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Statistical Modeling on Determinants of Traffic Fatalities and Injuries in Wolaita Zone, Ethiopia

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Abstract- Road traffic accidents are a major public health concern. In developing countries road traffic accidents are among the leading cause of death and injury. Ethiopia experiences the highest rate of such accidents in Sub-Saharan Africa. Out of all the accidents registered in Ethiopia, Addis Ababa accounts for 60% on average especially in Wolaita zone more 25% on average. The objective of this study is to identify factors that contribute to the occurrence of road traffic accidents leading to human injuries and death. For study purpose we employed ordinal logistic regression models to identify factors influencing traffic fatalities and injuries. Stratified sampling with proportional allocation and simple random sampling technique are used to select samples from recorded frame. The result of ordinal logistic regression analyses shows that drivers aged 18-30 years caused the largest number of accidents. Low educational background of drivers, absence and poor lighting along roads, wet surface and asphalt surface, morning and evening hours, places like offices, residential and commercial neighborhoods, automobiles and small taxis/Bajaj's were found to be associated with fatalities and serious injuries. We conclude that for effective and safe traffic management, the concerned transportation authorities can consider the above mentioned predictors as potential causes of accidents in their order of importance in order to take preventive measures.

Keywords: fatalities, injuries, odds ratio, ordinal logistic regression, traffic accident. wolaita zone, ethiopia.

I. Introduction

Road traffic accident is defined as any vehicle accident occurring on a public highway. It includes collisions between vehicles and animals, vehicles and pedestrians, vehicles and fixed objects or vehicles and vehicles. Road traffic deaths accounted for 23% of all injury deaths worldwide in 2002. It has also been estimated that nearly 1.2 million people, male-to-female ratio being 2.34 to 1, are killed and 20-50 million people are injured or disabled each year in road traffic accidents. On average 3,300 road users are killed and about 100,000 are injured and/or disabled each day in traffic (WHO, 2004). Road traffic injures are growing as the vehicle use of developing countries rises. By 2020, road traffic injures are expected to be the third leading cause of death and disability worldwide, by some calculations matching the toll of AIDS. Residents of developing countries are at much higher risk of road traffic injures than are residents of high-income countries. They are also at greater risk of death when a crash occurs. Developing countries also have inadequate trauma systems and are often unable to care for crash victims. Unless action is taken to improve road safety systems, poor countries will continue to bear the heavy toll of road traffic injuries (Lauren and Hill, 2005). The World Health Report (WHO, 2004) shows that of the 1.2 million people killed in road crashes worldwide, 85% are in developing countries. Sub-Saharan Africa alone with only 4% of the global vehicle registered accounts for 10% of the road fatalities, and the economic, social and health consequences are grave. Conversely, the high-income nations, with 60% of the total global vehicle fleet contribute only 14% of the annual road deaths. Human error, road environment and vehicle factors are reported by the traffic police as the main causes of road crashes. Two countries, South Africa and Nigeria, account for most of the reported deaths in Sub-Saharan Africa. The South Africa figure of over 9,000 has been consistent over time, while Nigeria with 6,185 deaths has declined from a high of over 9,200 in the early 1990s. Ethiopia, Kenya, Uganda, Tanzania and Ghana are the other countries that experience high number of road deaths (WHO, 2004). Out of all the accidents registered in Ethiopia, Addis Ababa accounts for 60% on average. This is partly because the city has only five outlets that connect it all regions of the country. In addition to this about 77% of vehicles in Ethiopia are registered here. Thus Wolaita zone, having a great concentration of vehicles and traffic, takes the lion's share in car accidents. Statistical data from the Wolaita zone Traffic. According to Tewolde (2007), the highest mean number of injuries per accident took place in residential areas by drivers in the age group of 18-30 who have elementary school level of education. Therefore, in our case we tried to identify factors that contribute to the occurrence of road traffic accidents leading to human injuries and death.

II. Data and Methodology

a) Source of Data

In Wolaita zone road traffic accidents are recorded by traffic department on daily basis. The data provide information on accidents that occur within 365 consecutive days. From the collected data we will registered as slight injury, serious injury and fatal, respectively. A pilot sample was used in order to

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determine and estimate the required sample size. From the total record pilot samples were taken as slight injury, serious injury and fatal. This means the data have three strata: slight injury, serious injury and fatal. Stratified sampling with proportional allocation and simple random sampling technique was used to select samples from recorded frame for each stratum.

b) Data Collection

According to the definition of the Traffic Police, a road traffic accident is considered to be any event of human injury and/or death as a consequence of a physical collision between a responsible party (motor vehicle including motorcycle, car, van or truck, and bicycle) and an injured/damaged party (motor vehicle, bicycle/ bike, pedestrian, or any physical object, e.g., building or tree). In cases when the crash involves a motor vehicle and/or bicycle with pedestrians, the information about the driver/rider of the motor vehicle/bicycle (age, sex, alcohol consumption, speed, type of motor vehicle) is recorded at Wolaita zone traffic department regardless of the responsible party. When the accident involves two motor vehicles the record is made only for the responsible party.

c) Variables included in the study

The response variable is "level of injury severity of road traffic accident involving humans". In this study the response is an ordered variable categorized into three: slight injury, serious injury and death. Slight injury assumes the lowest order one while serious injury and death have orders two and three, respectively.

