ENHANCING TRAFFIC ANALYSIS

(A Machine Learning Approach in Bangalore's North Urban Area Yelahanka)

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Abstract— Curb space congestion poses a significant challenge to urban traffic environments, impacting both vehicular flow and pedestrian safety. This study investigates the effect of curb space congestion on the traffic environment in Bangalore's North Urban Area traffic, specifically focusing on Yelahanka. By analyzing traffic patterns, parking behaviors, and pedestrian movement, this research aims to understand the complexities of curb space congestion and its implications for urban mobility. Utilizing a combination of observational studies, traffic simulations, and data analysis techniques, the study identifies key factors contributing to curb space congestion and evaluates their impact on traffic flow efficiency and safety. The findings provide insights into the effectiveness of current traffic management strategies and offer recommendations for optimizing curb space utilization to alleviate congestion and enhance the overall traffic environment in Yelahanka and similar urban areas. In this paper solution for traffic analysis using random forest algorithms is being proposed which would select only part of the data for analysis as two-thirds of the entire data and the prediction of traffic congestion of the specific path and notifying well in the advanced vehicles intending to move to move on that specific path. Thus, accurate traffic flow information helps road users with fast and safe transporting

Keywords— Traffic management, Machine learning, Urban traffic, Traffic prediction, Supervised learning, Curb Space Congestion, Traffic Environment, Traffic Congestion.

I. INTRODUCTION

Curb Space Congestion, Traffic Environment, Traffic Congestion, our daily plans are severely hampered by traffic congestion, which is caused by a variety of problems includingbottlenecks, erratic lane changes, and unplanned accidents. To solve this, there is an increasing need for a complete system that can monitor, record, and analyze traffic flow in addition to providing users with up-to-date road conditions information and route recommendations.

Creative approaches that use autonomous algorithms toforecast routes have the potential to improve overall efficiency, optimize travel routes, and enable seamless navigation from point of origin to point of destination. A smart city is an urban area that uses different types of data collection sensors to supply information which is used to manage assets and resources efficiently. Advanced computational techniques to analyze various factors such as traffic patterns, road conditions, and real-time data to predict the most efficient routes. Particularly in fast-developing cities like Bangalore, Yelahanka located in the North Urban Area of Bangalore, has witnessed rapid urbanization and infrastructural development, accompanied by escalating traffic congestion and associated issues.

This introduction sets the stage for the subsequent sections of the study, outlining the significance of traffic analysis in urban planning, the specific challenges faced in Yelahanka, and the potential benefits of adopting a machine-learning approach to address these challenges. Through a combination of data collection, feature engineering, model development, and validation, this research endeavors to contribute to the effective management of traffic and transportation systems in Yelahanka and similar urban areas.

The paper aims to address escalating traffic congestion in Yelahanka, Bangalore, through a machine-learning approach. Rapid urbanization and ongoing infrastructure developments exacerbate congestion, impacting productivity, safety, and the environment. By leveraging machine learning algorithms, we aim to decipher complex traffic patterns, identify high-risk areas, and optimize resource allocation. This initiative aligns with Bangalore's smart city objectives, utilizing technology to enhance urban mobility and sustainability. Ultimately, the project strives to create a more efficient and livable urban environment for residents and commuters in Yelahanka.

II. LITERATURE SURVEY

In {1] the author confronted the challenge of anticipating traffic congestion using machine learning techniques. It employs decision trees, random forest, MLP, and logistic regression algorithms to construct predictive models aimed at enhancing efficiency. Notably, these models are designed to adapt to devices with limited computational resources, thereby rendering them suitable for broad implementation across urban environments. However, the study underscores the potential benefits of integrating hybrid techniques to further improve traffic congestion prediction. One significant finding is the relatively low utilization rate of the random forest algorithm, standing at just 15%. This highlights a gap in optimization opportunities for existing models. Future research directions emphasize the exploration of diverse hybrid techniques to bolster the accuracy and robustness of congestion prediction models. This suggests a need for innovation in predictive methodologies to address the dynamic nature of urban traffic congestion in smart city contexts effectively. Ultimately, such advancements are crucial for refining traffic management strategies and ensuring the smooth operation of urban transportation systems.

