Predictive Analytics of Road Accidents in Oman using Machine Learning Approach

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***Abstract*— Road accidents are a major issue nowadays that causes death and disability all over the world. According to the statistical records of World Health Organization, Oman ranked at the 12th position in Road traffic accidents globally and 1st position among the Gulf countries. The paper addresses an in-depth analysis that identifies the contributory factors, causes behind the road crashes and the quantification of the factors that affect the frequency and severity of accidents based on the crash data available. It also review about the various factors involved in the background of different types of accidents and the associated methodologies that are applied for a thorough analysis in the field of interests. The determination of various parameters that leads to the crash is investigated by applying various statistical techniques which helps us to obtain a reliable conclusion and reconstruction based on the needs. The targeted analysis also provides a better understanding for developing measures to improve their safety performance. It also presents the innovative approach called machine learning based predictive analytics to foresee the number of accidents that may happen in the near future.**

Keywords—Oman Road Traffic Accidents; Predictive Analytics, Machine Learning; Boosted Trees Regression; Multiplicative Model; Casualty Severity; Accident Report Form

I. INTRODUCTION

Road accidents are a serious issue resulting in huge economic loss. There is a need to bring down the accident rate, for which a detailed analysis of the factors which are responsible for the accidents are to be analyzed. Road accidents are influenced by a large number of attributes such as road conditions, traffic flow, environmental state and user's behavior on the road [1]. Considering the mentioned attributes, 'n' number of models is built, ignoring the complexity of the factors associated with causing accidents and involving only one or more variables. Modeling the traffic accident scene brings together the influence of all relevant attributes which usually requires a careful analysis of the complex situation. It is seen that there are a number of factors like traffic volume, mix of modes, type of vehicles, pedestrians, traffic segregation measures introduced and road geometries influence the accident scene. Any model to study the traffic accident scene should therefore be comprehensive and accommodate all these factors. The following three factors are very crucial in ensuring road safety and reducing accidents: Traffic Engineering, Traffic Education and Traffic Enforcement [3].

Within GCC Countries, Oman ranked the highest in road traffic fatalities as per the report released by W.H.O., 2015. According to the reports from ROP's Directorate General of Traffic Facts and Figures 2016, there were 6,279 accidents in 2015, down from 6,717 in 2014. A total of 675 people died in 2015 accidents, less than the 816 reported deaths in 2014 [11]. Accident analysis was carried out based on the type of accident arose in each governorate during the period 2011 to 2015. In this research paper, the accident analysis focuses on the following comparisons: casualty severity vs. casualty type, casualty severity for nationals and expatriates, nationality and expatriates gender wise classification. These analyses were succeeded by the predictive analytics mechanism to predict the number of accidents in the coming years.

Proper analysis of the road accident data provides a useful insight regarding the causes and consequences of accidents. It is also good that, if the number of accidents is predicted well in advance so as to encounter the issues. Predictive analytics is the latest field which can be applied to this accident data to predict the future accidents. Machine learning is the artificial intelligence technique, which creates a model that learns from the past data. Once the model is created whenever a new set of data is given to it, it can predict the approximate values. Many machine learning algorithms are available like regression, classification, clustering, recommender system, churn prediction etc. If these artificial intelligence and machine learning concepts are applied on the data, a more accurate forecasting can be made possible.

The overall outline of this paper is organized as follows; section two gives the thorough review of various literatures about the road accident analysis. Section three highlights the data collection process required for this research. Section four discusses about the various accident data analysis and the results using easily understandable visual representations. Section five deals with the basic concepts of predictive analytics using machine learning approach. The sixth part deals with the prediction of number of accidents during the years 2017-2019, using various machine learning algorithms. In the last section conclusion is discussed.

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II. LITERATURE REVIEW

According to the authors Kopits et al., and Bener et al., the growth in economies is strongly associated with the motorization [8][9]. Jamal Al Matawah stated in his paper that different GCC countries have implemented different road safety strategies as a measure of different safety challenges. These strategies help to improve the accident data analysis. It also promotes in exploring the causes of road accidents, and provides a better understanding of the circumstances that lead to causalities [4]. M. Mazharul et al. showed in their study that the age of the drivers involved with Road Traffic Accidents (RTA) showed a negative association with the RTA in Oman. As per the results, the proportion of accidents declined with the age of the drivers. The young drivers of age between 17-36 years are more likely to be involved with accidents [5].

S. G. Farag et al. stated that the decrease in the total number of accidents reflects efforts at the national level in improving the safety through many factors, such as changing the road environment, drivers' behavior's, traffic management, the shift from high-risk transports to lower risk transports [6]. Galal did a comparative analysis and evaluation of traffic accident characteristics. This study also focused on the road safety in industrial and developing countries. The analysis compared between the accident causes, also including the drivers' behavior, road characteristics, vehicle condition, the level of enforcement, and finally fatality rates for 5 countries. The findings showed that the fatality rates are higher in developing countries than industrialized countries [7]. The bi and multi-variate analysis in the study showed that no significant association between speed violation and self-reported crash history. These results explained that when considering that, even driving 10 km/h above the speed limit is also posed as a violation, but may not necessarily increase the risk of involvement in crash on all the driving situations [10].

