SENSITIVITY ANALYSIS OF TRAFFIC ACCIDENTS CAUSES IN SULTANATE OF OMAN

Ahmad M. Abu Abdo
Department of Civil and Infrastructure Engineering, American University of Ras Al Khaimah, Ras Al Khaimah, United Arab Emirates
E-Mail: ahmed.abuabdo@aurak.ac.ae

ABSTRACT
Traffic accidents numbers and fatalities and injuries resulting from these accidents are increasing in an alarming rate, especially in the Sultanate of Oman. This paper focuses on the verification of the factors affecting numbers of traffic accidents and fatalities and injuries resulting from traffic accidents in the Sultanate of Oman. To achieve the goal of this study, sensitivity analyses via Tornado Plots and Extreme Tail Analysis were deployed to identify main affecting factors, which would assist decision makers to focus their efforts on the reducing traffic accidents. Results have shown that Failure to Follow Traffic Rules, Speeding, and Reckless Driving were ranked the highest contribution factors to traffic accidents and fatalities and injuries from these accidents, while Weather Condition, Drunk Driving, Fatigue, and Sudden Stopping had very low effect on traffic accidents. Finally, recommendations were proposed to Omani decision makers for implementation in current and/or future policies.

Keywords: traffic accidents, sensitivity analysis, tornado plot, extreme tail analysis, sultanate of Oman.

INTRODUCTION
Traffic Accidents and fatalities and injuries resulting from these accidents are considered one of the main concerns worldwide, especially their direct and severe impacts on any society, socially and economically. Records show that fatalities resulting from traffic accidents in the developing countries are very high [1]. Many studies were conducted to evaluate the impact of these accidents and argued that proactive law enforcement strategies and polices, public awareness campaigns play an important role in reducing traffic accidents [2-9].

Numbers of fatalities due to traffic accidents are raising in an alarming rate. Predictions suggested that by the year 2030, Traffic accidents fatalities would be the 5th top cause for death globally and would be doubled in the Sultanate of Oman. Sultanate of Omanis located on south eastern coast of the Arabian Peninsula with an area of 309,501 km² and low population of 3,632,000. Furthermore, studies argued that by 2020 traffic accidents fatalities would be the 3rd leading cause of death and disability in the Sultanate of Oman. Reports showed that among the Arabian Gulf Co-operation Council (GCC) countries, Sultanate of Oman has the highest death rate from road accidents and the 3rd highest in the Middle East [10-13].

Sultanate of Oman has witnessed rapid cultural and economical changes within the last decades, which resulted in an increase in number of vehicles and a big expansion of road network. Number of vehicles has increased by 190% from the year 2007 to 2014 (Figure-1), with an average yearly increase of 10%. It is speculated that number of vehicles would grow to be about 1,441,467 by the year 2016 (General Administration of Oman Royal Police (ROP) [14]). Thus, more fatalities and injuries due to traffic accidents are expected to occur.

![Figure-1. Vehicles count from 2007 to 2016 in Sultanate of Oman [8].](image-url)
Records showed that traffic violations in the Sultanate of Oman have increased in recent years [14], especially in speeding violations, which is considered to be the big factor for the increase of reported traffic accidents. In 2013, there were 7829 vehicle accidents caused by speeding, 913 reported fatalities and 10802 injuries due to traffic accidents (Figure 2). Failing to buckle up offences increased from 54,429 to 85,708 since 2009. Furthermore, right of way, dangerous overtaking, reckless driving, cutting a red light, and usage of mobile phones while driving violations increased by 155%, 295%, 174%, 72%, and 200%, respectively from 2009 to 2013[8]. This trend causes major concerns to all parties concerned. Therefore, an analysis of causes resulting in traffic accidents in the Sultanate of Oman is vital in order to focus on strategies and countermeasures to reduce the occurrence and severity of these traffic accidents.

OBJECTIVES

Due to the severe impacts of traffic accidents and the fatalities and injuries caused by these accidents, this study was conducted to examine and investigate causes leading to these traffic accidents and to provide decision maker’s insights to causes of traffic accidents. Thus, assist them in developing polices and proactive actions to prevent and reduce the large number of traffic accidents and fatalities and injuries caused by these accidents in the Sultanate of Oman.

SENSITIVITY ANALYSIS

Sensitivity analysis has been described as the best method to evaluate the effects of multiple factors on an end result. Thus, many studies have been conducted to evaluate the relationship between a result and factors affecting it by utilizing sensitivity analysis [15-22]. Until recently, sensitivity analysis was carried out by altering one factor, while fixing others, therefore concentrating on one variable at a time, which might lead to loss of the effect of the interaction between variables collectively [17]. Therefore, vigorous sensitivity analyses are needed. Tornado Plots and Extreme Tail Analysis proved to be better methods of evaluating the sensitivity of factors affecting a result [23, 24].