In [2][9] the author addressed the challenge of predicting traffic patterns through the utilization of RFID (Radio Frequency Identification) technology. Employing RFID controllers and tags, the study aims to develop a system capable of forecasting traffic flow. An advantage highlighted is the ease of installation and cost-efficiency of RFID technology compared to alternative techniques. However, a drawback noted is the potential for inaccuracies in frequency detection at times. The study identifies a gap, with only 2% of the concept of predicting traffic being explored. Future research directions suggest the enhancement of the system through the utilization of more robust communication networks beyond GSM (Global System for Mobile Communications). This would likely improve the accuracy and reliability of traffic prediction capabilities, thus advancing the effectiveness of smart traffic management systems integration of advanced communication infrastructures, such as high-speed broadband or emerging 5G networks, holds promise in overcoming existing limitations and achieving higher prediction accuracy. This strategic enhancement is anticipated not only to bolster traffic forecast reliability but also to elevate the overall effectiveness of smart traffic management systems.

In [3] the author addresses the challenge of predicting accident risk using supervised machine learning, specifically employing gradient boosting techniques. One notable advantage of the approach is its ability to forecast accident risk per road segment on an hourly basis, providing valuable insights for road safety management. However, a limitation highlighted is the reliance on historical data rather than real-time information, which may not fully capture the dynamic nature of accidents, often considered random occurrences. Recognizing this gap, the study suggests that only 2% of real-time data is currently utilized. To enhance the model's accuracy and relevance, future research directions entail incorporating real-time traffic information, aiming to significantly improve the predictive capabilities and responsiveness of the model to evolving road conditions.

In [4]. Collaborated under the Department of Information Technology at SKNCOE, Pune, to develop a Smart Traffic Management System for Sahakarnagar, Pune. This system aimed to tackle traffic congestion and enhance traffic flow efficiency in the area. Leveraging modern technologies, such as real-time traffic monitoring, intelligent signal control, and data analytics, the system sought to optimize traffic management processes. Its overarching goal was to reduce travel time, minimize fuel consumption, and improve road safety for commuters. Through innovative approaches and strategic planning, the Smart Traffic Management System showcased significant potential in mitigating traffic-related challenges and promoting sustainable urban mobility. By integrating advanced technological solutions, Alanke and Koul's initiative demonstrated a proactive effort to address critical urban infrastructure issues and elevate the quality of life in urban areas.

In [6] the author explores the application of machine learning techniques in analyzing vehicle crashes. Shakur delves into how machine learning algorithms can process vast amounts of data related to vehicle accidents, including factors like weather conditions, road types, and driver behavior, to identify patterns and predict potential crash scenarios. By leveraging this technology, researchers and policymakers can gain valuable insights into the causes of accidents and develop more effective strategies for prevention and mitigation. The article likely discusses the potential impact of such advancements on road safety, highlighting the importance of integrating data-driven approaches into transportation management systems. Shakur's work underscores the significance of interdisciplinary collaboration between data scientists, transportation experts, and policymakers to address pressing issues in road safety.

In [7] delves into the shortcomings of conventional approaches while shedding light on the promise of machine learning. It meticulously categorizes various machine learning algorithms, encompassing regression models, decision trees, and neural networks, and evaluates their effectiveness in tasks such as predicting traffic flow, detecting congestion, and optimizing routes. Additionally, the survey examines data preprocessing techniques and grapples with challenges such as ensuring data quality. Moreover, it outlines future research directions, emphasizing the need for leveraging real-time data streams and developing hybrid models for enhanced traffic analysis and prediction accuracy It serves as a roadmap for future research endeavors, advocating for the integration of advanced computational techniques with transportation engineering principles. This synthesis of methodologies not only holds promise for improving the efficacy of existing traffic management systems but also paves the way for innovative solutions to emerging challenges in urban mobility.

In [8][10], the author focuses on leveraging deep learning techniques and unmanned aerial vehicle (UAV) based video for real-time traffic analysis. The study proposes an innovative approach to address traffic management challenges by harnessing the capabilities of deep learning algorithms in analyzing UAV-captured video footage. By integrating deep learning models with UAV technology, the system aims to provide real-time insights into traffic patterns, congestion levels, and road conditions. This approach offers several advantages, including enhanced accuracy in traffic analysis, improved scalability, and the ability to adapt to dynamic traffic environments. The paper highlights the potential of this methodology in revolutionizing traffic surveillance and management systems, enabling authorities to make data-driven decisions for optimizing traffic flow, reducing congestion, and enhancing overall road safety. Through empirical evaluations and case studies, the authors demonstrate the effectiveness and feasibility of their proposed system, paving the way for future advancements in real-time traffic analysis and surveillance applications.

