



## Intelligent Predictive Model for Road Traffic Congestion and Monitoring System: A Systematic Survey

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**Abstract**—Traffic Congestion is major problem in many cities due to increasing more number of vehicles, low maintenance of traffic signal and lack of infrastructure. So traffic jams are one of the major serious problem leading to environmental pollution, fuel, economy, time wastage, and also serious impact of human health issues. The prediction of road traffic congestion is most essential while uses of intelligent predictive model technique. Based on this survey, to find the solution of these problem using artificial intelligence and various machine learning algorithms.

**Keywords**—Predictive model; artificial intelligence; machine learning; deep learning; traffic congestion.

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### I. INTRODUCTION

In increase of population, the majority of the cities are gradually developing into a smart city so rapidly increasing number of vehicles on road bring great pressure to predict traffic congestion in major areas. The problems in traffic congestion are very bad critical behavior of drivers, environment pollution, wasting of time, economy and vehicle emissions and degrades ambient air quality and it impacts on weather conditions, increase fuel consumption. The vehicle accidents are the major human health issues, according to road transport ministry of India as released data 4,61,312 road accident in 2022 and road crashes increase over 35% of such fatalities, the annual report of the NCRB (National Crime Records Bureau). In 2021 The tomtom traffic index covering 404 cities across 58 countries on 6 continents (Table 1) traffic index rank urban congestion worldwide provide free access city by city information in the world, the top most four Indian cities traffic congestion level [27].

In 2022 the tomtom traffic index covering 390 cities across 56 countries on 6 continents (Table 2). the traffic index measures cities around the world by their travel time, fuel costs and CO2 emissions, provide free access city by city information in the world, The India had top most four cities traffic congestion level [27].

In 2023 the tomtom traffic index covering 387 cities across 56 countries on 6 continents (Table 3). the traffic index measures cities around the world by their travel time, fuel costs and CO2 emissions, provide free access city by city information in the world, The India had top most four cities traffic congestion level are as follows [27].

Prediction of traffic congestion in urban road helps to manage traffic and make efficient decisions to reduce the negative effect of traffic congestion [Yi Liu, et al., 2014] [1] using Bayesian Network analysis (BN) predict urban road traffic congestion. The predictive road traffic congestion probability of 3 cases that is, Case 1 : Road construction, the predictive probability will be 40.74% in 2015, Case 2 : Bus development 23.50% in 2015 and Case 3: the road construction and bus development both probability will be 36.71% percentage.

The traffic congestion is one of the major problems in largest population countries, the author present [Toshio Ito, et al., 2017] [2] one of the solution is generation of traffic prediction based on driver behavior and sensor based on CAN (Control Area Network) to predict the additional driver

TABLE I  
THE INDIAN CITIES TRAFFIC CONGESTION LEVELS AT 2019 AND 2021

SI No	World Rank	City	Time Lost Per Year	Congestion Level 2019	Time Lost Per Year	Congestion Level 2021
1	5	Mumbai	219 Hours	65%	121 Hours	53%
2	10	Bengalure	243 Hours	71%	110 Hours	48%
3	11	New Delhi	156 Hours	56%	110 Hours	48%
4	21	Pune	186 Hours	59%	96 Hours	42%

TABLE II  
THE INDIAN CITIES TRAFFIC CONGESTION LEVELS AT 2022

SI No	World Rank	City	Time Lost Per Year	Congestion Level 2022
1	5	Bengalure	212 Hours	65%
2	6	Mumbai	203 Hours	63%
3	8	Pune	193 Hours	60%
4	20	New Delhi	166 Hours	57%

TABLE III  
THE INDIAN CITIES TRAFFIC CONGESTION LEVELS AT 2023

SI No	World Rank	City	Time Lost Per Year	Congestion Level 2023
1	6	Bengalure	132 Hours	63%
2	7	Pune	128 Hours	57%
3	44	New Delhi	81 Hours	48%
4	54	Mumbai	92 Hours	43%

behavior effects on environment and infrastructures. The different phases of detect the traffic congestion free travel phase due to changes of human behavior, and meta stability phase using machine learning methods to detect driver behavior based on neural network systems. The smart city traffic congestion prediction based on machine learning [Suguna Devi, et al., 2017][3] present IOT based traffic congestion using sensors for analyzing traffic flow. The smart cities connected sensors well deployed in the junctions while collect data from different junctions and classify the model called congestion algorithm for prediction. To apply machine learning technique for analyzing and prediction of road traffic congestion accurate result is Logistic regression is the best ML technique for classify the model.