Tornado plots

Tornado plots are frequently used as illustrative methods of the effect of individual factors on the result, it is determined using the Spearman’s rank correlation coefficient ($\rho$) as described in Equation (1).

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2-1)}$$  \hspace{1cm} (1)

where,

$\rho$: Spearman’s rank correlation coefficient,

$d_i$: difference in the ranks between factor and result values in the same data pair, and

$n$: number of simulations.

The value of $\rho$ ranges from -1.0 to 1.0 and the closer it gets to the ends of the range, the effect of the factor on the end result is the highest, and when it is closer to mid-range (i.e. zero), the effect of this factor is the least. In addition, a positive $\rho$ value shows that the end result is proportionally related to the variable (i.e., when the factor value is high, the end result will be high as well), and when $\rho$ has negative value, the variable is inversely affecting the end result [17,19,20].
Extreme tail analysis

Extreme tail analysis is utilized as a statistical method that is applied to methodically identify uncertain critical variables in a model, which depends on the tail of the end result distribution. It is used to determine factors with the least effect on the end result to ensure better results. To recognize those factors, the normalized variable $\alpha$ should be determined as shown in Eq.2 (more details are described in [24]). Factors in a group with $|\alpha| \geq 0.5$ are normally considered to be significant and contribute to the extremes of the end results. A positive $\alpha$ for a factor indicates that extreme values of this factor resulted in positive extreme end result values and vice versa [17,19,20].

$$\alpha = \left( \frac{\text{Median}_{\text{Group}} - \text{Median}_{\text{Total}}}{\sigma_{\text{Total}}} \right)$$  \hspace{1cm} (2)

where,

- $\text{Median}_{\text{Group}}$: median of a factor in the group,
- $\text{Median}_{\text{Total}}$: median of the factor in the total simulation, and
- $\sigma_{\text{Total}}$: standard deviation of the factor in the total simulations.

DATA ANALYSIS AND RESULTS

For the purpose of examining the sensitivity of factors affecting traffic accidents and number of fatalities and injuries due to traffic accidents, statistics (2003 - 2013) of traffic accidents and their causes were obtained from traffic statistics published by the General Administration of Oman Royal Police, Sultanate of Oman. To develop the tornado plots for factors causing traffic accidents, and based on their means and standard deviations, 50000 data points where generated using Monte Carlo Simulation, then the Spearman’s rank coefficients were determined using Equation (1). When it comes to traffic accidents, results showed that among the studied factors, Failure to Follow Traffic Rules was ranked the most affecting factor, then Speeding and Reckless Driving with $\rho$ values equal to 0.831, 0.431, and 0.272, respectively as shown in Figure-3. Furthermore, it was found that the Weather Condition, Drunk Driving, Fatigue, and Sudden Stopping had the lowest $\rho$ values, thus their effect on Traffic accidents was low. As for fatalities caused by traffic accidents, Figure-4 illustrates the results of the sensitivity analysis. Speeding was determined the main factor in causing fatalities in traffic accidents with the highest $\rho$ values equals to 0.803 and similar to traffic accidents, Weather Condition, Drunk Driving, Fatigue, and Sudden Stopping were ranked the least affecting factors. Furthermore, injuries due to traffic accidents followed the same trend (Figure-5), with Weather Condition, Drunk Driving, Fatigue, and Sudden Stopping were found to be the least affecting causes and Speeding, Reckless Driving and Failure to Follow Traffic Rules have the highest effects on injuries with $\rho$ values equal to 0.661, 0.51, and 0.463, respectively.

Figure-3. Sensitivity analysis of factors causing traffic accidents.
Using the same set of data points generated earlier, the extreme tail analysis was carried out. The reported traffic accidents, fatalities, and injuries due to these accidents values were arranged in descending order, for a reliable output, left and right tail of the distribution were evaluated. The lower and higher 5% of the reported traffic accidents, fatalities, and injuries due to these accidents values were taken as the left and right tails, respectively. Then $\alpha$ for all affecting factors were determined using Eq.2 and the results are shown in Table-1.
SUMMARY AND CONCLUSIONS

The number of fatalities and injuries caused by traffic accidents in the developing countries has been on the rise in an alarming rate. This large number has a devastating impact on all societies. In the Sultanate of Oman, with its low population, the numbers of these accidents are very high, especially when it is compared to neighboring countries. Thus, this study was conducted to investigate the leading causes to these accidents to assist policy makers in reducing traffic accidents in the Sultanate of Oman, by identifying the leading causes to traffic accidents.