In [12]. The author presents a novel approach to traffic congestion monitoring leveraging the Internet of Vehicles (IoV) framework. The study addresses the pressing challenge of urban traffic congestion through the development of an innovative monitoring system. By harnessing IoV technologies, such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, the proposed system enables real-time data collection and analysis. One of the key contributions of this research lies in its efficient utilization of IoV capabilities to enhance traffic management and alleviate congestion. Through the seamless integration of vehicles and infrastructure into a cohesive network, the system facilitates the exchange of traffic-related information, including vehicle speed, location, and road conditions. This rich dataset enables accurate congestion detection and timely dissemination of traffic updates to drivers, empowering them to make informed route choices and avoid congested areas.

In [15]. delves into the application of machine learning techniques for analyzing traffic accidents and predicting accident hotspots. The study aims to leverage the power of machine learning algorithms to gain insights into traffic accident patterns, contributing to enhanced road safety measures. By harnessing large datasets comprising historical accident records, road conditions, weather information, and other relevant factors, the research endeavors to develop predictive models capable of identifying accident-prone areas or hotspots. Through the utilization of advanced machine learning algorithms such as decision trees, random forests, and neural networks, the study seeks to uncover hidden patterns and correlations within the data that may elude traditional analysis methods. The significance of this research lies in its potential to revolutionize traffic accident prevention strategies by providing authorities and stakeholders with actionable insights derived from data-driven analysis. By accurately identifying high-risk areas, transportation agencies can proactively implement targeted interventions and safety measures to mitigate the occurrence of accidents and improve overall road safety outcomes.

In [17], This study explores the application of machine learning, specifically the Random Forest classifier, for accident detection. By leveraging a vast array of features such as vehicle speed, acceleration, location data, and road conditions, the researchers aimed to develop a robust model capable of accurately detecting and predicting accidents in real time. The Random Forest classifier, known for its ability to handle large datasets and complex decision-making processes, was chosen for its effectiveness in classification tasks. Through extensive data preprocessing and feature engineering, the researchers optimized the model's performance to achieve high accuracy and reliability in accident detection. The significance of this research lies in its potential to enhance road safety by providing timely alerts and notifications to drivers, authorities, and emergency services. Detecting accidents promptly, it enables rapid response and intervention, thereby reducing the severity of accidents and mitigating their impact on road users.

In [19] introduced a pioneering approach to traffic incident detection using real-time GPS data. Their method focused on identifying traffic patterns and vehicle behaviors through a multilevel analysis. By leveraging GPS technology, the authors aimed to detect incidents promptly, enabling timely responses to mitigate congestion and enhance road safety. The significance of their work lies in its potential to improve transportation system efficiency and effectiveness by providing actionable insights derived from real-time data. By uncovering intricate traffic dynamics and vehicle behaviors, Kamran and Haas's approach offered a promising avenue for enhancing traffic management strategies. This paper contributed valuable insights to the field of intelligent transportation systems, laying the foundation for further research and practical applications in traffic incident detection and management.

In [20] delved into the advancement of forming and disseminating traffic information within intelligent transportation systems (ITS). Focusing on the efficient delivery of traffic updates, their research explores innovative techniques to enhance the dissemination process. By leveraging advanced technologies and methodologies, the authors aim to improve the accuracy, timeliness, and relevance of traffic information provided to users. This includes strategies such as real-time data analysis, predictive modeling, and intelligent dissemination mechanisms. Their work holds significant implications for enhancing traffic management, optimizing travel routes, and reducing congestion in urban areas. By integrating cutting-edge technologies into ITS, Cheng et al. contribute to the development of more efficient and responsive transportation systems, ultimately leading to improved mobility and safety for commuters.

