,000 km, and urban roads total more than 250,000 km. The national highways (NH), with a total length of 70934 km, serve as the arterial network across the country (NHAI). Roads carry about 61% of the freight and 85% of the passenger traffic. National

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Highways total about 71000 km (2% of all roads) and carry 40 % of the road. Highways permit greater speed resulting in relatively greater number of road accidents with higher severities.

Among the various accidents it has been observed that national highways accounted for 29% in total road accidents and 36% in total number of persons killed in 2012. The accident figures are not in proportion to the highway network since national highways are only 2% of all roads. Hence the accidents involvement rate on national highway is extremely high.

2. NEED FOR THE PRESENT STUDY

Initial investigation of collected sample data on National Highway-163 (NH-163) of Rangareddy District as shown in the figure-2.1 and last three years i.e. 2012-2014 accident data of Rangareddy district that in 2010, 53 % of total crashes on NH-163 were fatal and 39 % were major injury crashes. While in 2013 major injury and fatal crashes were 51% and 44% and in 2012 it was 49% and 40% respectively as shown in figure-2.2. This clearly shows that crashes occurring on NH-163 rarely result in minor or no injury crashes, probably due to higher average speed of these facilities. A further investigation on share of crashes on various roadways in RangaReddy district shows that, 54% of the total people died in the district due to road traffic crashes occurred on NH-163 only, compared to other state and district roadways. These statistics clearly shows that the accident situation on NH-163 is worsening.

The present study was conducted to understand the contributing factors affecting severity of road crashes in RangaReddy with a broad consideration of driver characteristics, roadway features, vehicle types and environmental factors. For this purpose, the type of accident severity analyses have been incorporated, i.e. all vehicle crash severity to get an overview of the factors affecting the severity throughout the RangaReddy district. The reason behind choosing this type of accident in severity analysis is that they constitute about the accidents that occurred in RangaReddy district from 2012 to 2014.

Figure-2.1 Map of NH-163 in Ranga Reddy district.

3. LITERATURE REVIEW

Gray et al. (2012) observed that young male drivers are over-represented in car accidents in Great Britain. While investigating the factors affecting the severity of these young male drivers they observed that driving in darkness, trips during early morning and towards the end of the week (Friday and Saturday) are related with higher severities. They also observed that carriageway hazards such as passing a site where accident occurred may increase severity of crashes at a site afterwards that specific site. They also observed higher levels of severities during overtaking maneuvers, and on the single carriageway of speed limit 60 mph. Other variables leading to higher severities were driving on main roads, not being at a junction, towing something like a caravan or trailer, young male drivers of age group 20-22, and finally in fine weather condition with no high winds.

Kockelman and Young (2001) applied ordered probit models to examine the risk of different injury levels sustained under all crash types, two-vehicle crashes, and single-vehicle crashes. The results suggest that pickups and sport utility vehicles are less safe than passenger cars under single-vehicle crash conditions. In two-vehicle crashes, however, these vehicle types are associated with less severe injuries for their drivers and more severe injuries for occupants of their collision partners (including drivers and passengers). Crash types such as roll-over and head-on accidents resulted in more severe injuries. Female drivers are also found to be involved with higher crash severities.

Pai and Saleh (2007) estimated statistical models to identify whether a specific maneuver by motorcycle or vehicle (e.g., overtaking or changing lanes) is more hazardous to motorcyclists in sideswipe collisions at T-junctions. The modeling results show that injuries to motorcyclists were greatest when an overtaking motorcycle collided with a turning vehicle and such effect appeared to be more severe at unsignalized junctions.

Quddus et al. (2002) investigated factors leading to increase in the probability of severe injuries of motorcyclists and identified that motorcyclist who is not from Singapore experienced higher crash severities compared to Singaporean motorcyclists. , Among other factors they found that increased engine capacity, headlight not turned on during daytime, collisions with pedestrians and stationary objects, driving during early morning hours and motor cycles with pillion passengers experienced higher severities. Additionally they observed that in collisions where the motorcyclists are at fault, they sustained higher levels of injuries than otherwise.