III. DATA COLLECTION

A. Study Conducted Area

The study was conducted in Sultanate of Oman which lies on the southeast corner of the Arabian Peninsula. The total population Sultanate of Oman was 102, 998 during the year 2011, 109,867 during the year 2014 and 143,888 in the year 2016. The Sultanate of Oman is having 11 Governorates namely Muscat, Dhofar, Musandam, Al Buraimi, Al Dakhiliyah, Al Wusta, Al Batinah North & South, Al Sharqiyah North & South, and A'Dhahira.

In Fig.1, shows the map of Oman with all governorates and the number of accidents that occurred during the period 2011 to 2015. The maximum number of accidents had occurred in Muscat Governorate and is 12556 cases, due to population density and congested population rate compared to other Governorates, Al-Batinah and Al-Sharquiyah governorates ranks the second and third after the Muscat governorate with 8732 and 8571 accident cases. In Fig. 1, the color shade variation indicates the number of road accidents.

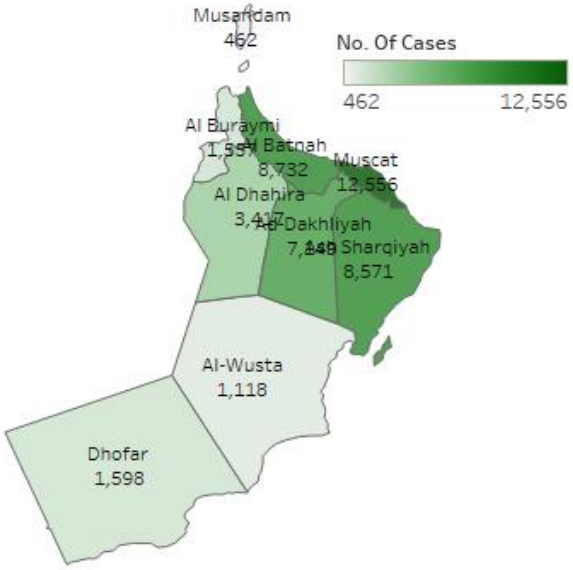

Fig.1. Number of road accidents in Oman Governorate

B. Accident Data

The accident data were collected from the year book of NCSI website [2]. In Oman, Royal Oman Police is the core organization for the road accident data collection and data storage. Under the current operating framework, police conduct investigation and is responsible body for reporting the accidents. The investigation form called Accident Report Form (ARF) is used to record all accidents that had occurred. The recording system is based on manual documentation for accidents. The ARF contain many attributes like date, time, main cause, number of vehicles involved, gender of drivers, age of the drivers, fatalities age, fatalities gender, injured age, injured gender, type of injuries, type of car, nature of damage, and accident description with a diagram and photos about the occurrences of various accidents.

IV. ROAD ACCIDENT ANALYSIS

The road accident analysis was performed in three stages; the first stage is all about the detailed analysis of the contributing factors of accidents, nature, and class, the second stage is about the trend analysis related to road accidents followed by a prediction of road accident analysis. The tools used for the visual analysis and prediction are Python and Tableau.

A. Cause Analysis of Accidents

The main cause of the traffic accidents are: speed, bad behavior, negligence and safety distance, flaws in the road, overtaking, vehicle defects, intoxication, sudden stopping, fatigue, and weather conditions. Fig 2, and data in Table 1 shows the levels and trends of RTA in Oman during the period (2011-2015). It is evident that speeding appeared to be the main cause of road traffic accident in Oman, since nearly half (48%) of the accident occurred due to high speeding of the vehicle.

The second factor for the cause of the accident is bad behaviors which cause about 20% of the accident. Negligence or careless driving is the third most important cause of

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accident, accounts about 8% of the accidents, followed by unsafe distance (7%) and flaws in road (6%). Although, there are many other factors that cause the road traffic accidents, it shows only a very little effect on road traffic accidents in Oman. However, the output is not surprising for Oman as the rules are very hard. The penalty and the offense are also very severe according to the strict traffic rules followed in the country; intoxication i.e. drunk driving and drug usage is very less in an entire Oman culture. The climate of Oman can be described as subtropical dry, hot desert climate with low annual rainfall, very high temperatures in summer and a big difference between maximum and minimum temperatures, especially in the inland areas. The summer season (June to September) is very hot with temperatures reaching as high as 49 degree Celsius and has very low rainfall. Fatigue can occur during the summer while day driving, or during fasting, or in case of any physical or mental tiredness. Sudden stopping is quite rare because most of the road infrastructure is wider and lengthy, with properly maintained signal boards, roundabout infrastructure and proper lane. This may be a reason that this accident cause type is very rare according to our results. Surprisingly, all these causes are human factors. It is observed that only fewer cases (9%) of road accidents happened based on non-human related causes such as vehicle defects, road defects or weather conditions, and 91% cases of the road accident happened due to human related causes. The result is highly consistent with the recent studies that documented that human actions are sole or a contributory factor for the majority of traffic crashes [3].