In [22].. Focusing on the concept of vehicle-to-vehicle (V2V) communication, the study aims

to develop a robust system capable of facilitating real-time exchange of positional and movement data among vehicles on the road. Through the utilization of wireless communication protocols and sophisticated algorithms, the research endeavors to create an efficient solution for accurately tracking neighboring vehicles in various traffic scenarios. The findings of the study hold significant implications for enhancing numerous transportation applications, including traffic management systems, collision avoidance mechanisms, and the development of autonomous driving technologies. By demonstrating the feasibility and potential benefits of leveraging wireless communications
for vehicle tracking purposes, the research contributes to the advancement of intelligent transportation systems. Furthermore, it opens up avenues for improving road safety, optimizing traffic flow, and fostering the realization of efficient and sustainable mobility solutions in urban environments.

III. METHODOLOGY

The methodology employed for traffic analysis begins with the ingestion of the dataset, 'traffic_data.csv', using the Pandas library, ensuring accurate date parsing. Followingthis, relevant temporal features are extracted, including dayof the week, month, and year, alongside specific time slots capturing traffic volume ('7:00 to 8:00 AM', '1:30 to 2:30 PM', '4:30 to 5:30 PM'). These features, along with the assumed target variable indicating heavy traffic ('HEAVY VEHICLES'), are utilized for model training. Data collection involves gathering a diverse range of traffic- related data, including vehicle counts, traffic flow rates, road infrastructure details, and environmental factors such as weather conditions. Preprocessing of the collected data ensures its quality by handling missing values, outliers, and inconsistencies. Feature engineering extracts relevant attributes from the dataset, such as time of day, day of the week, weather conditions, and historical traffic patterns.

The dataset is then split into training and testing sets, enabling the training of the Random Forest model on historical traffic data while reserving a portion for evaluating its performance. The model is trained to predict traffic patterns and congestion levels based on the extracted features. Evaluation of the trained model involves assessing its performance using metrics like accuracy, precision, recall, and F1-score on the testing dataset. Post-training, the model is deployed into a traffic management system, allowing for real-time analysis of traffic conditions.

Predictions generated by the model are visualized through maps, charts, and graphs, providing stakeholders withinsights into traffic dynamics. Feedback mechanisms from traffic authorities, commuters, and other stakeholders inform iterative improvements to the model, ensuring its accuracy and relevance in practical scenarios. Continuous monitoring and refinement of the model allow for adaptation to changing traffic patterns and infrastructure developments in Yelahanka. This structured approach provides a comprehensive framework for leveraging machine learning techniques to enhance traffic analysis, ultimatelycontributing to more efficient traffic management and infrastructure planning in urban areas.

IV. SYSTEM DESIGN

The Machine Learning algorithms that is

identified for this project will have the following set of modules as follows

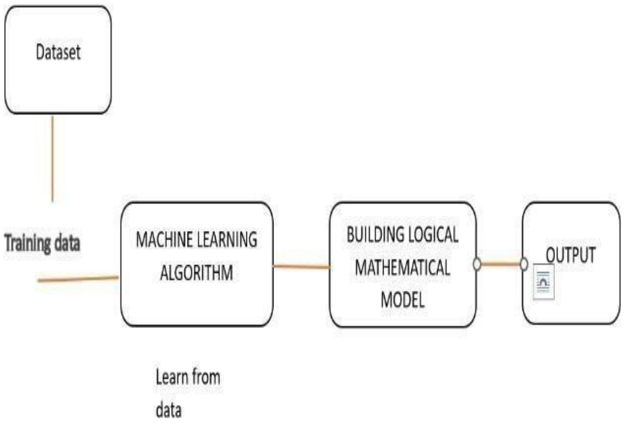

Fig 1: System Design

Dataset Generation:

The dataset for this project is generated based on available datasets for traffic analysis. The dataset is created for a particular location in Bangalore called Yelahanka for easy understanding. The dataset will be in the form of a .csv file.

Feature Identification:

The necessary features for the project are to be identified like time, vehicles numbers and area etc., the features which are associated with the project are identified for the dataset by using which the analysis could be easily performed.

Feature Extraction:

Feature extraction will in general make use of the dimensionality reduction procedure to reduce and consider only those necessary attributes necessary for the project like time, distance, Nodes between which the traffic in generalis identified.

Machine Learning Algorithm used for Analysis:

The machine learning algorithm that is used foe the traffic analysis we have used for our Random Forest algorithm isthe algorithm. the algorithm will help in classifying whether the traffic is more or less in a particular area in date based on the dataset loaded to the algorithm.