Abdel-Aty (2003) applied ordered probit models for analysis of driver injury severity levels at roadway sections, signalized intersections, and toll plazas. He found that older drivers, male drivers, and those not wearing a seat belt will have a higher probability of a severe injury and both signalized intersections and roadway sections models showed higher level of injuries in rural areas, possibly due to higher speeds. He also found that driver's violation was significant in case of signalized intersection. Alcohol, lighting conditions, and the existence of a horizontal curve affected the likelihood of injuries in the roadway sections' model. A variable specific to toll plazas, vehicles equipped with Electronic Toll Collection, had a positive effect on the probability of higher injury severity at toll plazas.

4.0 OBJECTIVE AND SCOPE OF STUDY

The principal objective of this study is to investigate how various factors such as the seasonal variation, weekly variation, time of day variation, collision type, victim gender, crash location, and vehicle type can lead to variations in the probabilities of sustaining different levels of injury severity in motor vehicle accidents on NH-163.
To do so injury severity levels had been categorized into three levels. Three levels are minor injury, major injury and death. Data have been collected from different police stations of RangaReddy district along NH-163. Then after initial investigations of primary data has been done. From those analyses it was found that there were over-representation of pedestrian and truck involved crashes. So three distinct model, all crash model, truck involved crash model, and model for all pedestrian involved crashes have been developed to get clear understanding of the factors influencing higher level of severities. Finally the probability of occurring different levels of injury severity associated with different factors such as collision type, vehicle type, time of day variation have been estimated.

In all the above studies environmental factors such as climatic condition, roadway geometry like horizontal curve, vertical curve are not taken into account due to lack of accident data. Victim's age have not been considered into model due to insufficient data and has been separately investigated.

To achieve the above mentioned objective ordered probit model have been applied to real accident data. Ordered probit model is a widely used statistical tool which is generally used for analysis of ordinal data. Here injury severities are ordinal data type. The models are analyzed to find the factors causing higher level of severities in traffic crash.

5.0 METHOLODGY

The methodology implemented to analyze police-reported crash data on national highway-163 to identify possible factors that cause these crashes and to understand their effect on injury severity using statistical modeling techniques. The method and procedures adopted for this study can be divided into three steps-

a. Collection of accident data,
b. Variable selection and development of statistical model and
c. Analysis and interpretation of model findings. A detailed description of the above mentioned steps is presented in the following sections.

5.1 DATA COLLECTION

As mentioned in Section 1.4 of Chapter one above, since the objective of the study was to understand the effects of various factors such as the seasonal variation, weekly variation, time of day variation, collision type, victim gender, crash location, and vehicle type on injury severity of crashes on NH-163, several data sources have to be used to obtain all the data necessary to carry out the study. In order to meet this objective of the research, which specifically is attempting to create a better understanding the effects of these factors believed to possibly influence injury severity, collection of accurate and representative data was the most critical and of course lengthiest part of the research.

5.2 COLLECTION AND PROCESSING OF ACCIDENT DATA

Due to lack of any standard traffic crash data reporting system a field survey have been done to collect all police-reported crash data on NH-163. Since the study area was NH-163 in RangaReddy district all the police station that were reporting any crash occurred on national highway have been taken into consideration. Unfortunately, police reports at accident sites do not describe injuries in much detail because of the lack of police qualifications and training as well as facilities needed to perform complex examinations. All these police station having theses crash data in form of FIR sheets and complaint lodged by victim or else one. All the reported crashes occurring in last three years i.e. from 2008 to 2010 were collected. From these FIR sheets and complain letter a data set have been prepared. Preparation of data set was the most time consuming part of the study.