TABLE I. NUMBER OF ACCIDENTS AND ITS CAUSES FOR THE PERIOD 2011-2015

Causes of Accident*	2011	2012	2013	2014	2015	Total	%
Speed	9386	10347	11346	5681	5522	42282	48
Bad Behavior	4936	4599	3263	2406	2133	17337	20
Negligence	1212	1487	1785	1049	1068	6601	8
Safety Distance	1672	1499	1128	914	755	5968	7
Flaws in road	2093	473	454	522	1440	4982	6
Overtaking	1537	1467	753	617	521	4895	6
Vehicle defects	632	728	547	310	264	2481	3
Intoxication	281	231	276	141	67	996	1
Sudden stopping	166	174	46	20	46	452	1
Fatigue	74	95	38	26	103	336	0
Weather condition	61	86	110	33	40	330	0
Total	22050	21186	19746	11719	11959		
Percentage (%)	25	24	23	14	14		
*Data were available in NCSI website							

When we observe the total number of accidents occurred during each year from the data in Table 1, the accident rate is steadily decreasing from 2011(25% over the total for the lustrum) to 2015(14% over the total accidents for the lustrum) and is reaching a constant state.

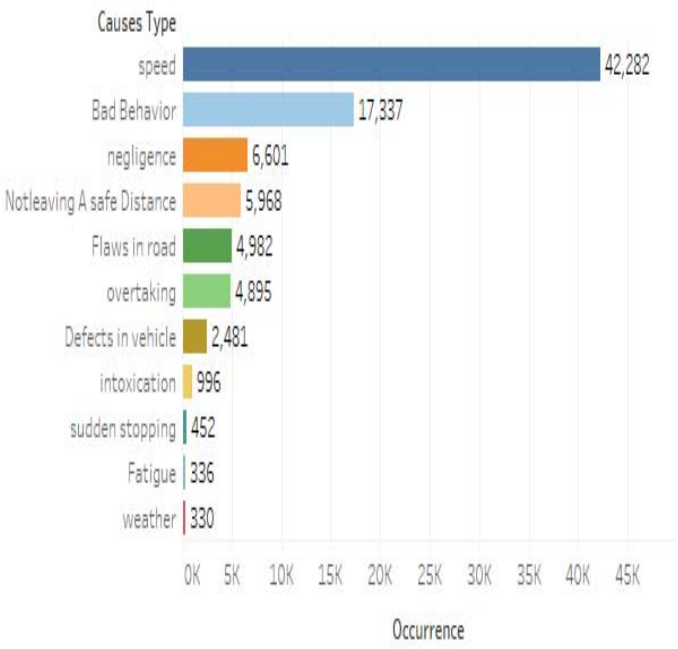

Fig.2. Average number of accidents occurrence

B. *Analysis based on Nationality*

A comparative picture of the level of total number of accidents occurred among nationals and expatriates are presented in the Fig.3. It also clearly indicates a moderate decrease in the number of road traffic accidents during the recent years in Oman. The color in the figure shows details about Nationality and the size shows the sum of the number of accidents. The number of accidents recorded drops down from 9782 cases in 2011 to 3226 cases in 2015, a drastic decline over the period in Omani nationals and in expatriates, further dropped down from 2,711 cases in 2011 to 1078 cases in 2015. From 2011 to 2015, it was observed that a steady decline in the total number of accidents for both nationals and expatriates.

The comparative analysis among the nationals and expats shows that the numbers of accidents are more among nationals due to several rationales: They are: the population of nationals is more compared to expatriates is more, population of young Omani drivers is more; driving licenses issued are more for nationals, annual increase in the number of vehicle registrations, economic condition etc.

TABLE II. ACCIDENT NUMBERS AMONG NATIONALS AND EXPARTRIATES

Nationality*	2011	2012	2013	2014	2015
Omani	9782	10,031	9,144	3,362	3226
Expatriate	2711	2726	2571	1289	1078
Total	12493	12757	11715	4651	4304
*Data were available in NCSI website					

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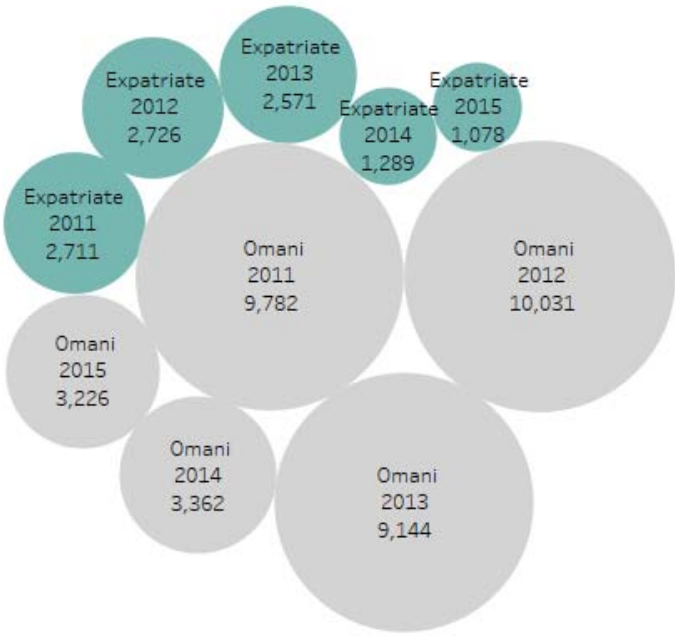

