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Development of Road Traffic Accident Prediction Model by Using Artificial Neural Network: A Case Study of Mumbai-Pune Expressway

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Abstract: People's lifestyles have improved as a result of the rapid development in urbanisation.However, these developments have placed a burden on roadways by expanding vehicle ownership,causing traffic problems to worsen at an alarming rate. The primary cause of road traffic accidents couldbe an increase in the rate of traffic volume.In rapidly developing metropolitan agglomerations, road traffic accidents are a big concern. There is asubstantial body of research literature that sheds light on the scope of the problem and the remediesthat are required. Road traffic accidents are the third leading cause of unnatural death among all deaths.Transportation engineers and academics have attempted to construct safe roads that adhere to suitabledesign standards, yet traffic accidents are inescapable. If an accident occurs, the reasons that caused itmust be identified, and suitable corrective measures must be established and implemented as soon aspossible. The goal of this study is to gain a better knowledge of the problem of road traffic accidents onthe Mumbai Pune Expressway (MPEW) and the factors that may contribute to the high accident rates.Using Artificial Neural Networks, this research will construct an accident prediction model to anticipatethe amount of accidents along the MPEW (ANN)

Keywords: Artificial Neural Network, Road traffic Accidents, Planning, Management, Prediction, Deep learning Algorithm, Highway, Expressway, MPEW

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INTRODUCTION

Significant effort and money have been expended in recent years to improve road and highway safety. A continuing problem for transportation engineers is to build and operate the transportation system in such a way that it serves a variety of social goals such as shortening travel time and increasing safety. There has been an increase in due to an exceptional surge in road transportation and automotive traffic in India as a result of and the economy's and consumers' consumption habits have grown at an exponential rate, resulting in dangerous conditions. Circumstances on our Indian roads, including highways and expressways. The number of people killed or injured in traffic accidents on these roads is increasing year after year. The path Accidents, deaths, and injuries are global events, but the issue is more severe in mixed communities.

The traffic situation on Indian multi-lane motorways; the true situation is likely to be far worse due to under reporting of incidents to make the road worse

Furthermore, there is a culture of poor car upkeep, poor driving practice, and a lack of enforcing the law, and the casual attitude of road users Road safety has become a major concern for the general population, and highway safety in particular.

Professionals in particular, because road accidents are a major cause of death; Furthermore, the economic losses as a result of property damage or lost working days as a result of injuries the annual cost of fatalities is estimated to exceed billions of dollars. Road safety is both a health and a safety concern and development issue of significance given its magnitude and gravity, as well as the as a result, negative effects on the economy, public health, and general well-being individuals, particularly those with modest means

Road Accident Trend in India

There have been numerous types of vehicles on the road in India due to the development of road networks, such as cars, buses, motorcycles, trucks, vans, and others that have been used as a base to move from one place to another. According to the statistics from the Road Transportation Department website in 2019, as shown in Figure, the registered public vehicles in India are increasing every year, indicating that road safety is an important aspect because it involves the majority of the people in this country who are primarily transported by road.

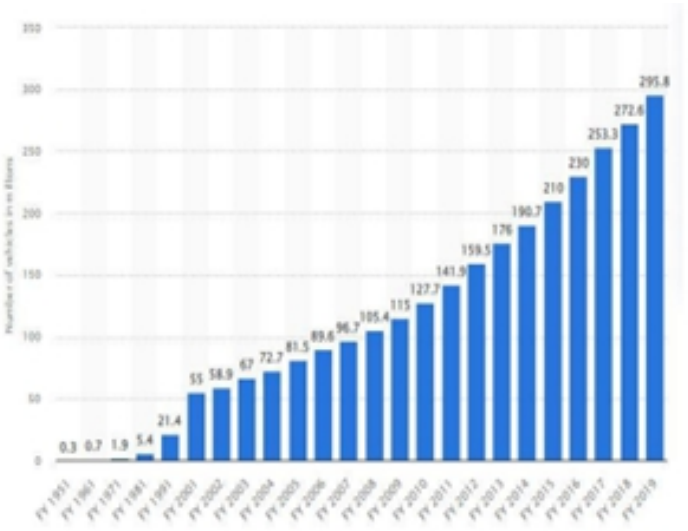


Figure 1: Total cumulative of registered public vehicles in India upto year 2019 (MoRTH website)

It is quite concerned based on the development of the complete situation about motor vehicles for that period. This is due to the fact that, as the diversity of motor vehicles on the road has increased, so has the number of accidents that have happened in India. This scenario must be investigated, and study must be conducted to determine the root reasons of the accident. It is also critical to ensure that India's present transportation infrastructure is in perfect working order in serving all types of vehicle users in this country.

Safety on the Road

The availability of transportation is directly and strongly tied to the economic development of any

country, and the objective of transportation systems is to facilitate the efficient and safe movement of freight and passengers from one location to another. The increasing number of automobiles on the road had produced a serious social problem in the form of traffic accidents, which resulted in the loss of lives and property. According to several accident studies, road accidents are not caused by natural causes, but rather by negligence and lack of road safety rules. Environmental factors, such as fog in the winter, also have a significant part in the causes of road accidents. As a result, road/highway safety is a modern-day necessity.

