Analysis of Road Accidents of Southern States in India Using Smeed’s Model

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ABSTRACT

This paper studies mathematical formulation of total fatalities per vehicle with respect to vehicle ownership and total fatalities (F) with respect to both vehicles (V) and population (P), assuming that the characteristics that influence the road accidents are differ from state to state. The mathematical model (Smeed’s) was for state variant (southern states) and time variant (from 2008 to 2011), and also estimated fatalities per vehicle during 2008 to 2011.

This model can be used as a tool for measuring the effectiveness of road safety improvements in the southern states. The goodness of fit of developed mathematical model was tested by using Chi-Square statistics at 5% and 1% level of significance. Based on the results obtained conclusions were drawn about the goodness of fit and total fatalities per vehicle.

Key words: Accident rate, Prediction of accident, Fatalities, Population, Vehicles, Principle of least squares, Regression analysis.

1. INTRODUCTION

From the past two decades the population of various countries in the world enormously increasing. As a result of these economic activities, motor vehicles, pollution in different sectors has been increasing and deterioration in the eco-friendly environment can be observed. Due to population explosion, motor vehicles and economic activities road traffic accidents and their resulting fatalities may be considered as a growing social and economic problem. The world health organization (WHO) has reported that traffic fatalities will be the third leading cause of deaths thus world wide by 2020. Thus the traffic accident problem attracted to many researchers.

In this regard many traffic accidents models were developed by many researchers. The tremendous growth of motor vehicles is one of the primary factors responsible for road accidents in many states of India and especially in southern states. The increasing number of road accidents is in turn leads to social and economic burdens on the victims and various direct and indirect costs, such as traffic accidents related to deaths and injuries result in not only substantial economic losses but also serious physical and mental sufferings. Developing countries are much more affected from traffic accidents than developed countries.
An improper interaction between a vehicles, between vehicles and other road users or road features is usually referred as road accidents. An increasing or decreasing number of accidents will be depends on many factors such as pavement characteristics, geometric features, road users behaviors, drivers behavior, vehicle design and environmental characteristics etc.. A proper identification of these causes not only save the live but also provide both private and public sector organizations. the necessary information to help improve their future planning and efficient budgeting. Thus the whole system of accident occurrence is a complex phenomenon. In the modern scientific investigation many researchers have contribute their work in the area of road accidents and traffic safety measures aspects. The importance of this area of research and its broad applications has attracted many researchers Smeed (1949) proposed a conceptual model to analyze road accidents data. Many authors followed his analysis of estimating regression coefficients in the generalized form of Smeed's equation that is relevant to their fields of study.

Jamal R.M. Ameen, Jamal A. Naji studied causal models for road accidents fatalities in Yemen. He developed a general modeling strategic to analyze and forecast road accident fatalities. Two alternative models are proposed based on both statistical grounds and that of practicality in viable decision making. They identified the influence of consuming a locally grown stimulant called QAT. This is this major cause for increasing the risk of accidents.

Raj. V. Ponnaluri developed a model for road traffic fatalities in India. He considered Smeed’s law as predictive model and studied traffic fatalities over the time variant (1991-2009) and state variant (29 states across the India).He examined statistical significance of state and time series regressions. Using these techniques he determined that India carries a significant 17% of the world population and 16% of the global road traffic fatalities.

Dr Jamal At Matawah and prof. Khar Jadaan (International Journal of Applied Science and Engineering, 2009, pp 169-175) studied a regression analysis of time series fatality data for the development and testing of the model for the statistics available from the UAE, Jordan and Quatar. They used generalized linear model (GLM) technique to develop a model that incorporates various significant contributory factors such as nationality, aggressive driver behavior, dangerous offences and marital status, speed and experience etc.,

Ali Payidar Akugngor and Erdem Dogan, Scientific research and essay Vol. 4(9), pp 906-913, September 2009 studied two analytical models and artificial neural network model to estimate the number of deaths due to traffic accidents in three metropolitan cities of turkey based on the data between 1996 to 2005. They considered population, number of vehicles as independent variables and modified Smeed model and adapted Andrassean model. In the ANN approaches the sigmoid and pureline functions were used as activation functions with feed forward back propagation algorithm. The results obtained were compared with observations.

predicted that vehicle ownership would be equivalent to 0.4409 by the year 2010. This result suggested that a minimum a 2.18% decrease per annum is required to achieve national target in the year 2010.

Christo J. Bester, Accident analysis and Prevention, 33(2001), pp. 663-672 proposed a model by means of regression analysis to explain the differences in road fatalities of individual countries. It found that the passenger’s car ownership is a better predictor of fatalities per one lakh passenger cars than vehicle ownership as a predictor of fatalities per one lakh population. He found that socio-economic variables and many individual infrastructures have a significant effect on the fatality rate and conclude that by estimates obtained can be used to determine whether its road fatality rate is in line with its ownership, infrastructures provisions and other socio-economic factors.