Fig 3: Number of accidents based on nationality

The box plot in Fig. 4 shows the number of accidents occurred every month from 2011-2015 based on the nationality. The box that represents the Omani national has the upper whisker with the value 1098 accidents that occurred during March 2012 and the lower whisker is with 124 accidents occurred during December 2014. The median value of the plot is 700. The box for the Omani national indicates that most of the values are between the lower and the upper hinges with the values 298.5 and 807 respectively.

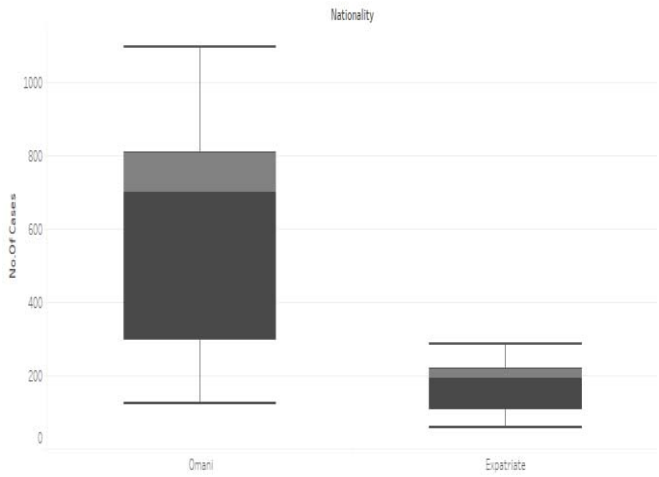

Fig 4. Accident based on Nationality from 2011-2015

The box that represents the expats has the upper whisker with the value 287 accidents that occurred during May 2012 and the lower whisker is with 57 accidents occurred during December 2014. The median value of the plot is 194. The box for the expatriate indicates that most of the values are between the lower and the upper hinges with the values 105.5 and 218 respectively.

The box plot values and the size of the plot shows that more number of accidents occurs with the Omani national when compared with the expatriates.

C. Road Accident Analysis based on Month

Fig. 5 ranks the number of road accidents based on month of a year. The dark shaded color represents the highest rate of accident occurrence and the lighter shaded color represents the fewer rates of accident occurrences. The average rate of road accidents based on the months in the Oman governorate is 3062.75 cases per month.

The month based road accident analysis is closely related to the climate effect of that particular month. When considering the months of the year- September, October, November, December, January, and February are the months with pleasant weather conditions, whereas March, April, May, June, July and August are the hottest months. From the Fig. 5, the months May, June and July are ranked 1, 4, and 3 which are prone to increase in road accidents because of the hot climate and at the same time the month January ranked as 2 and prone to increase in road accidents because of the rain and cooler climates. The remaining months are ranked as 5,6,7,8,9,10,11,12 which are having a pleasant climate and less prone to increase in road accidents according to our analysis and datasets.

Fig 6 represents the area chart of accident rates over the years 2011-2015 against months of a year. The color of each of area represents a year and there is clear indication that the number of accidents occurred during the same months for all the five years are uniform in nature which supports the findings from fig 5. The area chart depicts two horizontal shades on the top, the first bar represents the minimum and maximum number of accidents during various months, and the second bar represents 60 to 80 percentage of average number of accidents during various months.

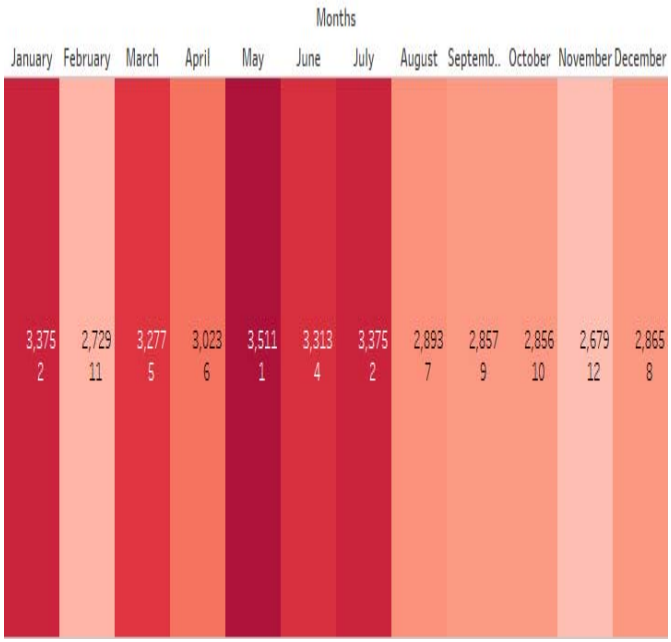

Fig.5. Rank the number of road accidents based on month.