Initiatives to Improve Highway Safety

The Highway Police, Maharashtra State project "Highway Mrityunjay Doot" was launched on March 1, 2021.

Following a thorough investigation into the causes of mortality in road accidents, it was discovered that the lack of rapid Medical Aid was the biggest source of worry.

In many cases, the injured were not properly evacuated and transported, which compounded the injuries and medical condition. Employees from nearby Malls, Petrol Pumps, Local Dhabas or Hotels, and neighboring villages establish groups of up to 4-5 persons as part of this project. These groups are known as "Mrityunjay Devdoot" (Angels of God) and are trained in First Aid (including CPR, precautionary procedures for lifting and transporting injured people, and so on) with the assistance of Government/Semi-Government or Social Organizations. The Maharashtra State Highway Police has developed the "Highway Mrityunjay Doot "Project to avoid any such scenarios and to enable timely and effective evacuation of people injured in accidents within the "Golden Hour," which is critical.

Artificial Intelligence Techniques

In highway safety research, statistical or accident prediction models are widely used. They can be used to identify important contributing elements or to establish relationships between crashes and explanatory variables such as traffic flows, traffic control type, and highway geometric characteristics, among other things. Aside from statistical models, neural network models have been created for road accident prediction and are being used effectively in numerous transport research domains, including traffic safety studies, with high performance. Artificial Neural Networks (ANN) are utilized to combine greater flexibility, precision, generalization, and forecasting power than traditional statistical models. ANN is one of the Artificial Intelligence (AI) algorithms that can outperform all other models for the prediction of road accidents and can readily represent non-linear functions without any statistical simulation.

ANN Algorithm

The term "Artificial Neural Network" is derived from Biological neural networks that develop the structure of a human brain. Similar to the human brain that has neurons interconnected to one another, artificial neural networks also have neurons that are interconnected to one another in various layers of the networks.

To understand the concept of the architecture of an artificial neural network, we have to understand what

a neural network consists of. In order to define a neural network that consists of a large number of artificial neurons, which are termed units arranged in a sequence of layers. Lets us look at various types of layers available in an artificial neural network.

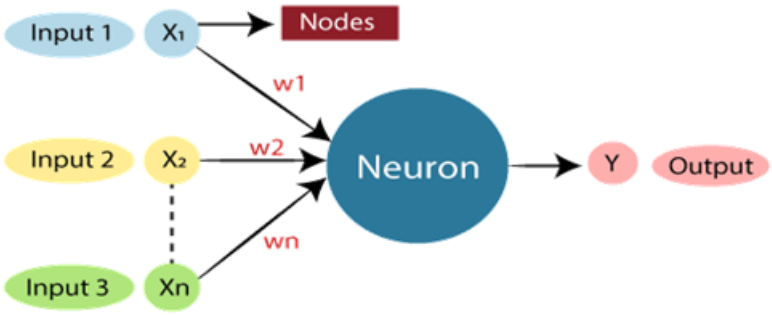


Figure 2: ANN network

Artificial Neural Network primarily consists of three layers:

Figure 3: ANN architecture

Input Layer: As the name suggests, it accepts inputs in several different formats provided by the programmer.

Hidden Layer: The hidden layer presents in-between input and output layers. It performs all the calculations to find hidden features and patterns.

Output Layer: The input goes through a series of transformations using the hidden layer, which finally results in output that is conveyed using this layer.

The artificial neural network takes input and computes the weighted sum of the inputs and includes a bias. This computation is represented in the form of a transfer function.

$$\sum_{i=1}^{n} Wi * Xi + b$$

It determines weighted total is passed as an input to an activation function to produce the output. Activation functions choose whether a node should fire or not. Only those who are fired make it to the output layer. There are distinctive activation functions available that can be applied upon the sort of task

we are performing.

Linear Activation Function:

The linear activation function, also known as "no activation," or "identity function" (multiplied x1.0), is where the activation is proportional to the input.

The function doesn't do anything to the weighted sum of the input, it simply spits out the value it was given.

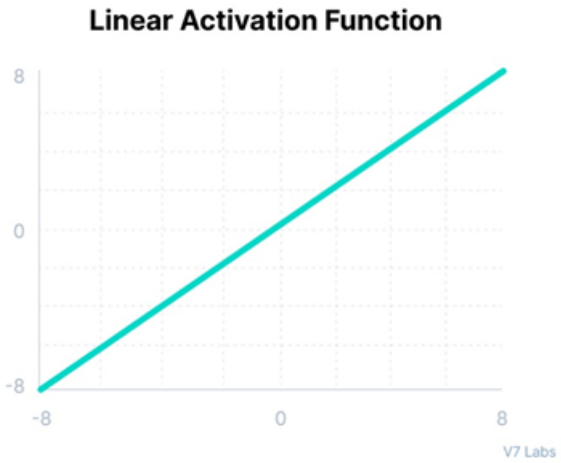


Figure 4 : Linear function graph

Problem statement

"By studying different examinations like Highway survey and traffic analysis that the problem at city by pass Highway is due to insufficiency of Highway space for the vehicles to pass through the junction at different instants of time in a day which is effecting the free flow of traffic, and improper movement of traffic also results in occurrence of accident in different instants of time."