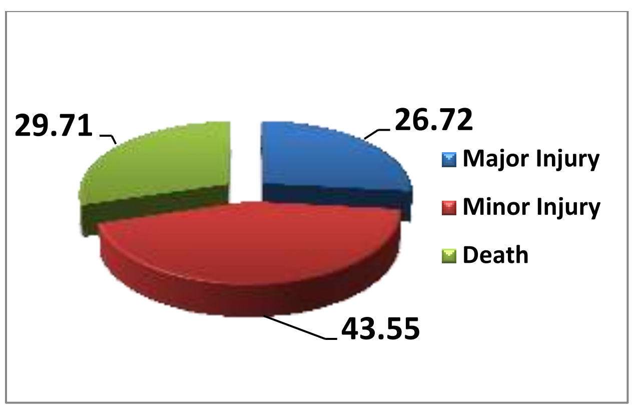


Fig 1 Percent share of crash severity on NH-163 in RangaReddy district

Monthly distribution of crash injury severity:

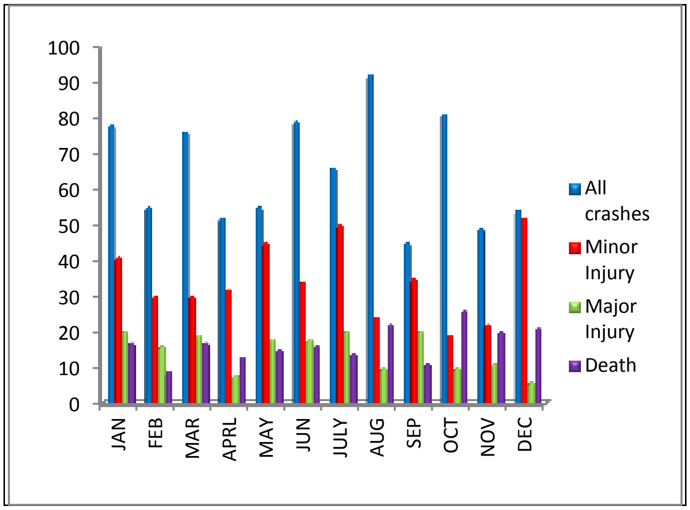


Fig 2 Monthly variation of crash Severity on NH-163 during 2012-2014

Weekly distribution of crash severity:

Days	Minor injury	Major injury	Death
MON	19.31	11.88	16.12
TUE	17.16	13.98	20.64
WED	13.3	22.37	10.96
THR	17.16	13.98	6.45
FRI	18.88	11.18	19.35
SAT	12.44	12.58	8.38
SUN	12.87	13.98	18.6

Weekly distribution of crash severity:

Through-out the week no major variation have found. All crashes are between1% to 4 %, minor injury crashes are between 4% to 8 % whereas major injury and fatal crashes are always greater than 20%.

Hourly variation of crash injury severity

Hourly variation of crash severity is estimated with four hours of interval throughout the day by plotting percent distribution of crash severity on Y-axis. Table 4.1 show that between night 00:00 hrs to morning 03:59 hrs percentage of occurring fatal crashes are higher which is 31.20% of total crash occurring between that hours.

Also, medical reports were hard to obtain because police accident data and medical data are not kept together. Consequently, it was impossible to obtain details on the degree of accident severity. All that can be learned from the police records is that the accident is a fatal accident, minor injury, severe injury on accident. Each observation in this data set is a record of the level of injury severity sustained by crash victim, Vehicle type involved in crash, location of the accident, type of collision, year, month, day, date, and time of the collision, victim gender, victim age, and lane direction.

PRIMARY INVESTIGATION OF ACCIDENT DATA.

A total of 10 major factors contributing to higher crash severity were summarized from those 535 crash counts. A preliminary investigation of these factors was done so that their impacts on injury severity could be estimated. Detailed discussion of these major variables is given in following paragraphs.