The worldwide intelligent traffic system [Pallavi A. Mandhare, et al., 2018][4] for better results of traffic related issues, the ITS application focus on emergency management, congestion management, advance traffic information, advance traveller, commercial vehicle, vehicle controlled system. The implementing proper road network using different ITS technologies. In worldwide some countries like USA, Dubai, Canada, Uk etc, are using ITS application and get the promising solution for traffic control and management system. In india has started a big take off towards the journey of ITS.

In this paper the artificial intelligence techniques to improve ITS [Mirialys Machin, et al.,2018] 5][23] the processing of large amount of data collected from the sensor and network devices to apply the traditional solutions is not effective, so the artificial intelligence applied vehicle control, traffic control and prediction, and road safety and accident prediction based on four techniques, Artificial Neural Networks (ANNs), Genetic Algorithm (GA), Fuzzy Logic (FL), and Expert Systems (ESs). In vehicle control system using Genetic Algorithms, in traffic control and prediction

service use ANNs more specifically, road traffic and accident prediction use Fuzzy Logic and ANNs been applied. Finally, the ANNs more effective to accurate prediction based on wireless big data analysis. Road traffic condition is one of the major problems in cities especially big countries, like Indonesia. There are too many bad effects by traffic problem like, delays in traffic, fuel wastage increases, losses of cost due to overcome this present [Jason Kurniawan, et al.,2018][6] an intelligent traffic congestion and detection method using image classification approach on CCTV camera image feeds. Use deep learning and convolutional neural network (CNN) currently use image preprocessing method. The CNN model use to train and convert binary classification on road traffic condition using 1000 CCTV images. The result using CNN is simple, basic design and average classification accuracy of 89.50%.

The Intelligent transportation system is the important component to predict the traffic condition in short and long term basis [S. Narmadha, et al.,2018][7][24][25] in smart city. The traffic data from sensors, incident detection, lane closure and weather data is the main reasons to cause the congestion. The promising technology is a deep learning used to predict the traffic congestion with high accuracy.

The real time traffic congestion and prediction is an important role in ITS [T. Manoranjitham, et al.,2018][8][22]. The present systems of road traffic congestion prediction do not make full of available resources. The deep learning is the solution for finding the short term traffic prediction in particular area. The one more additional challenge GPS based system gives data about real time traffic to improve the accuracy and efficiency of short term traffic prediction. The performance metrics of the deep learning algorithm to find the mean absolute percentage error (MAPE) and Root mean square error (RMSE) to define different algorithms like they