As previously said, the number of incidents is increasing year after year and has become a major source of safety concern. As a result, doing this research is vital in order to grasp the scale of the problem, as well as to understand what causes accidents and injuries and what steps can be taken to prevent them. Furthermore, an effective solution for ensuring the safety of road users must be offered.

Aim of project

This study focuses on accident investigations along the Mumbai-Pune Expressway, which runs through the Pune District. The goal of this study is to identify the primary elements that influence the occurrence of accidents and to construct an accident prediction model utilizing Artificial Neural Networks (ANN)

Objectives

To collect road accident data on MPEW.

To analyze the accident trend and accident parameters on MPEW.

To determine the critical accident variables for accident prediction purposes.

To develop an Accident Prediction Model for MPEW by using Artificial Neural Network (ANN) applied software.

RESEARCH METHODOLOGY

What is ANN?

Artificial neural networks (ANNs) have gained popularity in recent years due to their ability to solve a wide range of issues. ANNs have been used to detect road traffic accidents in the transportation sector (RTAs). This section introduces basic neural network concepts and discusses why neural networks are appropriate for traffic data prediction.

A biological neuron is to the brain what an artificial neuron is to an ANN. The basic building block of the ANN is an artificial neuron. A neural network is a set of algorithms that attempts to uncover underlying relationships in a set of data by simulating how the human brain functions.

In this context, neural networks refer to neuron architectures that are either biological or artificial in nature. An ANN has three layers: an input layer that receives external signals, an output layer that sends external signals, and one or more hidden layers (nonlinear input transformations that have been entered into the network). Different learning rules have been employed for training networks. The multilayer perceptron (MLP) learning rule is one of the most well-known. MLP is a feed forward network in which data flows from the input side to the hidden layers and then to the output layer to generate outputs. The basic function of a neural network is depicted in Figure below.

The structure of an artificial neural network model for traffic accidents is depicted. The basic functions of all types of neural networks are data receipt from external situations or sources, deciding whether this data will be activated and taken into account.

The total of the numerous xn inputs multiplied by their corresponding weights of the relation wn is thus the beginning stage of an artificial neuron. After that, the wn.xn products are fed into the summing function, which is iterated to reduce error.

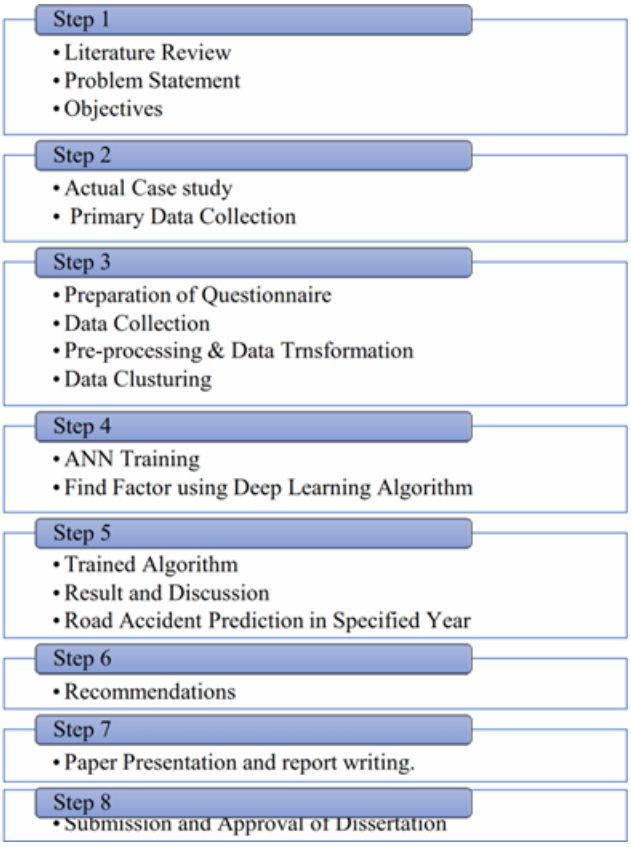


Figure 5: Methodology Flow

DATA COLLECTION & EXPERIMENTATION

MPEW starts from Khopoli Exit in Raigad district with Latitude, Longitude 18° 46' 14" N, 73° 20' 13" E and diverts towards the South –East. It passes through the high mountains of Bor Ghat and meets again with the existing MPEW to end at Kusgaon in Pune district near Sinhagad Institute with Latitude 18° 44' 06" N and Longitude 73° 25' 58" E. For this research the dataset which is considered is available from Kamshet (at Chainage 55/800) to Near about Adhoshi(at chainage 78/200) as shown in map below.

Figure 6: Map Showing Mumbai – Pune Expressway Chainage deatails

Data Source

Ministry of Road Transport & Highways (MoRTH), Maharashtra state road development corporation(MSRDC) and Highway Police Maharashtra State (HPMH) are the authorized entities to collect the information and accident data. Their website provides necessary data. However, accident data

collection system was tendered to a third part contractor, the dataset is limited and available in cumulative figures. Information is gathered between 2015 to 2016 were acquired and it is utilized to understand the accident pattern and trend and also to identify the factors influencing the accident.