Monthly distribution of crash injury severity:

As illustrated in figure-4.2 highest accidents are occurring in month of August. It is 11.76% of all accident occurring during 2008-2010.

About 12.93 % of all fatal crashes are occurring in August and October each. In August highest major injury has been observed which is about 11 % of all major injury occurred during 2008-2010.

Model Selection

The crash injury severity is a typical ordered variable which could be categorized at different levels from the least severe level to the most severe. In this study crash injury severity is ordinal variable categorized as “no injury = 0,” “minor injury = 1,” “major injury = 2,” and “fatal = 3”. As ordered response models are capable of recognizing the indexed nature of various response variables so it is commonly used for analyzing the data sets that include categorical and ordered dependent variable. Among ordered response model ordered probit/logit are the most often used models

Model Specification

The general specification of each single equation model is:

$$Y_n^* = \beta' x_n + \varepsilon_n,$$

Where, Y_n^* is the latent and continuous measure of injury severity faced by the accident victim 'n' in a crash, x_n is a vector of explanatory variables measuring the attributes of accident victim.β' is vector of parameters to be estimated, and ε_n is a random error term which assumed to follow a standard normal distribution with mean zero and variance one.

The observed and coded discrete injury severity variable, Y_n, is determined from the model as follows:

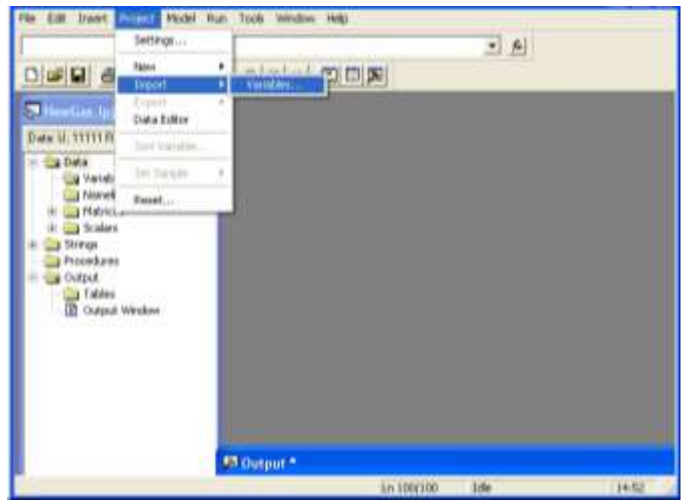
$$Y_n = \begin{cases} 0 & \text{if } -\infty \le Y_n^* \le \mu_1 \quad \text{(no injury)}, \\ 1 & \text{if } \mu_1 < Y_n^* < \mu_2 \quad \text{(not severe injury)}, \\ 2 & \text{if } \mu_2 < Y_n^* < \mu_3 \quad \text{(severe injury)}, \\ 3 & \text{if } \mu_3 < Y_n^* < \infty \quad \text{(fatal)}, \end{cases}$$

Where, the μ_i represents thresholds to be estimated along with the parameter vector β.

The probabilities associated with the coded responses of an ordered probit model are as follows:

$$P_n(0) = \Pr(Y_n = 0) = \Pr(Y_n^* \le \mu_1) = \Pr(\beta' x_n + \varepsilon_n \le \mu_1)$$
$$= \Pr(\varepsilon_n \le \mu_1 - \beta' x_n) = \varphi(\mu_1 - \beta' z_n)$$
$$P_n(1) = \Pr(Y_n = 1) = \Pr(\mu_1 < Y_n^* \le \mu_2)$$
$$= \Pr(\varepsilon_n \le \mu_2 - \beta' x_n) - \Pr(\varepsilon_n \le \mu_1 - \beta' x_n)$$
$$= \varphi(\mu_2 - \beta' x_n) - \varphi(\mu_1 - \beta' x_n)$$
$$P_n(k) = \Pr(Y_n = k) = \Pr(\mu_k < Yn^* \le \mu_{k+1})$$
$$= \varphi(\mu_{k+1} - \beta' x_n) - \varphi(\mu_k - \beta' x_n)$$
$$P_n(K) = \Pr(Y_n = K) = \Pr(\mu_k < Yn^*)$$
$$= 1 - \varphi(\mu_k - \beta' x_n)$$