TABLE IV  
A SUMMARY TRAFFIC CONGESTION USING MACHINE LEARNING TECHNIQUES

Reference and year	Approach	Learning Techniques	Characteristics
(Yi Liu, 2014)	Bayesian Network	Supervised	<ul style="list-style-type: none"> <li>Reasonable prediction</li> <li>Reduce the negative effect of traffic congestion</li> <li>uncertainty and probability of traffic congestion</li> </ul>
(Toshio Ito, 2017)	Neural Network	Supervised	<ul style="list-style-type: none"> <li>Free Travel phase</li> <li>Meta stability phase</li> <li>Traffic congestion phase</li> </ul>
(Suguna Devi, 2017)	Machine learning approach	Supervised	<ul style="list-style-type: none"> <li>Help road users to make better travel decisions</li> <li>Improve traffic operation efficiency</li> <li>Reduce pollution</li> </ul>
(S. Narmadha, 2018)	Deep Learning	Unsupervised	<ul style="list-style-type: none"> <li>Multi Type data used</li> <li>Reduce and Dimensionality</li> <li>Spatio temporal traffic flow prediction</li> </ul>
(Jason Kurniawan, 2018)	Image Classification approach	Unsupervised	<ul style="list-style-type: none"> <li>Traffic condition</li> <li>Gray scale image</li> <li>To detect traffic congestion automatically</li> </ul>
(Mirialys Machin, 2018)	ANN Genetic Algorithms Fuzzy Logic Expert System	AI Technique	<ul style="list-style-type: none"> <li>Vehicle control</li> <li>Traffic Control and Prediction</li> <li>Road safety and accident prediction</li> </ul>
(Tin T.Nguyen, 2019)	Point based approach Area based approach	Unsupervised/ Image Processing Technique	<ul style="list-style-type: none"> <li>Clustering analysis</li> <li>Pattern Segmentation</li> </ul>
(Nadia Slimani,2019)	Neural Network	Supervised	<ul style="list-style-type: none"> <li>Short term traffic flow forecasting</li> <li>Predict daily traffic flow</li> </ul>
(John F. Zaki, 2020)	Hidden Markov model approach	Supervised	<ul style="list-style-type: none"> <li>Short term traffic prediction</li> <li>Clustering</li> <li>Pattern classification</li> </ul>
(Shridevi Jeevan Kamble, 2020)	ML Approach	Supervised	<ul style="list-style-type: none"> <li>Short term traffic prediction</li> <li>Real time, Future traffic prediction</li> </ul>
(Xueyan Yin,2021)	Deep Learning	Supervised	<ul style="list-style-type: none"> <li>Knowledge graph fusion</li> <li>Long term prediction</li> <li>Multi source data</li> </ul>
(Nishant Kumar, 2021)	Deep Learning	Reinforcement	<ul style="list-style-type: none"> <li>Human performance level in computer vision</li> <li>High Predictive Power</li> </ul>

are Auto Regressive Integrated Moving Average (ARIMA) (25.95%, 413.86 veh/h), Deep Belief Networks (DBN) (20.19%, 374.33Veh/h) and Long Short Term Memory (LSTM) (19.55%, 346.83Veh/h).

This paper present the classification of congestion pattern using machine learning techniques. If the large number of traffic pattern for clustering is point based and area based [Tin T Nguyen, et al.,2019][9]. The point based approaches is widely used for image processing literature and extract local interest points in images. The area based approach combines spatial temporal segments and extract the images using watershed (Hill Climb algorithm) Segmentation for moving traffic jam patterns. The drawbacks of area based approach the limited number of features are used, require more number of data and the ability to recognize new traffic pattern for

future research. [E. Heyns, et al.,2019][10] present the traffic prediction from driver behavior using signals and Control Area Network (CAN)bus. The predictive model for learning approach using Bagged Trees and RUSBoosted Trees for imbalanced data and the accuracy of the result is 95% achieved and the precision is 92%. the limitation of sensor data collection only from cars and truck passengers. The traffic jam is most significant problem in the big cities [Nadia SLIMANI et al.,2019][11]. The solution to solve the issues artificial neural network using Multilayer Perceptron architecture with a total MSE (Mean Square Error) 0.00927 with train set and 0.01321 in the test set. The artificial neural network is the functioning of human brain network contains 10 and thousands of billions of connection. The artificial neural network can be based on modelling, simulation,

optimization, classification and prediction on traffic forecasting in cities. The future research the traffic forecasting problem can solve different models such as ARMA, ARIMA, ANFIS and also deep learning using feedback loop process.

The Advanced Traffic Information System (ATIS) to manage traffic congestion basically using ICT (Information and Communication Technology) [Williams Achaak, 2019][12][25]. The ATIS include the traveller plan using Geographical Information (GPS) systems such as incident detection, events on road construction, traffic condition, weather condition and also take the information from Media, Variable Speed Limit, Dynamic Navigation System, Radio and Television Broadcast, Internet Service and Mobile Phone Services. Main disadvantage is less information collecting from the users, limited data from on road sensors, expensive and initializing cost and maintenance of services.

The machine learning is identify the traffic congestion based on multiple parameter [Shridevi Jeevan Kamble, et al.,2020][13] using Gaussian Process model. The traffic speed prediction using machine learning use 3 dataset that is training set, prediction set and road sector data frame. Machine learning is effective approach to find hidden insight through iteratively learning from the data. The gaussian process for prediction of traffic speed only short term traffic prediction and GPS trajectory is more exhaustive in real time and a large scale data. The ITS for traffic congestion uses various hardware and software tools to capture traffic flow in smart cities a lot of techniques are implemented but the expensive cost is more to installation and maintenance. So the use of ultrasonic sensor propose [Obad Appiah, et al.,2020][14] to gather the traffic information and using image processing techniques by non vehicular moving objects and cheaper cost as compared to all other ITS applications. The artificial intelligence can be used to applied in diverse field of studies on different sources like Recurrent and Non-recurrent congestion in Johannesburg city [I.O. Olayode, et al.,2020][15].