However, data for development of the model which is required in categorized format is collected from the authorized open dataset webiste "Kaggle" which is used for institutional, academic and research analysis work. The website link is given here -https://www.kaggle.com/code/brittabettendorf/visual-analysis-eda/data is provide the data in the categories and factors like date, road surface condition, weather condition, no of accidents, vehicle speed , no of vehicles, casualties & etc. However, data has been extracted as per the requirement from available data

Data collection for Model Development

Data available on the website is in .csv format. Note that the URL will redirect you to a web-page that requires no authorized log in or credentials. The main page has number of dataset in various domain.From here, one can search for required data.

Data collection for this thesis centered on detecting an incident as close to real time and also a the past incidents. Data averaging was selected and downloaded . The goal was obtaining a more granular dataset for machine learning or deep learning to characterize turbulence in speed and leverage other features to successfully.

The data has downloaded for year 2013 to 2016. The primary data source was used to train and validate models. The downloaded .csv file was stored as the primary data frame

Expert Opinion about factors causing road traffic accidents

As per the summary and analysis of the available data it can be concluded that there are many factors which are leads to the accident or cause of accidents. But there some maximum influencing factors that causes of highest number of accident. In this analysis those factors are human errors, road infrastructure and weather conditions followed by sub factors.

However, to proceed further for development of model it is important and necessary to understand which factors are to be taken into consideration as maximum influencing factor and for that matter 20 expert people in civil engineering domain has been approached and asked to decide these factors. They have given one form which are listed with factors and asked them to tick mark the maximum influencing factors as per their belief and knowledge.

Experts have marked the factors and then each tick mark has counted and total is written in particular column. Then, highest number out of 20 has been ranked 1 and other in descending manner. According to ranking system it can be concluded the maximum influencing factors that are considered to train and develop the model are as follows:

1. Over speeding
2. Road Surface condition

3. Heavy rain

4. Lightening Condition

5. High winds

ANN MODEL DEVELOPMENT & IMPLEMENTATION

The development and implementation process consists of two components:

1. Machine Learning and Data Process

2. Results Presentation

1. Machine Learning and Data Process

In this process a software tool Jupiter Lab for ANN model is used. This tool is used to generate ANN model based on the historical data that has been provided. The historical accidental data is provided in .CSV format to this tool so that it can train the model to predict results based on this historical Data

2. Results Presentation

This component of the application is used to show the predict results based on the inputs that is provided to the model. For this a web application is programmed in python that uses the model generated from the above process. Visual Studio Code is used to write a the code and run the application.A web page is developed where the input are taken from the user to predict the results. The entered input are provided to the ANN model and it returns the prediction results. These results are taken from model and displayed on the screen

ANN Architecture

Multi-Layer Perceptron style artificial neural networks, as discussed in chapter 3, were found to be the most beneficial tool for use in the given prediction study. The details of the given architecture are given by Table 5.1, with one input layer, six cascading node Dense hidden layers, and one node for the output layer. The number of nodes depending on the specific model editions number of variables (here referred to as X), and as such was found by setting the number of variables equal to X. Y is the output of the network. These particular values were chosen to provide a gentle decrease in the number of nodes per layer. Note the use of a Dropout layer, which prevents over-fitting by randomly turning hidden nodes off (that is, the node is set to zero, or no) with a given probability. Here, that probability is set to 10%, meaning that there is a ten present chance that any given node will be deactivated. This means that neighbouring nodes will become more important when considering changing the weights within the back propagation process.

Layer	Location	Type	Node	Activation
1	Input	Dense	X	Linear
2	Hidden	Dense	X-128	Linear
3	Hidden	Dense	X-64	Linear
4	Hidden	Dense	X-32	Linear
5	Hidden	Dense	X-16	Linear
6	Hidden	Dense	X-8	Linear
7	Hidden	Dense	X-4	Linear
8	Output	Dense	Y-1	Linear

Figure 7: ANN Architecture

Model input details

In the ANN model, independent variables are named as the input(X), and dependent variables are named as the output(Y). The input importance chart shows the relative importance of each input column (Ref table 5.2). For this research 6 input variable are decided by expert opinion (table 4.5) explained in previous section and they are Year (X1), chainage/distance(X2), Vehicle speed(X3), Whether condition (X4), Road surface condition (X5) and Lightening condition (X6). Number of accidents (Y) is the output of the model.

Design Parameters	Definition	Binary/Numerical code
X1	Years	Categorical value
X2	Chainage/Distance	Categorical value
X3	Vehicle Speed	Numerical value
X4	Wheather condition	Categorical value(hevay rains/high winds/fog)
X5	Road surface condition	Categorical value(Dry/wet)
X6	Lightening Condition	Categorical value(day light/night light)
Y	Number of accidents	Numerical value

Figure 8: Input variables

Evaluation & Performance of ANN model

Total 1493 data divided into 3 categories. Data of year 2016 considered as network test data and among data of 2013 to 2015, 25% were testing-validating data and the rest,75% randomly categorized as network training data. Actually validating data is a criterion witch indicates that what would be the result of network in meeting non-experienced data (network test data). For training network, ANN algorithm coded in python language is used and performance and accuracy is verified by MSE and MAE

It should be mentioned that a model which meets above two criteria would be a desired model. For example the MSE error changes with multiplying the output values in a fixed number. The least, MSE and MAE errors approaching zero the most acceptable the results of the network. In the current study ANN model is investigated and the summary of the models and results represented in table below.