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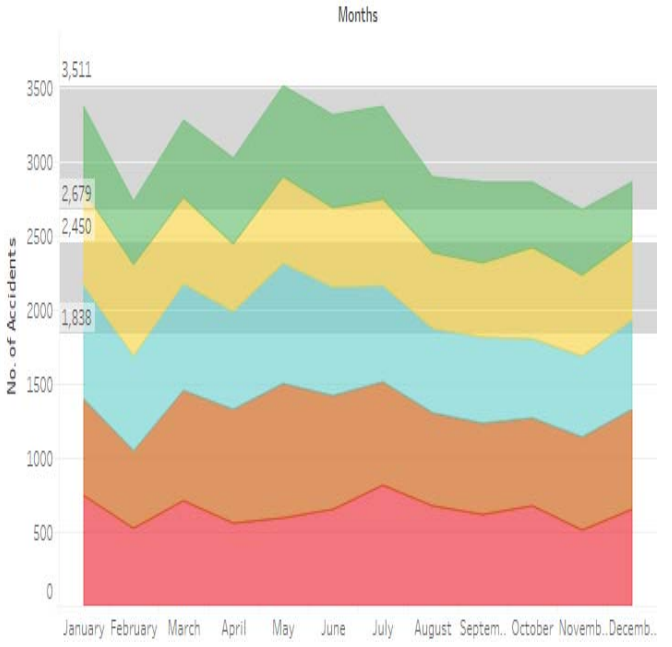

Fig.6. Number accidents occurred every month during 2011 - 2015.

Fig. 7, represents the monthly casualty severity of road accidents like the death and injury for the period 2011-2015. The number of deaths and the injuries are almost similar for all the months. Also, there exists a proper correlation between the number of injuries and deaths. According to our research death rate is high in the months of July and August as estimated, which are 441 and 484.

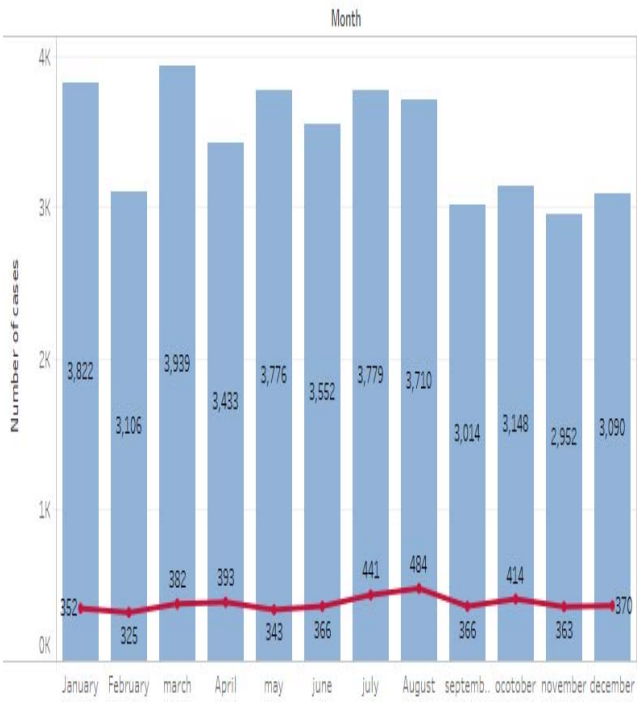

Fig.7. Monthly Causalty severity for 5 years

D. Road Accident Analysis based on Casualty Class

This road accident analysis provides greater insights on the casualty severity of between the nationals and the expatriates based on the gender. Fig 8, shows the highest number of people injured and died are the Omani men with 22,876 and 2568 respectively. 1350 expatriate male died during the accidents when compared to 527 Omani women and 154 expatriate women. The expatriate women are having the least number of casualty severities since less number of these people has driving licenses. The graph also shows the average and median number of cases based on the nationality and gender.

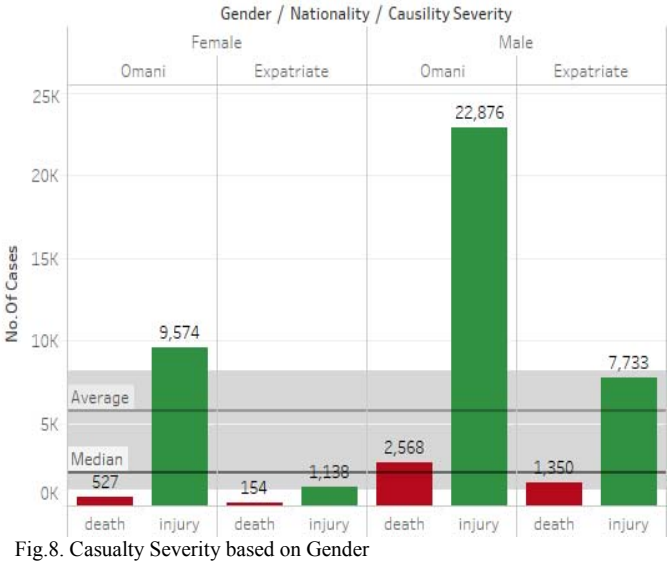

Fig.8. Casualty Severity based on Gender

According to data analysis, casualty class is categorized into three major groups such as Driver, Passenger and the Pedestrian. The casualty severity can either be death or injury..