Predictor factors considered as determinants of traffic accidents involving human injuries are grouped into human, vehicle, road, environmental, and other factors.

Human factors are sex of driver, age of driver, driving experience, vehicle ownership status and driver educational background.

Vehicle factors are driving direction at the time of accident, vehicle type, and vehicle age.

Environmental factors are atmospheric condition, light condition, day of accident, time of accident, and road condition.

Road factors are place of accident, road situation, road junction, road class, and surface/ pavement roughness.

Other factors include reason for accident and accident type.

III. Methodology

Both ordinal logistic regression as well as cumulative logit model were used. For ordinal logistic regression response variable can take the three levels of injury as indicated above, and these are ordered depending on the level of severity as slight injury, serious injury and death – the lowest, middle and highest orders being slight injury, serious injury and death, respectively. When the response variable denoted Y, is ordinal, the categories can be ordered in a natural way. One way to take account of ordering is the use of cumulative probabilities and cumulative odds. In general considering k ordered categories, these quantities defined are defined by:

$$P(Y \leq i) = p_1 + p_2 + \cdots + p_i$$

$$odds(Y \leq i) = \left(\frac{P(Y \leq i)}{1 - P(Y \leq i)}\right) = \frac{p_1 + p_2 + \cdots + p_i}{p_{i+1} + \cdots + p_k} \quad i = 1,2, \ldots, k-1$$

Currently, the most popular model for ordinal response uses logits of cumulative probabilities, often called cumulative logits.

$$logit(Y \leq i) = \ln\left(\frac{P(Y \leq i)}{1 - P(Y \leq i)}\right) \quad i = 1,2, \ldots, k$$

The cumulative logistic model for ordinal data is described below.

a) Cumulative Logit Models

A cumulative logit model is one of the most commonly used models for the analysis of ordinal categorical data and belongs to the class of generalized linear models. It is generalization of a binary logistic regression model when the response variable has more than two ordinal categories. It is also the cumulative logit model is used when the response of an individual unit is restricted to one of afinite number of ordinal values. In cumulative logit model, the effect of β is the same for all i, often referred to as a proportional odds model (McCullagh and Nelder, 1989). In other words, the model assumes that the effect of each independent variable is the same for each cumulative probability. This model provides a single odds ratio (OR) estimate for all response categories, which can be obtained by exponentiation of the β coefficient. The estimate is quite convenient in terms of the model's ease of interpretation and parsimony. The proportional odds model is used to estimate the odds of being at or below a particular level of the response variable. If there are i levels of ordinal outcomes, the model makes k-1 predictions, each estimating the cumulative probabilities at or below the ith level of outcome variable. This model can estimate the odds of being at or beyond a particular level of the response variable as well, because below and beyond a particular category are just two complementary directions. The model's threshold varies for each of the equations and satisfies the conditions $\beta_{o1} \leq \beta_{o2} \leq \cdots \leq \beta_{ok-1}$, where $\beta_o's$ are cut points, usually nuisance parameters of little interest. A model can simultaneously describe the effect of an explanatory variable on all cumulative probabilities for y. the model is defined by:

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$$logit\left[P(Y \leq i|x_1, x_2, \ldots, x_p)\right] = ln\left[\frac{P(Y \leq i|x_1, x_2, \ldots, x_p)}{P(Y > i|x_1, x_2, \ldots, x_p)}\right] = \beta_{io} + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p ,$$

$i = 1,2, \ldots, k-1$. When $\beta > 0$, this means that the corresponding independent variable is more likely to have higher values of y. Also the parameterization of this model is in accord with the usual formulation, in sense that a positive β corresponds to a positive association (a higher x tending to occur with higher y) in other words If $\beta > 0$ (odds greater than one) in this study this means increased likelihood of accident can be fatal/serious injury.