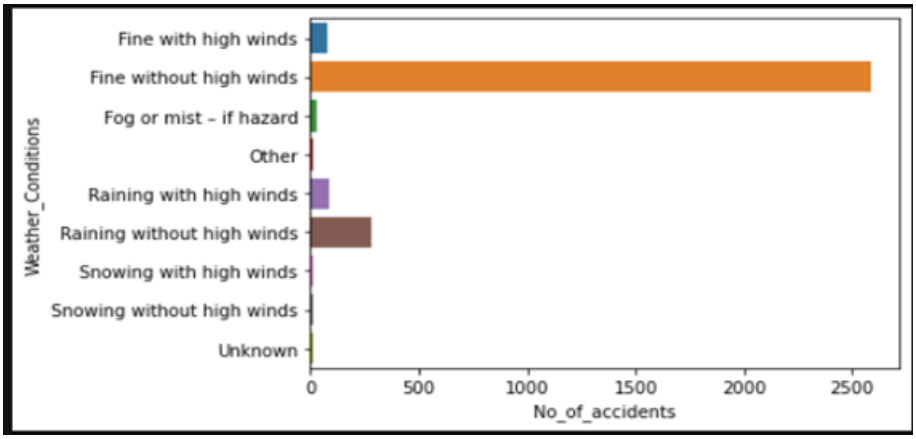
	Training model	Testing Model
Model	1	2
Algorithm	ANN	ANN
Hidden layers	6	6
nodes	128	128
Function	Linear	Linear
MSE	1.7201	1.4586
MAE	4.5562	3.445
Loss	1.7201	1.4586
Accuracy	0.7582	0.8260

Figure 9: Summary of model training result

RESULT AND INTERPRETATION

In this research, the factors which cause accidents have been investigated and results has been derived through the analysis by evaluating relation between factors and number of accident.For the geometrical features of highway sections and traffic accident reports the year 2015 were used to form the database.Following figures and graphs shows the relation between input factors & accidents. Cumulative Severity of accident is categorized as fatal, major and minor is shown through the graph.

Distribution of accidents by Weather Conditions



	Weather_Conditions	No_of_accidents	percent
0	Fine with high winds	81	2.603664
1	Fine without high winds	2588	83.188685
2	Fog or mist – if hazard	26	0.835744
3	Other	14	0.450016
4	Raining with high winds	84	2.700096
5	Raining without high winds	281	9.032465
6	Snowing with high winds	14	0.450016
7	Snowing without high winds	10	0.321440
8	Unknown	13	0.417872

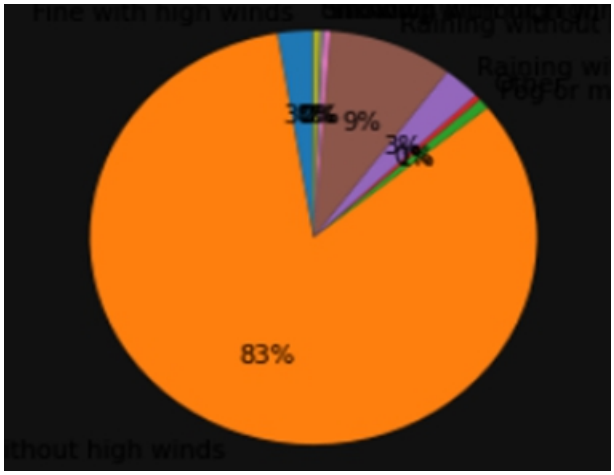


Figure 10 : Distribution of accidents by Weather Conditions

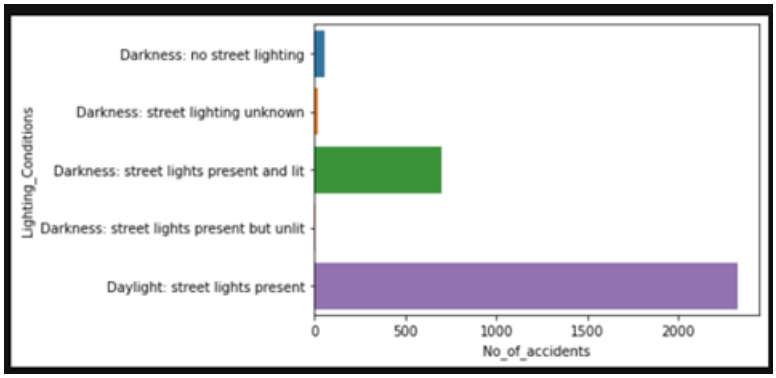
Accident distribution for different weather conditions is shown in Fig.10 It was seen that 83% accidents occurred in fine without high-winds weather environment. Only 9% accidents occurred in raining without high winds weather condition and other percentage of weather conditions shown in fig no.1.6.