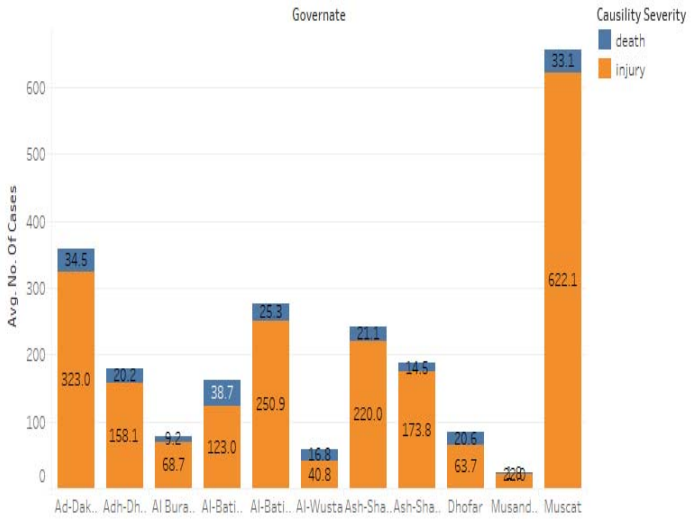

Fig.9. Governorate based Casualty Severity

Fig. 9 represents the number of cases registered against casualty class and severity during the year 2011-2015 for various governorates. Also in this road accident analysis, there is a clear indication that the injuries are greater than deaths;

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especially driver injury and death are more than other two casualty classes such as passenger and pedestrian

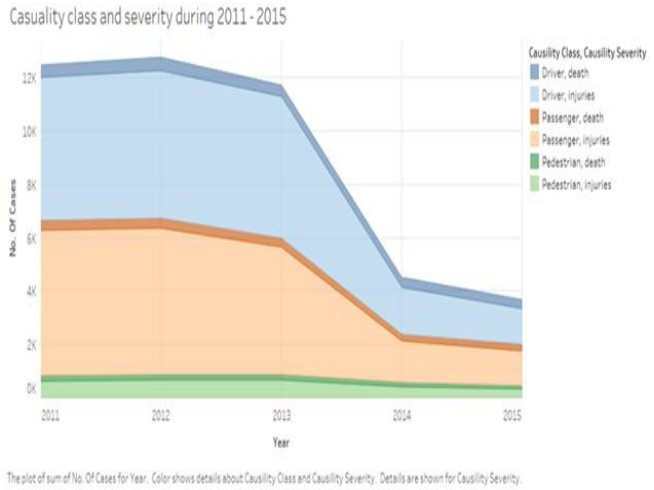

Fig.10. Year wise Casualty class and Casualty severity

Fig. 10. Shows about the accidents based on the casualty class and the casualty severity. The graph clearly indicates the number of accidents decreases over the period of years for all types of casualty classes like driver, passenger and the pedestrian. The graph also shows the ratio between the death and the injuries.

E. Road Accident Trend Analysis

The trend analysis in Fig. 11, shows the number of accidents and the accident types over the years 2011 – 2015 for the various governorates: Musandam and Al-Wusta governorates regions recorded the least number of accidents for fixed object collision, run over and downfall. The most number of accidents occurred in Muscat, Ad-Dakhliyah, Al-Batinah governorates due to collision between vehicles and fixed object collision.

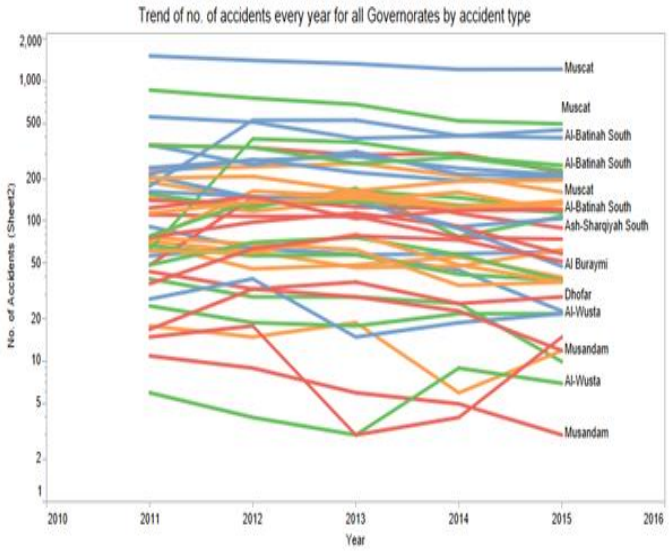

Fig.11. Trend analysis of yearly Accident type

As shown in Fig 12, over the years injury percentage is declining i.e. the major part of the number of road accidents. Other accident type, accident is also sinking. But death percentage is gradually increasing compared to other two accident type.