Sandip Chakraborty and Sudip K. Ray, Transport and Communications Bulletin for Asia and the pacific, No. 74, 2005 discussed the current level of road safety and traffic accident characteristics of Kolkata. They made an attempt to develop models which may be used to estimate the future number of different types of accidents in the city based on the secondary data. They analyzed the data based on the four parameters namely accident severity index, accident fatality rate, accident fatality risk and accident risk. The models could be used to measure the effectiveness of future safety improvements implemented in the city.

P. Pramada Valli (2005), IATSS Research , Vol 29, No1 studied road accident models for large metropolitan cities of India based on the factors that responsible for causing road accidents. He developed a predictive model for analyzing road accidents data at an all India level as well as for major metropolitan cities. In order to develop the model he considered the data for the 25 years period from 1977 to 2001. Assuming that all the states over the India have the same significant effect with respect to population, socio-economic activities and geographic characteristics and he determined that metropolitan cities have a significant share of the road accidents. For estimating road accidents in seven metropolitan cities, he developed a model based on the data population and motor vehicle growth rate for the years 2007-2010.

The above all the researchers contributed to understanding and analyzing accident pattern, accident rate and accident severity index are developed based on the various factors that influence the accident rate. Naturally the accident rate varies due to enormously increasing of the population, environmental, geographical, socio-economic characteristics and motor vehicle ownership. Thus it is very essential to study and analyze an accident rate based on the data obtained from different states which are similar environmental conditions.

Therefore we motivated to developed accident rate models by modifying Smeed and Andreassean models based on the secondary data obtained by southern states only.

Thus in this chapter we study and developed predictive model for estimating traffic fatalities with respect to population and motor vehicles over the time variant from the year 2008 to 2011 and state variant over the southern states.
Based on the results obtained we test whether the predicted models are the best fit or not by using Chi-Square statistic.

2. MODEL DESCRIPTION

In the road accident analysis there are number of variables such as number of accidents, injuries, vehicles, population, driver experience, weather conditions and economic activities etc., are inter related each other. For example, as driver’s experience increases the road accidents naturally decreases, thus road accidents and driver experience are inversely related, while the fatalities and population are positively related. The total numbers of accidents, fatalities, injuries are influenced by vehicle, population and weather conditions. Generally weather conditions are differs from southern states to northern states. Therefore we motivated to developed mathematical model (Smeed’s) for time variant (from 2008 to 2011) and for state variant (southern states).

The main objective of this paper is to develop mathematical model based on the data relating to the road accidents during the period of 2008 to 2011.

Smeed’s Model

Let the mathematical relationship between \( F/V \) and \( V/P \) is

\[
\frac{F}{V} = \alpha \left( \frac{V}{P} \right)^\beta
\]  (2.1)

Where in the above models \( \alpha \) and \( \beta \) are the parameters.

In order to estimate these parameters, we consider principles of least squares by regression analysis. By the principle of least squares, we obtained the following normal equations

\[
\sum y = na + b \sum x \quad (2.2)
\]

\[
\sum xy = a \sum x + b \sum x^2 \quad (2.3)
\]

These normal equations are obtained from smeed’s model.

Where \( y=\log \ (F/V) \)
\( x=\log \ (V/P) \)
\( a=\log \ \alpha \)
\( b=\beta \)

by using the data set from 2008 to 2011, by solving the above equations 2.1, 2.2 and 2.3, We can determine the parameters of the model.

By substituting these parameters in 2.1, we get the developed model for time variant (from 2008 to 2011) and for state variant (southern states).

The goodness of fit of the model in equation 2.1 was tested by using Chi-Square statistics.
In order to test the goodness of fit, first we define the following statistical hypothesis.

H₀: The smeed’s model is good fit for the data during 2008 to 2011
H₁: The smeed’s model is not good fit for the data during 2008 to 2011

To test the hypothesis, the Chi-Square statistics is given by

\[ \chi^2 = \sum_{i=1}^{n} \left( \frac{(O_i - E_i)^2}{E_i} \right) \sim \chi^2_{(n-1)} d.f \]  

(2.8)

Where \( O_i \) = observed fatalities
\( E_i \) = Estimated fatalities
n= Number of data sets

If \( \chi^2_{cal} \leq \chi^2_{(n-1)} d.f \)

at \( \alpha \% \) level of significance, we accept H₀, otherwise we reject H₀.