Where, n is an individual, k is a response alternative (Y_n=k) is the probability that individual n responds in manner k, and φ(.) is the standard normal cumulative distribution function. The model is usually identified by setting μ_0=0. So the unknown parameters needing to estimate then become β and (μ_1, μ_2, μ_3,……. μ_k).



The parameters of ordered multiple choice models are estimated by the method of maximum likelihood (ML). In very simple terms, the method of ML is a method for choosing parameter estimates in order to maximize the probability, or likelihood, of observing given data. A likelihood function is an equation expressing this probability/likelihood as a function of the data and the unknown parameters, and ML estimation involves the systematic evaluation of this function at different points (i.e. sets of parameter values) in order to find the point at which the function is maximized. This set of parameter values then becomes set of ML estimates.

For a sample of N accident victims, the log-likelihood function (i.e. the logarithm of the likelihood function) for ordered probit models can be written as

$$\log(L) = \sum_{n=1}^{N} \sum_{k=1}^{K} d_{nk} \log[P_n(k)]$$

Where d_{nk} is a dummy variable which takes the value one if individual n chose alternative k and $d_{nk} = 0$ otherwise.

Table-3 Description of all Variables Used in This Study

Explanatory variable	Description
Dependent variable	

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CRASH SEVERITY	Injury severity level: Property damage only = 0, Minor injury = 1, Major Injury = 2, Fatal = 3
Seasonal effects	
JAN	If accident occurs in January = 1, otherwise = 0
FEB	If accident occurs in February = 1, otherwise = 0
MAR	If accident occurs in March = 1, otherwise = 0
APR	If accident occurs in April = 1, otherwise = 0
MAY	If accident occurs in May = 1, otherwise = 0
JUN	If accident occurs in June = 1, otherwise = 0
JUL	If accident occurs in July = 1, otherwise = 0
AUG	If accident occurs in August = 1, otherwise = 0
SEP	If accident occurs in September = 1, otherwise = 0
OCT	If accident occurs in October = 1, otherwise = 0
NOV	If accident occurs in November = 1, otherwise = 0
DEC	If accident occurs in December = 1, otherwise = 0
Day of Week	
MON	If accident occurs on Monday = 1, otherwise = 0
TUE	If accident occurs on Tuesday = 1, otherwise = 0
WED	If accident occurs on Wednesday = 1, otherwise = 0
THU	If accident occurs on Thursday = 1, otherwise = 0
FRI	If accident occurs on Friday = 1, otherwise = 0
SAT	If accident occurs on Saturday = 1, otherwise = 0
SUN	If accident occurs on Sunday = 1, otherwise = 0
Time of the Day	
TIME1 (00:00 hrs to 03:59 hrs)	If accident occurs during this time = 1, otherwise = 0
TIME2 (04:00 hrs to 07:59 hrs)	If accident occurs during this time = 1, otherwise = 0
TIME3 (08:00 hrs to 11:59 hrs)	If accident occurs during this time = 1, otherwise = 0
TIME4 (12:00 hrs to 15:59 hrs)	If accident occurs during this time = 1, otherwise = 0
TIME5 (16:00 hrs to 19:59 hrs)	If accident occurs during this time = 1, otherwise = 0
TIME6 (20:00 hrs to 23:59 hrs)	If accident occurs during this time = 1, otherwise = 0
Accused vehicle	
LORRY	If accused vehicle is lorry = 1, otherwise = 0
BUS	If accused vehicle is bus = 1, otherwise = 0
AUTO	If accused vehicle is minilorry or pickup vans = 1, otherwise = 0
CAR	If accused vehicle is SUV or car = 1, otherwise = 0
MOTORCYCLE	If accused vehicle is motorcycle = 1, otherwise = 0
UNKNOWN	If accused vehicle is unknown = 1, otherwise = 0
OTHERS	If accused vehicle is other type (tanker, trailer, any other vehicle) = 1, otherwise = 0
Victim Vehicle	
PEDESTRN	If victim is pedestrian = 1, otherwise = 0
MOTORCYCLE	If victim vehicle is motorcycle = 1, otherwise = 0
LORRY	If victim vehicle is lorry = 1, otherwise = 0
SUVCAR	If victim vehicle is SUV or car = 1, otherwise = 0
Vitim Gender	
VICTIMGE	If gender of victim is male = 1, otherwise = 0
VICTIM AGE	
0-10	If victim age is 0-10=1, otherwise=0
11-20	If victim age is 11-20=1, otherwise=0
21-30	If victim age is 21-30=1, otherwise=0
31-40	If victim age is 31-40=1, otherwise=0
41-50	If victim age is 41-50=1, otherwise=0
51-60	If victim age is 51-60=1, otherwise=0
61-90	If victim age is 61-90=1, otherwise=0