Distribution of accidents by Lighting Condition:

Distribution of accidents by Lightening Conditions

Figure 11 depicts the accident distribution for various lighting conditions. It was discovered that 73 percent of accidents occurred in bright daylight with street lights turned on, while 22 percent occurred in darkness with street lights turned on and illuminated light condition, as well as other percentages of light conditions given in fig.11.

	Lighting_Conditions	No_of_accidents	percent
0	Darkness: no street lighting	58	1.864352
1	Darkness: street lighting unknown	21	0.675024
2	Darkness: street lights present and lit	696	22.372228
3	Darkness: street lights present but unlit	8	0.257152
4	Daylight: street lights present	2328	74.831244



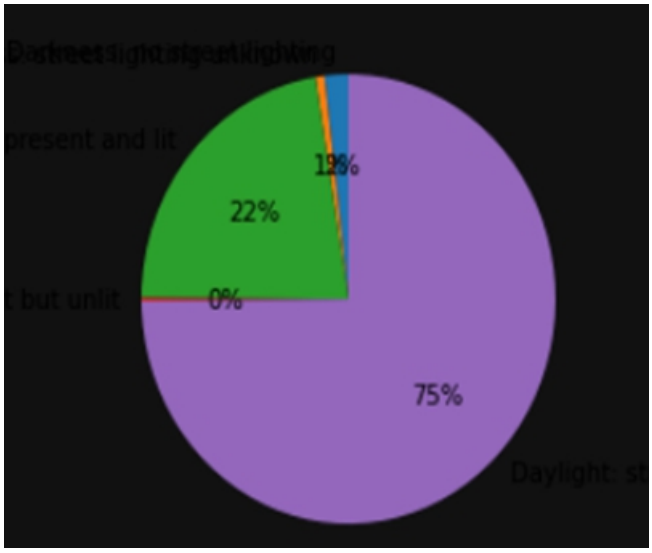


Figure 11: Distribution of accidents by Lighting Condition

Distribution of accidents by Road Surface:

Accident distribution for different road surface Condition is shown in Fig. 11 It was seen that 71% accidents occurred in Dry condition and 27% accidents occurred wet/Damp condition and other percentage of light conditions shown in fig no.12.

	Road_Surface	No_of_accidents	percent
0	Dry	2216	71.231115
1	Flood (surface water over 3cm deep)	10	0.321440
2	Frost / Ice	13	0.417872
3	Snow	22	0.707168
4	Wet / Damp	850	27.322404

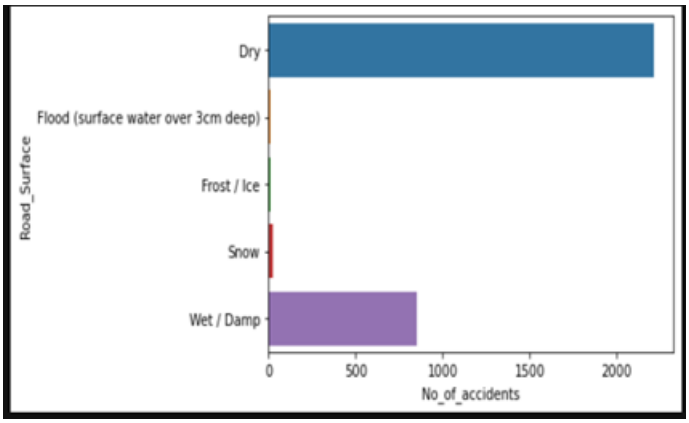


Figure 12 : Distribution of accidents by Road Surface

Distribution of accidents by Speed:

Accident distribution involvement of the speed is shown in Fig. 12 It was seen that most of the accidents (53%) occurred due to over speeding of the driver

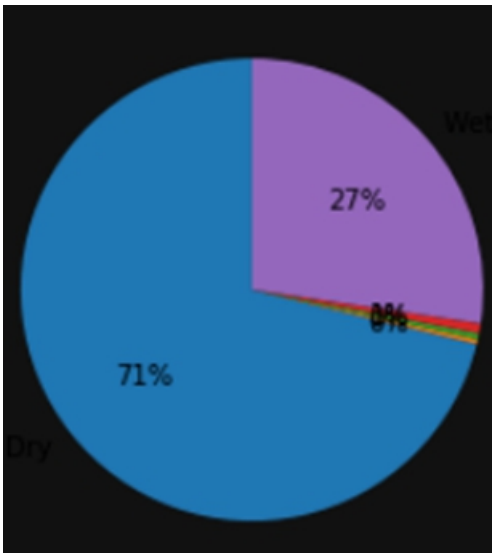


Figure 12 : Distribution of accidents by Speed

High speed vehicles are more prone to accident than slower moving vehicles. It was also found that 22% accidents occurred due to driver carelessness.

Distribution of accidents by chain age/distance

It was seen that there are 5 spot where maximum number of accidents have been occurred That are 60.5 chainage with 15%, 63.5 chainage with 14%, 62 chianage with 11%, 58.5 chainage with 9%, 77.2 chaiange with 4% as shown in table 6.1.From this analysis it is observed the maximum accidents are happened on this chainage/spot so can be considered as accident black spot.