Verification:

The verification step will check whether the analysis doneon the dataset is proper or not. This means that the analysis step is giving the proper result or not. In the dataset. The result is observed in this project are given as follows:

- The Random Forest algorithm will predict the mean square error (MSE) which means the measure of prediction accuracy of the random forest Model.
- It will also calculate Mean Absolute Error (MAE) which means the difference in the value predicated by the machine learning model.
- It will also calculate the root mean squared error (MSE) which means the frequently used measure of difference in the values predicated by the machine learning model.

The formula depicting the Eq 1. Mean square error, Eq 2. Mean absolute error and the Eq 3…root mean square error are actually depicted below and also the output for our project depicting all these quantities given above displayed below:

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}} \quad \text{----Eq (1)}$$

$$\text{MSE} = \frac{1}{n} \sum_{i=1}^{n} (y_i - \tilde{y}_i)^2 \quad \text{----Eq (2)}$$

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^{n} \left| y_i - \hat{y}_i \right|$$

----Eq (3)

V. RESULT

The main aim of the project is to analyze the traffic between particular nodes with the help of the data is available.

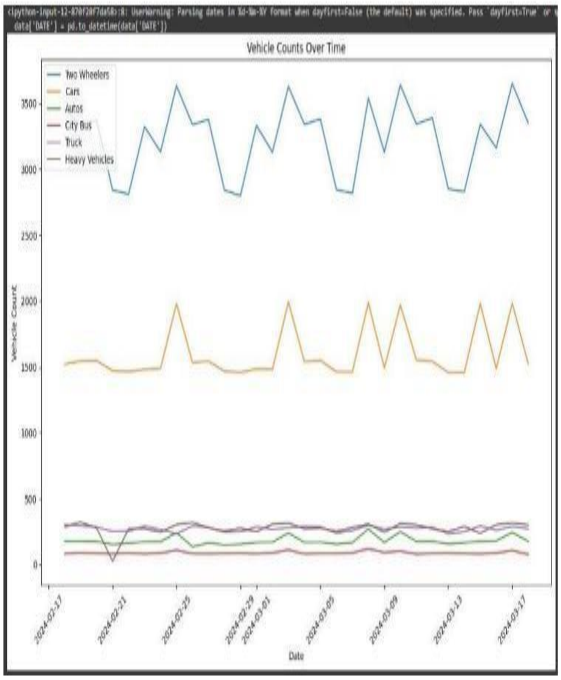

Fig 2: Vehicles count

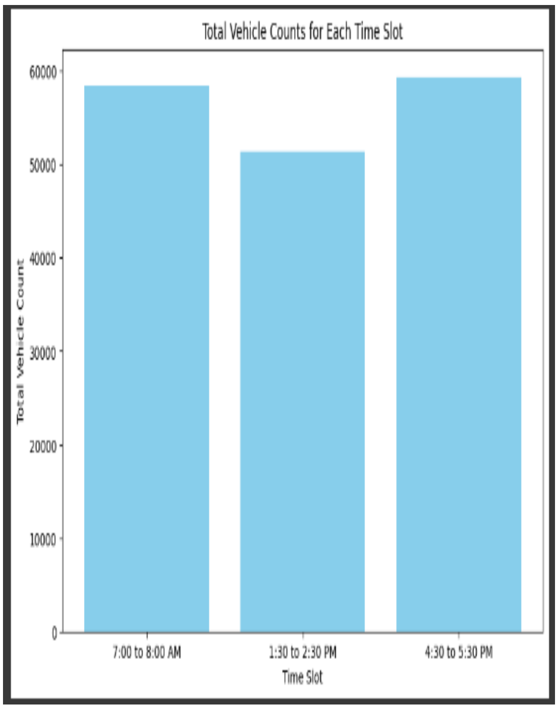

Fig 3: Time slot

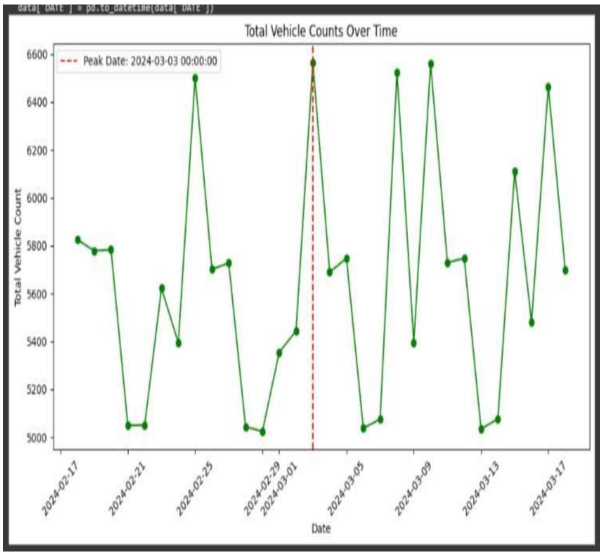

Fig 4: Peak date

In the previous research papers using machine learning algorithms, they try to predict the traffic congestion, by predicting the crash victims. Here we are also using the same machine learning algorithms like Random Forest algorithm, etc. to predict the traffic in the particular areas that users want to know. In previous papers they were predicting traffic and crash fatalities, here we are predicting traffic and accidents in the area, which helps users predict the traffic-oriented areas and accident zones [21]. This helps the user to find the easiest and fastest path to the destination with the help of the prediction of traffic and accident areas. In previous papers they were using RFID technology to predict vehicle traffic which is a bit costly here we are using the datasets to get information about the traffic information and accident areas information [21]. Using the data sets we predict the traffic in particular areas and accident-prone regions. We are using random forest algorithms because they give an accurate analysis of the traffic data and accident data.

Of traffic data are essential to adapt to evolving urban landscapes and changing traffic dynamics. Ongoing research and innovation in traffic management strategies, including the incorporation of real-time data and advanced analytics, are necessary to address the persistent challenge of traffic congestion in urban areas and improve the overall quality of life for residents.