## II. MATERIAL AND METHOD

In this paper present traffic congestion prediction using Hidden Markov Models (HMM). In short term traffic prediction both the speed and contrast are used together to construct a 2D space representing different traffic states [John F.Zaki, et al.,2020][16]. The hidden markov model describe the data in different categories and such divide into data processing, clustering, training and testing, classified and predict the traffic. In this approach prediction accuracy is 91.5% achieved. The purpose of this paper is to provide a comprehensive survey of deep learning algorithm on traffic prediction [Xueyan Yin,et al.,2021][17]. There are two methods, classical and deep learning methods. The classical method called traditional machine learning to find the traffic prediction problems applied in time series analysis. The deep learning methods are using spatial dependency and temporal dependency model and obtained the accuracy of 83.85% and the limitations of deep learning is high data demand, high computational complexity and lack of interoperability. [Yue Hou, et al.,][2021][18][26] present the dataset in different region, two way road data, weather data, driving angles, and congestion level. The two categories of prediction methods qualitative prediction and quantitative prediction using the

algorithm LSTM (Long Short Term Memory) and GRU (Gated Recurrent Unit), ASE (The Stacked Auto Encoder). The limitation this algorithm is not effective because of lack of dataset and improper two way lane and weather data. The collecting average time also very less (average of 10 mins).

The deep learning application is one of the important transportation domain because the deep learning detecting, predicting and alleviating traffic congestion and non congestion states [Nishanth Kumar, et al., 2021][19]. the timely access to traffic data is essential to development of intelligent traffic system such as weather data and traffic incident, to solve this problem improve the Deep Belief network (DBN) [Xuexin Bao, et al.,2021][20] for accurate prediction under poor weather. To calculate the ARIM model in traditional neural network the experiment result traffic prediction error 9%, maintained good robustness extension of the time interval. The traffic crashes is one of the leading causes in the United States, to detect real time incident crashes using deep learning techniques with accuracy achieved such as LSTM (Long Short Term Memory, 91.3%), GRUs (Gated Recurrent Units, 91.8% and DNN (Deep Neural Network, 93.7%) [Homa Taghipour, et al.,2021][21].

## III. RESULT AND DISCUSSION

In this section, we discuss the challenges of compiling the research paper these are the major challenges discussed are as follows.

The real time video streaming data: the collection of data by city traffic center on CCTV video streaming data up to two or three years above and apply the machine learning model and discuss the result. The long term traffic prediction: the collect the data in one or two hours streaming data apply the long term traffic prediction model and predict peak hours traffic, week or weekend traffic, weather traffic, incidents on roads and get the better results. The incident detection in geographical location: to find the incidents location like accidents, vehicle breakdown, road working condition or any other serious issues related to traffic to taking the action immediately. Automatic emergency vehicle free way services: to find the emergency vehicle like ambulance and fire engine for giving automatic free way signal services. Automatic traffic rule violation and detections: to predict the traffic rule violation automatically like without helmet bike riders, unnecessary traffic signals breakdown, high speed vehicle moving, etc for taking instant solution.

## IV. CONCLUSION

In this paper present a systematic survey on several works related to traffic prediction on different road segments that is several approaches are ultrasonic sensors, global positioning system(GPS), intelligent transportation system(ITS) using artificial intelligence, traffic congestion prediction based on driver behavior, road traffic prediction based on deep learning and neural networks technique, image processing technique, hidden markov model to find the traffic congestion. The result and performance of the accuracy is varies from one model to another model. The main contribution of this survey is how to predict the traffic congestion using highly influenced predictive model with efficient result.

In future research of the traffic congestion and prediction, some of problem arise based on our findings after the literature survey in terms of machine learning techniques, artificial intelligence and deep learning are as follows.

- a) Lack of labeled data.
- b) Structure data is difficult to using in deep learning.
- c) Lack of successful result in deep learning technique.
- d) Real time prediction problm.
- e) The optimal network architecture choice.

#### DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing direct or indirect financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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