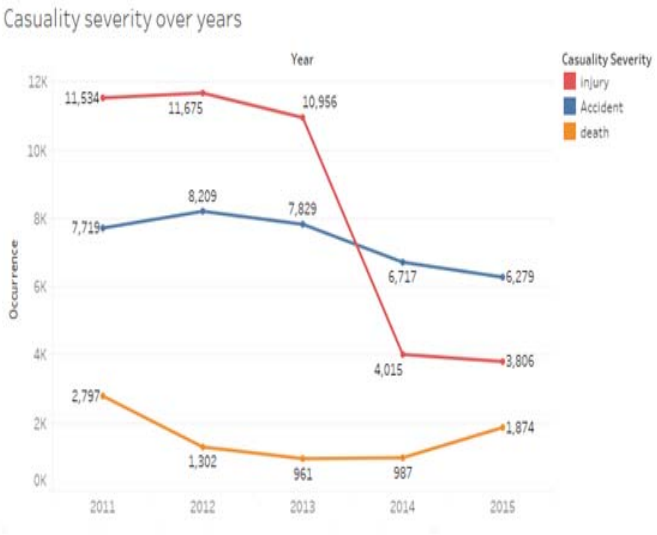

Fig.12.Trend analysis based on Casualty Severity over years.

V. PREDICTIVE ANALYTICS USING MACHINE LEARNING

There are three main types of data analytics approaches such as descriptive analytics, predictive analytics and prescriptive analytics. Descriptive analytics is nothing but analysing the past to see what has happened. This type of analytics, analyses the historical data for insights on how to approach the future. The main intention of descriptive analytics was to unearth the reasons behind the success or failure in the past. Predictive analytics is like a navigation system that will analyse the past data patterns and trends and can precisely update a person about what could occur in the future. Prescriptive analytics is the next stage of predictive analytics that combines the feature of manipulating the future [14].

Predictive analytics is the advanced type of analytics that is used to predict the unknown values using the known ones. It uses various skills like statistics, machine learning, data mining, etc. Predictive analytics is finding patterns in data and predict value in the future or future trends and outcomes by using that pattern. Machine learning techniques have become more and more popular in accomplishing predictive analytics due to their exceptional usage in managing large scale. Predictive models have been applied effectually in several domains such as health care, education, fraud detection, social media, etc. The machine learning and artificial intelligence algorithms can also be used to optimize and uncover new statistical patterns in the road traffic accident analysis.

This paper uses two different machine learning approaches such as Boosted Trees Regression and the Multiplicative Model to predict the future number of accidents.

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A. Boosted Regression Trees

The Boosted Regression Trees (BRT) are also called as the Gradient Boosted Regression Trees (GBRT) model is one of the most effective machine learning models for predictive analytics, making it a standard for machine learning [12].

The BRT Model is a type of additive model that makes predictions by combining decisions from a sequence of base models. The model can be generalized as:

$$g(x) = f0(x)+f1(x)+f2(x)+... \quad (1)$$

Where the final classifier g is the sum of simple base classifiers fi. The BRT model uses the simple decision tree as a base classifier for each base model. This broad technique of using multiple models to obtain better predictive performance is called model ensembling. Unlike Random Forest, which constructs all the base classifiers independently, each using a subsample of data, BRT uses a particular model assembling technique called gradient boosting which is similar to the gradient descent in numerical optimization [15].

The BRT model is very good at handling tabular data with numerical features, or categorical features with less number of categories.

B. Multiplicative Model

The second approach used for the prediction is by the Exponential Smoothing Models (ESM) based on the Multiplicative Model. For a high-quality prediction of values, a simple pattern in the data must match the pattern described by the model sensibly well. If the quality is low, the precision measured by the confidence bands is not important because it measures the precision of an inaccurate estimate.

Exponential smoothing models iteratively predict the future values of a regular time series of values from weighted averages of past values of the series. The simplest model, Simple Exponential Smoothing, computes the next level or smoothed value from a weighted average of the last actual value and the last level value. The method is exponential because the value of each level is influenced by every preceding actual value to an exponentially decreasing degree more recent values are given greater weight [16].

Exponential smoothing models with the trend or seasonal components are effective when the measure to be forecast exhibits trend or seasonality over the period of time on which the forecast is based. A trend is a tendency in the data to increase or decrease over time. Seasonality is a repeating, predictable variation in value. The exponential smoothing can be done using both additive model and multiplicative model.

An additive model is one in which the contributions of the model components are summed, whereas a multiplicative model is one in which at least some component contributions are multiplied. Multiplicative models can significantly increase the prediction quality for data where the trend or seasonality is affected by the magnitude of the data, like the road accident data. The multiplicative model finds the product between the seasonal effect, trend, cyclical nature and the residual of the data.