Table 2: Parameter estimates of the ordinal logistic model

Variables	Estimates	S.E	Wald	Df	Sig	Odds-ratio
Threshold [severity level=1]	3.5	1.3	2.7	1	.000	
[severity level=2]	6.3	1.5	4.2	1	.000	
Age of driver	**-.51**	**.11**	**21.5**	1	.000 *	
18-30	1.21	.51	5.63	1	.000*	3.4
31-50	1.11	.78	2.62	1	.000 *	3.0
≥51(ref.)						
Driving experience	**.55**	**.11**		1	.000*	
≤1 year	-1.53	.15	104.0	1	.000*	.22
1-2 years	-1.25	.22	32.3	1	.000*	.29
2-5 years	-.58	.14	17.1	1	.000*	.56
>5years (ref.)						
Educational background	**-.65**	**.12**			.001*	
Elementary school	1.75	.32	29.9	1	.000*	5.79
Junior school	1.43	.15	90.8	1	.000*	4.18
Secondary school	.75	.12	39.2	1	.000*	2.11
Above secondary school(ref.)						
Vehicle type	**-.23**	**.11**	**44.0**	1	.000*	
Automobile	1.45	.14	107.3	1	.000*	4.26
Bajaj	1.50	.20	56.5	1	.002*	4.48
Minibuses	.95	.42	14.1	1	.000*	2.58
Cargo	1.32	.45	2.26			
Buses	1.21	.55	8.6	1	.000*	3.35
Other vehicles(ref.)						
Atmospheric condition	**- 1.42**	**.38**	**13.96**	1	.000*	
Good condition	1.78	.41	18.84	1	.000*	5.93
Rainy(ref.)						
Light condition	**1.41**	**.15**	**88.4**	**1**	**.000***	
Day light	-2.75	51	29.0	1	.000*	.06
Dark but lighted	-2.68	.55	23.74	1	.000*	.07
Dark(ref.)						
Time of accident	**- .57 .10**	**32.5**		1	.000*	
Morning	1.40	.35	16.0	1	.000*	4.05
Day	1.35	.40	11.4	1	.000 *	3.85
Evening	1.79	.30	35.6	1	.000*	5.99
Night(ref.)						
Road condition	**1.65**	**.35**	**22.2**	1	.000*	
Dry	- 1.88	.31	13.6	1	.000*	.153

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Wet(ref.)	**1.65**	**.35**	**22.2**			
Road surface roughness	**-1.98**	**.55**	**12.96**	1	.000*	
Asphalt	1.78	.51	49.00	1	.000*	5.75
Not asphalted(ref.)						
Road junction	**-.46 .23**	**4.0**		1	.000*	
No junction	.66	.12	30.5	1	.000*	1.93
Junction(ref.)						
Place of accident	**-1.65**	**.63**	**6.85**	**1**	**.000***	
Office	1.55	.45	11.9	1	.000*	4.71
Residential	2.50	.54	21.4	1	.000*	12.18
Commercial	1.75	.35	25.0	1	.000*	5.75
Religion centers	1.18	.75	2.5	1	.000*	3.25
Recreation	1.00	.33	9.2	1	.002*	2.78
School(ref.)						
Accident type	**-.78**	**.11**	**50.3**	1	.000*	
Crashing with pedestrian	1.50	.40	14.1	1	.000*	4.48
Crashing with another vehicles	1.60	.44	13.1	1	.000*	4.95
Others	1.75	54	10.5	1	.000*	5.75
Cashing with objects(ref.)						

**Significant at 5% level of significance*

IV. Results and Discussion

The results of the ordinal logistic regression analysis in Table 2, shows that age of drivers is a significant indicator of fatal and serious injuries. The odds-ratio of accidents causing fatal/serious injury is higher in the case of young drivers (18-30 years and 31-50 years) compared with the elderly drivers (aged above 51 years). As compared to those with driving experience of more than 5 years, the odds-ratio of causing fatal/serious injury for drivers with driving experience of utmost one year, 1-2 years and 2-5 years were lower by a factor of 0.22, 0.29, and 0.56 times, respectively. Drivers with elementary, junior secondary and secondary level of education are about 5.75, 4.18, and 2.11 times more likely to get involved in fatal/serious injuries as compared to those with above secondary school level of education, respectively. The odds-ratio of traffic accidents causing fatal/serious injury is higher for drivers with automobile (4.26 times), buses(3.35 times), Bajaj (4.48 times), and taxis or minibuses(2.58 times) as compared to the reference category "other vehicles". The odds-ratio of accidents causing fatal/serious injury is higher during a clear condition as compared with a rainy condition. There is a significant relationship between light condition and severity level of accidents. The odds-ratio of traffic accidents causing fatal/serious injury is higher in a dark condition as compared to daylight and dark-lighted conditions. The odds of traffic accidents causing fatal /serious injury are higher in the morning, day and evening as compared to accidents at night. Regarding road condition, the likelihood of fatal/serious injury is higher on wet roads as compared to dry condition. Fatal and serious injury is about 5.75 times more likely to take place on asphalt roads compared to those driving on not asphalted roads. Accidents causing fatal/serious injuries at roads without junction are 1.93 times higher as compared to accidents at junction roads.