DISCUSSION AND RECOMMENDATION

In this model the developed study on crashes occurring in night, are resulting higher level of crash severity. Particularly accidents occurring between midnight to early morning hours are more sensitive to higher level of crash severity. This may be due to poor illumination and absence of warning measures such as retro-reflective signs which helps in roadway hazard identification. Hence to avoid such crashes proper illumination in night hours on highways along with retro-reflective materials is strongly recommended. For this purpose installation of solar lights may be very effective.

Seasonal variation

Seasonal variation was estimated using month of the year as dummy variable considering January as a reference month. Results show that accidents occurring in month of August (β = 0.4004, t = 2.13, $p < 0.05$) and October (β = 0.3469, t = 21.817, p = 0.0692) are resulting higher level of crash severity than month of January.

Victim Age

Effects of age on crash injury severity have been measured with reference of 0-10 age. 21-30 ($p<0.05$, t = 3.239) and 31-40 ($p<0.05$, t = 2.239) types of ages are resulting higher level of crash severity in comparison of crashes.

Type of collision

Effect of types of collision on injury severities were estimated with a reference of head-on collisions. Results associated with higher level of crash severity are conflicting with previous result of all single vehicle crash of trucks resulting in as lower crash injury severity.

Hourly variation

Time of day effects in model were measured with dummy variable at four hour interval with respect to midnight 00:00 hrs to morning 03:59 hrs same as of all crash model. Result is quite interesting. Coefficients of TIME2 ($p<0.05$, t = 2.178) showing that with respect to reference time interval accident occurring in morning 04:00 hrs to 7:59 hrs are resulting higher severity.

Weekly variation

Effects of day of week have been estimated with reference to Monday. Result is consistent with result of all crash model. Statistical significance levels of variable coefficient are showing that there is no variation in injury severity level.

CONCLUSIONS

This study highlights factors that are responsible for higher level of crash severity on national highway-163. Ordered probit regression methodology has been used to develop statistical models that were able to recognize those factors. To get clear understanding of those factors affecting higher crash severity three distinct models- all crash model, truck involved crash model and pedestrian involved crash model, have been developed. Finding of all this study may be concluded as follows:

- Accidents occurring during night time are more severe than accidents occurring in day light. In case of trucks, the early morning time crashes between 4 and 8 am resulted in higher severity than other time of the day.
- Accidents occurring at intersections are less severe than other roadway sections.
- Pedestrians, bicycle, motorcycle, and auto-rickshaws are always facing higher level of crash severity.
- Unknown vehicles and trucks are responsible for high crash severity on national highway.
- Both all crash model and lorry involved crash model show that hit and run and overturning crashes are more severe than head-on collision.

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