	Speed	No_of_accidents	percent
0	40	51	1.639344
1	45	67	2.153648
2	50	594	19.093539
3	60	666	21.407907
4	70	1056	33.944069
5	80	319	10.253938
6	90	160	5.143041
7	100	147	4.725169
8	110	51	1.639344

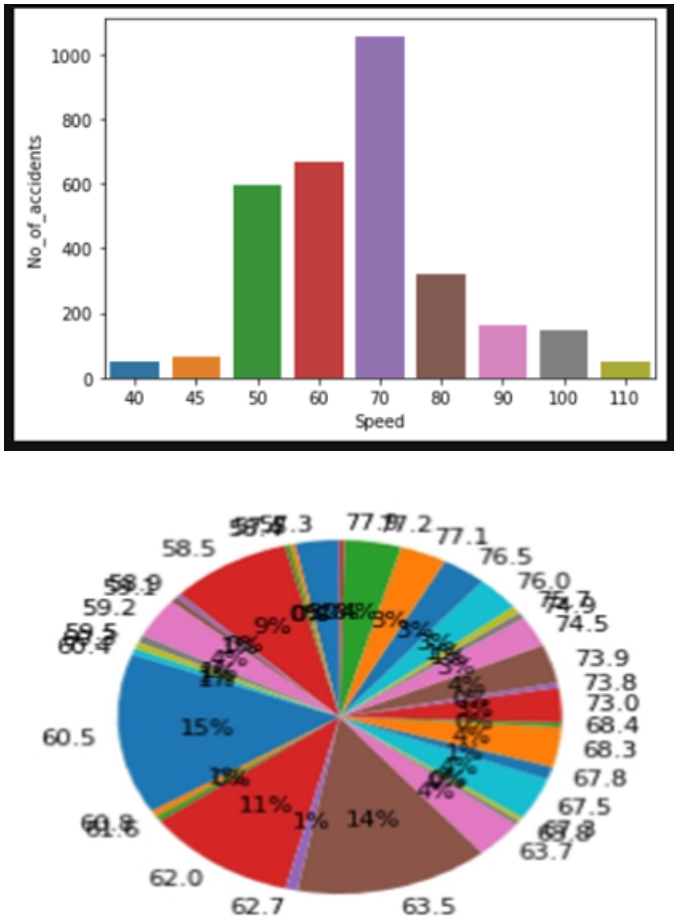


Figure 13 : Distribution of accidents by chainage

The figure 14 and 15 shows the home page of the web application. The web domain is secured with HTTPS which has been obtained from the certificate authority for secure data transfer. Figure shows the input parameters taken from users. These include the future date, Lightening condition, weather condition, road surface condition, chainage and speed of vehicle.

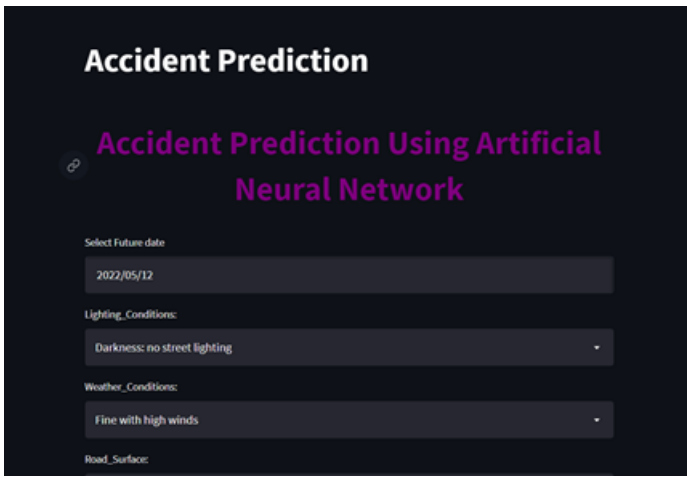


Figure 14: Web page

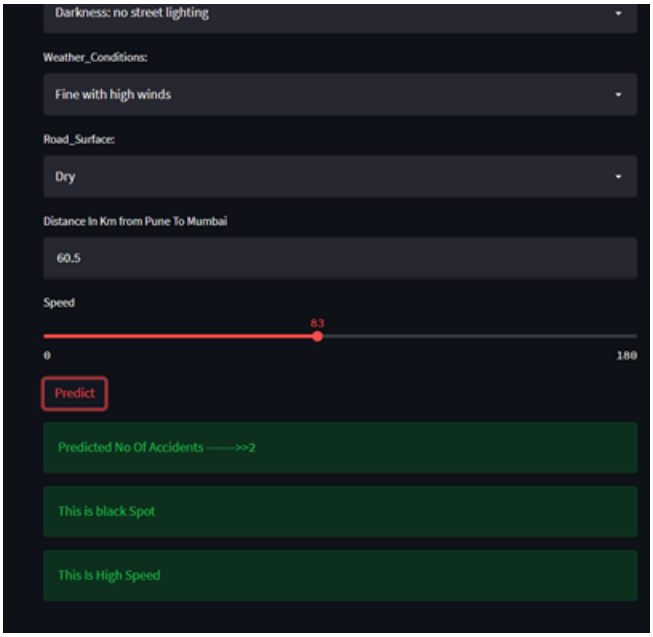


Figure 15: Web page

Once all the input parameter are chosen, user clicks on "PREDICT" button, the data is sent to the backend from where it is feeded into our chosen machine learning algorithm which is ANN. The result output predicted is in the form of "number of accidents". Also it shows where the speed chosen by user is high speed or not and the chainage/distance which is selected whether it is accident black spot or not.For e.g in above image the result ouput for selected parameters is

Predicted no of accidents =2

This is black spot

This is high speed.