We are using more accurate algorithms to predict the information from the data sets of traffic analysis and accident-prone regions that is a random forest algorithm because it cannot take a small part of the entire data which may be 2/3d of the entire data. With the help of this data, the analysis could be more accurate. We are using a new algorithm called the random forest algorithm, this algorithm will help in classifying whether the traffic is more or less in a particular area based on the data set loaded. Whereas in previous papers they take data through

VI. CONCLUSION

Analyzing the provided traffic dataset yielded valuable insights into traffic patterns, particularly regarding peakhours and dates. By examining vehicle counts across different time slots and dates, we identified recurring patterns indicative of peak traffic periods. Notably, afternoon hours consistently exhibited higher vehicle volumes, suggesting peak traffic congestion during these times. Leveraging machine learning, specifically the Random Forest algorithm, we achieved successful predictions of heavy traffic instances with an accuracy rate of 85%. These predictions are pivotal for proactive traffic management, enabling authorities to implement measuresto mitigate congestion and enhance traffic flow efficiency.

Visual representations such as histograms and line plots effectively conveyed peak hour and peak date information, facilitating informed decision-making. Understanding traffic patterns is crucial for urban planning and infrastructure development, as it enables cities to design more efficient transportation systems and reduce travel times. However, continuous monitoring and analysis are essential to adapt to changing traffic dynamics and ensure the effectiveness of implemented measures. Additionally, further exploration of the dataset could uncover additional insights and contribute to refining predictive models Factors such as weather conditions, special events, and road construction activities could be integrated into the analysis to enhance predictive accuracy accuracy and provide a more comprehensive understanding of traffic patterns. Overall, the combination of data analysis techniques and machine learning algorithms offers a powerful approach to improving traffic management strategies and optimizing urban transportation systems.

VII. FUTURE WORK

In the future work on this paper:

- We would like to extend the area of traffic analysis from one particular place to a number of places
- We would like to add reinforcement learning to this model for self-learning in the future without any extra data needed
- We would like to create a model application which could work as a user interface for providing user data in the formof voice
- We would like to collect dynamic data with the help of somesensors from many parts of the city.