Table: 1 Smeed’s application: cross-sectional analysis

<table>
<thead>
<tr>
<th>Region</th>
<th>n</th>
<th>( \alpha )</th>
<th>( \beta )</th>
<th>( R^2 )</th>
<th>( F = e^{\alpha \left( \frac{V}{P} \right)^\beta} )</th>
<th>( \chi^2 )-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>4</td>
<td>-3.53</td>
<td>-0.778 0.911</td>
<td>0.000 293(V/P)^{0.778}</td>
<td>5.61E-06</td>
<td></td>
</tr>
<tr>
<td>Karnataka</td>
<td>4</td>
<td>-3.76</td>
<td>-0.938 0.966</td>
<td>0.000 174(V/P)^{0.938}</td>
<td>4.22E-06</td>
<td></td>
</tr>
<tr>
<td>Kerala</td>
<td>4</td>
<td>-3.82</td>
<td>-0.849 0.971</td>
<td>0.000 154(V/P)^{0.849}</td>
<td>8.86E-07</td>
<td></td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>4</td>
<td>-3.17</td>
<td>-0.285 0.455</td>
<td>0.000 669(V/P)^{0.285}</td>
<td>3.6E-06</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>-3.57</td>
<td>-0.713</td>
<td>0.255</td>
<td>0.253</td>
<td></td>
</tr>
<tr>
<td>Std. Dev</td>
<td></td>
<td>0.255</td>
<td>0.253</td>
<td>0.071</td>
<td>0.355</td>
<td></td>
</tr>
</tbody>
</table>

Table: 2 Smeed’s application: time-series analysis

<table>
<thead>
<tr>
<th>Region</th>
<th>n</th>
<th>( \alpha )</th>
<th>( \beta )</th>
<th>( R^2 )</th>
<th>( F = e^{\alpha \left( \frac{V}{P} \right)^\beta} )</th>
<th>( \chi^2 )-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>4</td>
<td>-3.68</td>
<td>-0.854</td>
<td>0.60</td>
<td>0.000 210(V/P)^{0.854}</td>
<td>0.000146336</td>
</tr>
<tr>
<td>2009</td>
<td>4</td>
<td>-3.65</td>
<td>-0.823</td>
<td>0.47</td>
<td>0.000 225(V/P)^{0.823}</td>
<td>0.000199160</td>
</tr>
<tr>
<td>2010</td>
<td>4</td>
<td>-3.60</td>
<td>-0.785</td>
<td>0.37</td>
<td>0.000 252(V/P)^{0.785}</td>
<td>0.000234769</td>
</tr>
<tr>
<td>2011</td>
<td>4</td>
<td>-3.55</td>
<td>-0.704</td>
<td>0.35</td>
<td>0.000 279(V/P)^{0.704}</td>
<td>0.000184258</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>-3.62</td>
<td>-0.792</td>
<td>0.049</td>
<td>0.056</td>
<td></td>
</tr>
<tr>
<td>Std. Dev</td>
<td></td>
<td>0.049</td>
<td>0.056</td>
<td>0.014</td>
<td>0.071</td>
<td></td>
</tr>
<tr>
<td>CoV</td>
<td></td>
<td>0.014</td>
<td>0.071</td>
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</tbody>
</table>

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RESULTS & DISCUSSIONS

From the table (1) & (2), it is observed that smeeds’s mathematical model is good fit at 1% level of significance as well as 5% level of significance. Thus the fatalities per vehicle can be forecast at the given value of vehicle ownership from table (1).

The number of fatalities was regressed over vehicle volume (to obtain smeeds’s model equation number (2.1). In this case the intercept -3.57 and gradient is -0.713 and standard deviations of intercept and gradient respectively were 0.255, 0.253. Thus, the fatalities were influenced by 25.3% with respect to vehicle ownership in southern states such as Andhra Pradesh, Karnataka, Kerala, Tamil Nadu.

A higher degree positive correlation is observed in the Andhra Pradesh, Karnataka, and Kerala. While a lower degree positive correlation observed in the state of Tamil Nadu. Obviously 97.1% relationship is exists between fatalities and vehicle ownership in the state of Kerala, while 91.1%, 96.6% in the states of Andhra Pradesh, Karnataka respectively. Thus, smeeds’s fitted model is very much useful to forecast fatalities with respect to vehicle ownership in the state of Kerala.

From table (2), the smeeds’s individual models for all years were significant at 1% and 5% level of significance, clearly all the individual smeeds’s models were good fit in all the years. The values of intercept and gradient were -3.62 and -0.792 respectively. The standard deviations of intercept and gradient were 0.049 and 0.056 respectively. Therefore in the year wise analysis the fatalities were influenced by only 5.6%. Thus, in the year wise analysis there is not much variation in the fatalities per vehicle.

From table (1), the CoV (coefficient of variation) of intercept and gradient were 0.077, 0.640 and from table (2), the CoV value of intercept and gradient were 0.014, 0.071 respectively. Thus, by comparing CoV of gradient in state wise and year wise, it can be observed that the coefficients of gradient is minimum in the year wise analysis. Therefore fatalities are very much consistent over the years. Because a uniform weather conditions and economical factors. Where as in the state wise analysis, the coefficient of variation is 0.640 that is fatalities are not consistent over the southern states, because of different policies, improved governance and other factors are at work to lower the fatality rates. For example, the state government of Andhra Pradesh introduced a 108 and 104 emergency vehicles dispatch systems, which saved numerous lives by providing post-accident care. The absolute value of gradient is less in the Andhra Pradesh. Therefore there is a less variation in the fatalities.

REFERENCES