Human Factors: While the actions of people might be influenced by subconscious motives and subliminal cues, they are also the most adaptive elements in the traffic system. They can create risk situations as well as respond to ever changing new demands of the traffic environment. The findings of the study show that accident rates of young drivers are more than the rest of the examinees. This may be related to reckless driving, psycho-biological immaturity, an excessive belief in one's own abilities, lack of experience, driving culture,

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and lifestyle induced risky type of exposure such as night driving. Drivers who have more than 5 years of experience cause fatal/serious injury than those who have less driving experience. This could be due to overconfidence and carelessness. The highest risk group for accident is drivers with primary school educational level. The risk of accident decreases a bit among junior high school graduates. Drivers with above secondary school level of education have the least involvement in accidents. This indicates that education is a considerable factor to prevent road traffic accidents. Thus, it can be said that understanding, interpreting and obeying the regulations are parallel to education and behaving more logical.

Vehicle Factors: Vehicle type was found to be an important factor which affects human injury/fatality caused by traffic accidents. Even if buses and taxies/ minibuses play an essential role in public transportation, our results showed that these vehicles (in addition to automobiles, cargo vehicles and buses) pose a significantly greater fatal/serious injury risk to pedestrians. Note that cargo vehicles have larger mass, greater momentum and longer stopping distance. For any given speed, the greater the mass of the vehicle, the greater would be its force of impact at collision with the pedestrians leading to higher injury severities. Furthermore, it is possible that drivers of small vehicles but high speedy are more likely to weave around in traffic, change lanes, dart ahead of others or even take corners and curves faster. This finding seemed to be in accordance with other studies (Tewolde, 2007).

Environmental Factors: Most of the accidents occurred in good conditions. Poor light conditions contributed to causing fatal/serious injuries, which indicates that poor light conditions could increase the probability of causing fatalities when a crash occurs. This is possibly due to poor visibility at night in the absence of street light is limited by the range of headlights and glare from oncoming vehicles headlights. In addition, drivers are also unable to distinguish pedestrians from the shaded surroundings due to their darker outfits. All these can lead to drivers braking later or taking less effective avoidance maneuvers leading to increased risk of crash and serious injury. This finding is consistent with other studies (Luma and Sivak, 1992). Traffic accidents causing fatal/serious injury are higher in the morning, during the day, and in the evening as compared to accidents during the night. This indicates that in the morning (the beginning of the working day) and evening (the end of the working day) the roads are typically busy with traffic volume, and during daytime, there are increased activities such as commercial activities and work related (office) activities, etc. So this situation gives rise to increase in the number of accidents. In terms of road surface condition, this study found out that wet surface condition resulted in a higher likelihood of fatal/ serious injury than dry surface. This could be because on wet road surfaces it is difficult to stop vehicles easily. This implies that the possibility of death/serious injury will be high.

Road factors: The environment with its road network creates the framework for the behavior of traffic and exposes those who are on the network to various accident risks. Traffic environment can support and promote safe behavior, but it can also encourage or lead to risky behavior. The findings of the study show that the majority of the fatal/serious injuries have occurred on asphalt roads. This finding is consistent with previous studies (Yayeh, 2003). This is due to the fact that asphalt roads increase vehicular speed. Therefore, if a crash happens, a pedestrian is more likely to suffer from more severe injury due to the higher impact speed. The findings of this study show that traffic accidents causing fatal/serious injuries at no-junction roads are higher as compared to accidents at junction roads. This finding is consistent with the study by Singh *et al*. (1998). This could be due to the reason that at junction not only drivers but also pedestrians are more careful and also there may be traffic lights at junctions. Most accidents took place around offices, residential and commercial neighborhoods. It should be noted that these places are typically busy with traffic volume giving rise to increase in the number of accidents. A study by Tewolde (2007) also reported the same result. The findings of this study also show that the odds of accident being fatal/serious injury due to crashing with pedestrians, and crashing with another vehicle were higher as compared to crashing with objects. As expected, the serious injury risk significantly increased for pedestrians who tended to cross a road without proper right of way. Since drivers do not expect pedestrians at locations not designated for pedestrians, they might fail to detect the pedestrian in time and take evasive actions accordingly. This might result in higher impact speed during collision leading to greater injury risk. Negligent crossing behavior has been reported to be a major cause of pedestrian collision and injury by Yayeh (2003).

V. Conclusion

Drivers with driving experience of more than 5 years are significantly exposed to traffic accidents causing fatal/serious injury. Drivers aged 18-30 years and aged 31-50 year, drivers with lower educational background, no-junction roads, absence of lighting, wet surface and asphalt surface are highly associated with fatal/serious injuries. Accidents occurring in the morning and evening and accidents that occur in office areas, residential and commercial neighborhoods are more likely to result in fatal/serious injuries. Automobiles and taxis/Bajaj create fatal or serious injury.

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