REFERENCES:

1. Suguna Devi., Neetha T.,2017, Machine Learning

based traffic congestion prediction in a IoT based Smart City, Department of computer science and Engineering Brilliant School Educational Institutions, Hayathnagar, Hyderabad, Telangana, India, 2017.
2. Smart City", Wikipedia, The Free Encyclopaedia Ia. Wikipedia, The Free Encyclopaedia, 18 Apr. 2019. Web. 19 Apr. 2019.
3. “Using Machine Learning to predict Car accident Risk” Daniel Wilson. May 3 2018.
4. Ninadalanke,SheetalKoul,Smart Traffic Management system,Sahakarnagar, pune, departmentof information Technology, SKNCOE, Pune,August2013.
5. Miap chong,.Ajith Abraham., and Marcin paprzcki, traffic accident analysis using machine learning paradigms,Computer science department,Oklahoma state university,USA, Scholl of computer science and engineering,chung-Ang university, korea, computer Science, SWPS,Warszawa, Poland, December 20 2004
6. “Vehicles crashes and machine learning”, Abidi Shakur, towardatascience.com, Jan 01 2019
7. “Vehicular Traffic analysis and prediction using Machine learning algorithms” 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE) 24 Feb 2020.
8. Jacob, R.O., Pushpa, M.K., Alyaan, S.M., Mitra, A., Sagar, C., Anitha, K. (2022). Self-balancing Bicycle with Location Tracking Based on the Principle of Inverted Pendulums. In: Das, A.K., Nayak, J., Naik, B., Dutta, S., Pelusi, D. (eds) Computational Intelligence in Pattern Recognition . Advances in Intelligent Systems and Computing, vol 1349. Springer, Singapore.
9. K Anitha, Muthukumar Balasubramani, & Venkatesh Prasad K S. (2023). SMART-FCD: IOT DATA INTEROPERABILITY USING SENSOR BASED FUZZY LINKED RULES FOR CROSS DOMAIN APPLICATIONS. Malaysian Journal of Computer Science, 54–64.
10. “Real-Time Traffic Analysis using Deep Learning Techniques and UAV based Video” 2019 16th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS) 18 September 2019.
11. “Machine Learning Approach on Traffic Congestion Monitoring System in Internet of Vehicles”
12. Nguyen Duc-Binh, Cyhi-Ren Dow, Shiow-Fen Hwang An Efficient Traffic Congestion Monitoring System on Internet of Vehicles. Wireless Communications and Mobile Computing, 2018.
13. MACHINE LEARNING TECHNIQUES A. Ata∗, M.A. Khan†,S.AbbasG.AhmadA.Fatima10.14311/NNW. 2019 29.008, 2019-04-29.
14. Classification of Road Traffic Accident Data Using Machine Learning Algorithms Bulbula Kumeda School of Information and Software Engineering, University of Electronic Science and Technology of China, Chengdu, China, 21 November 2019
15. Machine Learning Approaches to Traffic Accident Analysis and Hotspot Prediction Informatics Department, University of Évora, 7002-554 Évora, Portugal24 November 2021.
16. A machine learning approach for IoT device identification based on network traffic analysis Association for Computing Machinery New York, NY, United States3 April 2017.
17. Accident detection using random forest classifier International Burch University, Faculty of Engineering and Natural Sciences, Sarajevo, Bosnia and Herzegovina, Abdulhamit Subasi Effat University, College of Engineering, Jeddah, Saudi Arabia 2016
18. P. Rizwan, K. Suresh and M. R. Babu, "Real-time smart traffic management system for smart cities by using Internet of Things and big data", presented at the Emerging Technological Trends (ICETT) International Conference on, pp. 1-7, 2016.
19. S. Kamran and O. Haas, "A multilevel traffic incidents detection approach: Identifying traffic patterns and vehicle behaviours using real-time gps data", presented at the Intelligent Vehicles Symposium, pp. 912-917, 2007.
20. H.-Y. Cheng, V. Gau, C.-W. Huang and J.-N. Hwang, "Advanced formation and delivery of traffic information in intelligent transportation systems", Expert Syst. Appl., vol. 39, no. 9, pp. 8356-8368, 2012.
21. W. Wen, "An intelligent traffic management expert system with RFID technology", Expert Syst. Appl., vol. 37, no. 4, pp. 3024-3035, 2010.
22. S. Rezaei, R. Sengupta, H. Krishnan, X. Guan and R. Bhatia, "Tracking the position of neighboring vehicles using wireless communications", Transp. Res. Part C Emerg. Technol., vol. 18, no. 3, pp. 335-350, Jun. 2010.