VI. PREDICTION OF NUMBER OF TRAFFIC ACCIDENTS DURING 2017-2019

The main aim of this research paper is to apply predictive analytics to predict the number of accidents that may occur in the future. The BRT model is a type of additive model that is used for making predictions by coalescing results from a sequence of base models in the form of multiple decision trees. The total number of accidents occurred during the year 2016 is also taken into consideration for the prediction of the subsequent years. The features that are used for the prediction of the number of accidents using this model are the year, month and region. The following figure, Fig.13 shows the prediction of the number of accidents per month during the year 2017 to 2019 using the BRT model. The prediction is based on the data available for the years from 2011 to 2016. The BRT model predicts a slight more number of accidents for the year 2017 when compared with 2016 but it shows the gradual decrease in the number of accidents.

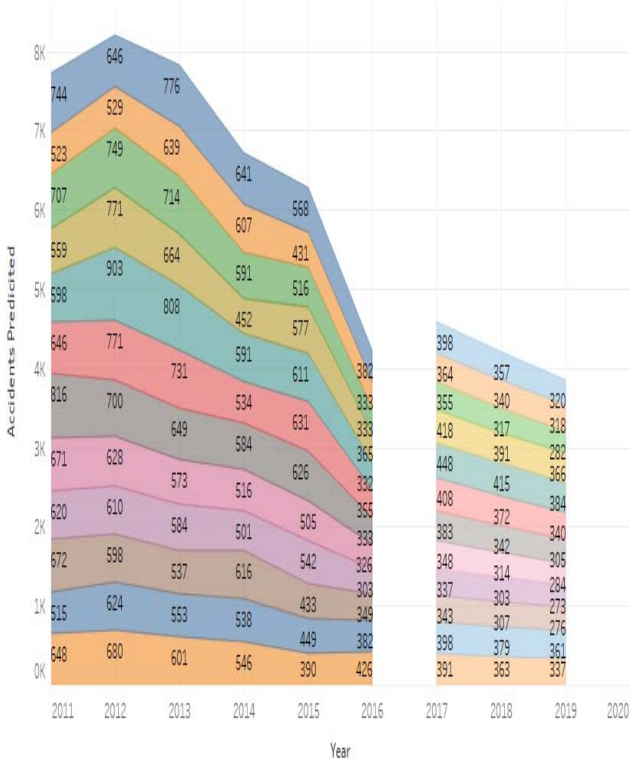

Fig.13. Predicted number of accidents during 2017 – 2019

The best model to predict any time series data is the Multiplicative Model (MM). The multiplicative model is used to predict the trends by using the seasonal values, the cycle and the residue [13]. The multiplicative model uses the multiplicative season and 90% confidence interval to predict the number of deaths during 2017 – 2019 based on the traffic accident deaths happened during 2000 – 2016. The prediction of the number of deaths is shown in the below given graph in Fig. 14. The graph shows the number of deaths is also reducing gradually after 2012.

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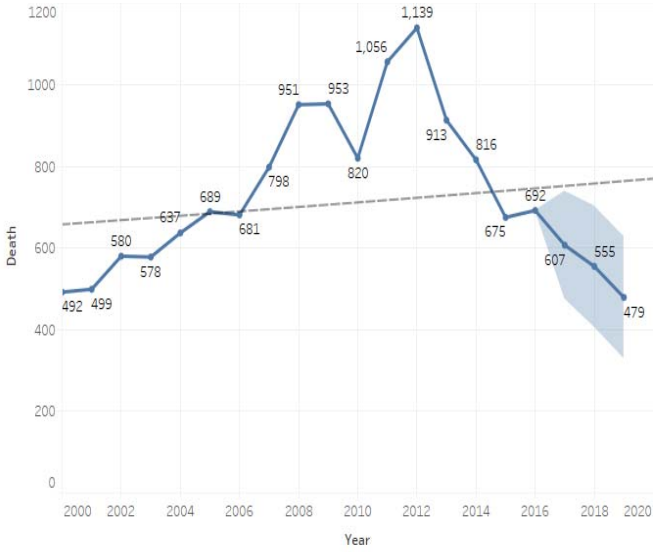

Fig.14. Predicted number of deaths during 2017 – 2019

VII. CONCLUSION

Roads are the main means of transport in Oman which in turn leads to substantial number accidents. This paper analyzed almost half of the decade data with the virtuous indication in various road accident type and casualty severity. The key findings emerged from our study indicates that the severity of crashes and the accidents rates are reduced considerably over the period. The main reasons behind this reduction of number accidents are due to the awareness created by the government in the minds of the people. In addition to that, from April 2016, onwards ROP had taken most noteworthy steps towards traffic violation. The severe laws and punishment are implemented for road traffic violation including fine range from 200 OMR to 3000 OMR and jail term. Oman needs a sustainable transport policy to reduce the traffic volume and its severe consequences. From 2015 onwards, Public Bus Transport System was introduced widely in Muscat Governorate. Waiting hopefully in future 2017- 2018, as data are mirrored to show how much beneficial is the new law implementation and whether it plays a vital role in decreasing road accident percentage.

ACKNOWLEDGMENT

Heartiest thanks to the National Center for Statistics and Information (NCSI) of Oman that published the consolidated dataset in statistical yearbook. This significant data was applied in various analysis of our research.

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