To determine the role of causes and their contribution to numbers of fatalities and injuries resulting from traffic accidents in the Sultanate of Oman, sensitivity analyses were conducted to identify key factors, which would enable decision makers to focus their efforts on the reducing traffic accidents. Until recently, changing a one factor while maintaining other factors constant was the norm when conducting sensitivity analysis, which might lead to loss of evaluating the interaction between the different factors and their collective effect on the end result. In this study, powerful means of sensitivity analyses were used; tornado plots and extreme tail analysis. The main advantage of these tools is that they can capture the combined effect of different factors and quantify the sensitivity of a specific factor on end result.

The means and standard deviations of the traffic accidents and fatalities and injuries resulting from those accidents were utilized in a Monte Carlo simulation to generate 50000 data points. These data points were used to generate tornado plots and to conduct the extreme tail analysis. Results have shown that Failure to Follow Traffic Rules, Speeding, and Reckless Driving were ranked the highest contribution factors to traffic accidents and fatalities and injuries from those accidents, while Weather Condition, Drunk Driving, Fatigue, and Sudden Stopping had very low effect on traffic accidents. It may come as a surprise that drunk driving had low effect; however, it is speculated that since the Sultanate of Oman has strict regulations when it comes to drugs and alcohol consumption and culturally considered as unacceptable behavior, the number of traffic accidents caused by drunk driving is low.

RECOMMENDATIONS

Failure to Follow Traffic Rules, Speeding, and Reckless Driving was found the main causes for traffic accidents, decision makers’ attention should be focused on these factors. These factors depend mainly on drivers’ behaviors. Earlier studies [7,8] showed that drivers in Dhofar Region in southern part of the Sultanate of Oman did not fully comply with speed limits, low number of drivers always used seatbelts, a high number used mobile phone when driving and drove when feeling fatigued. Surprisingly, these studies showed that drivers had the knowledge of wrong driving behaviors. Therefore, the following recommendations should be taken into consideration by Omani decision makers and be utilized and adopted in current and future policies and regulations to improve road safety and to reduce traffic accidents:

<table>
<thead>
<tr>
<th>Causing factors</th>
<th>Traffic accidents</th>
<th>Fatalties</th>
<th>Injures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\alpha$, Left tail</td>
<td>$\alpha$, Right tail</td>
<td>$\alpha$, Left tail</td>
</tr>
<tr>
<td>Speeding</td>
<td>0.852</td>
<td>-1.244</td>
<td>1.679</td>
</tr>
<tr>
<td>Failure to Follow Traffic Rules</td>
<td>1.757</td>
<td>-0.934</td>
<td>0.71</td>
</tr>
<tr>
<td>Fatigue</td>
<td>0.023</td>
<td>-0.015</td>
<td>0.134</td>
</tr>
<tr>
<td>Drunk Driving</td>
<td>-0.008</td>
<td>-0.015</td>
<td>0.075</td>
</tr>
<tr>
<td>Overtaking</td>
<td>0.052</td>
<td>-0.146</td>
<td>0.621</td>
</tr>
<tr>
<td>Weather Condition</td>
<td>0.007</td>
<td>-0.031</td>
<td>0.053</td>
</tr>
<tr>
<td>Sudden Stop</td>
<td>0.002</td>
<td>-0.024</td>
<td>-0.003</td>
</tr>
<tr>
<td>Safety Distance</td>
<td>0.066</td>
<td>-0.194</td>
<td>0.089</td>
</tr>
<tr>
<td>Reckless Driving</td>
<td>0.52</td>
<td>-0.767</td>
<td>0.671</td>
</tr>
<tr>
<td>Vehicle Defects</td>
<td>0.038</td>
<td>-0.097</td>
<td>0.221</td>
</tr>
<tr>
<td>Road Defects</td>
<td>0.052</td>
<td>-0.047</td>
<td>0.078</td>
</tr>
</tbody>
</table>
a) Ideal use of road safety measures: construction of road dividers and speed humps, installation of speed control devices in critical locations.

b) Addressing drivers’ wrong behavior by developing traffic safety awareness programs and campaigns from early stages (school level), and strengthen promoting compliance with traffic rules and regulations.

c) Similar to neighboring countries (e.g. United Arab Emirates), a point system that is based on traffic violations and offences should be introduced to assist in the reduction of wrong drivers’ behaviors.

d) Developing a better and effective public transportation system to reduce number of private vehicles on the road.

e) Establish and develop outlet venues (e.g. race tracks), similar to the European countries experience, where drivers can practice speeding and drifting in a safe environment, without affecting other road users.

f) Authorities should intensify the efforts to enforce traffic regulations especially when it comes to speeding and the usage of mobile phones while driving.

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REFERENCES