CONCLUSION

In this research, the factors which cause accidents have been investigated and accident prediction models which include relations between these factors have been established. The historical data for mumbai pune expressway from chainage 55 to 78 and traffic accident reports for the years from 2013 to 2016 were used to form the database. The obtained data from the database have been investigated with ANN as a tool of forecasting techniques.

The performance of the ANN model varied depending on the accident type and input data provided to the model.The results are interpreted by using the validation data for year 2016.From the result it can be concluded that the highest(50%) fatal injuries are due to over speeding of vehicle.Maximum number of accidents are seen is due weather condition(83%) followed by lightening condition(75%), road surface condition(71%) & speed(60%).

It was seen that there are 5 spot where maximum number of accidents have been occurred That are 60.5 chainage with 15%, 63.5 chainage with 14%, 62 chianage with 11%, 58.5 chainage with 9%, 77.2

chaiange with 4% as shown in table 6.1 in chapter 6 .From this analysis it is observed the maximum accidents are happened on this chainage/spot so can be considered as accident black spot.The low values of the MSE and MAE in ANN indicate the superiority of the model as shown in below screenshot.

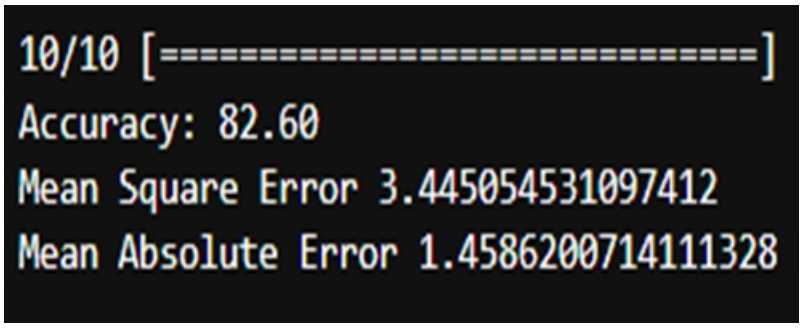


Figure 16: Model accuracy

To determine the performance of the ANN model, the comparison of model prediction performance between the target and output is examined as shown below.

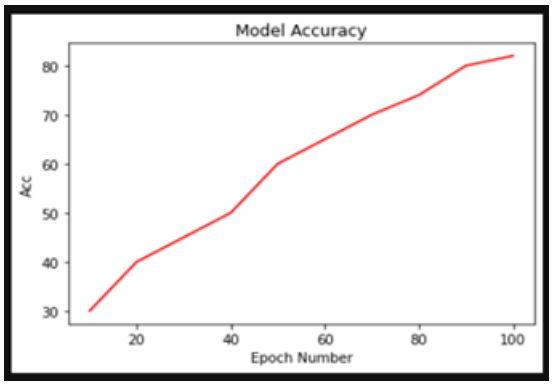


Figure 17: Model accuracy graph

	Actual Values	Predicted Values
0	[2]	3
1	[1]	3
2	[2]	3
3	[1]	4
4	[1]	3
5	[2]	3
6	[4]	4
7	[1]	3
8	[1]	2
9	[2]	3
10	[2]	3
11	[3]	3
12	[2]	3
13	[1]	3
14	[2]	3

Figure 18: Actual Values and Predicted Values

FUTURE SCOPE

The modelling results obtained using the annual data (the years from 2013 to 2016) are encouraging for further research by the expanded data sets. By setting up some random variables in the design parameters, it may be possible to predict the number of accidents for the years in the future. The future work might focus on how to improve the prediction performance of ANN models. It would also be interesting for future studies to predict the number of accidents on expressway with using the other accident forecasting technique to see if the prediction performance could be improved.

Future work in this area should be focused on trying to reduce the errors in prediction even further – for example, by developing other options to overcome over dispersion and extending the work to cover other non-infrastructure factors – for example, driver age, experience, condition and vehicle factors. Any future work should also give serious consideration to the coming automation of vehicles, which will drastically change how and why accidents occur.

Also this research only represent defined section on expressway and research revolves around specific area.These areas or such section area could be explored further to determine the other influencing factors and development of newer model.

Periodically, the model back-end of the application would need to be assessed and retrained, to determine if accident hot spot trends had shifted or flared in additional areas. This would involve the collection of accident records, weather, and roadway information up to the date of reassessment to retrain the model using the most recent incidents. This would allow for the model to understand trends in a timely fashion, and to remain relevant to the purpose at hand.

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