An Efficient and Intelligent System for Controlling the Speed of Vehicle using Fuzzy Logic and Deep Learning

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***Abstract*—Vehicle collisions are a significant problem worldwide, causing injuries, fatalities, and property damage. There are several reasons for the collapse of vehicles such as rash driving, over speeding, less driving skills, increasing number of vehicles, drunk and drive, etc. However, over speeding is one of the critical factors out of all the reasons for vehicle collisions. To address the critical issues, the current article proposes a Fuzzy-based algorithm to prevent and control the speed of the vehicle. The major objective of the proposed system is to control the speed of the vehicle for proactive collision avoidance. Deep learning and fuzzy system provide better integrated approach for the controlling of the speed and avoid vehicle collision. Fuzzification of the speed variable provides an advanced or viable solution for speed control. The current research used RNN and other deep learning algorithm to predict the traffic and identify the traffic frequency. The traffic frequency in a time-series frame provides the frequency of the traffic within a time frame that can be detected by using involvement of IoT.**

Keywords—Speed control; fuzzy logics; deep learning; decision making; collision avoidance

I. INTRODUCTION

Vehicle collisions, often referred to as traffic accidents or crashes, have significant social, economic, and public health implications. Vehicle collisions are a significant problem worldwide, causing injuries, fatalities, and property damage. Most vehicle collisions are caused by human error, including distracted driving, impaired driving (e.g., alcohol or drugs), speeding, and reckless driving. Adverse weather conditions such as rain, snow, ice, and fog can increase the risk of collisions, as can poorly maintained roads. This is one of the major reasons for the vehicle collision and accidents [1]. Mechanical failures, such as brake or tire problems, can lead to accidents. And problems at intersections, junctions, improper signaling, and traffic congestion can contribute to collisions. Vehicle collisions are a leading cause of death worldwide, particularly among young people aged 15 to 29. The World Health Organization (WHO) estimated that approximately 1.35 million people died in road traffic accidents globally in 2018 [2].

Vehicle collisions incur significant financial implications, such as missed productivity, medical expenditures, property damage, and legal fees. According to the National Highway Traffic Safety Administration (NHTSA), motor vehicle accidents cost the US economy more than $242 billion in 2010 [3]. Vehicle collisions cause a significant number of injuries and fatalities each year. These injuries range from minor to severe, leading to long-term disabilities in some cases. In 2019, the United States reported over 38,800 fatalities in motor vehicle crashes, according to the NHTSA.

Advanced driver assistance systems (ADAS) and vehicle safety technologies have shown promise in reducing the severity of collisions and preventing accidents. These include features like automatic emergency braking, lane departure warning, and adaptive cruise control. Vehicular Ad-Hoc Networks (VANETs) can also prevent or minimized the vehicle collisions. VANETs are wireless communication networks that enable vehicles to exchange information with each other and with infrastructure components like traffic lights and road signs [4]. VANETs enable communication between vehicles and roadside infrastructure through wireless communication. Each vehicle in the network is equipped with onboard units (OBUs) that can transmit and receive data. VANETs can facilitate real-time exchange of information such as vehicle speed, position, direction, and emergency warnings [5]. Here are several ways VANETs can help improve road safety and reduce vehicle collisions:

1) Collision avoidance systems: VANETs can enable vehicles to communicate with each other in real-time, sharing information about their speed, location, and direction. Collision avoidance systems can use this information to alert drivers or even automatically take control of the vehicle to prevent collisions. For example, if a vehicle suddenly brakes or encounters an obstacle, it can send a warning message to nearby vehicles, allowing them to react and avoid a collision.

2) Intersection management: VANETs can help manage traffic flow at intersections more efficiently. Vehicles can communicate their intended routes and timing at intersections. Traffic signals can adjust their timing based on real-time traffic information to minimize congestion and reduce the likelihood of collisions.

3) Emergency vehicle warning systems: Emergency vehicles equipped with VANET technology can broadcast their status and location to surrounding vehicles. Nearby vehicles can receive warnings and move out of the way, reducing the risk of collisions with emergency vehicles.

4) Pedestrian safety: VANETs can be used to improve pedestrian safety. For example, smartphones or wearable devices carried by pedestrians can communicate with vehicles, making drivers aware of pedestrians' presence even when they are not in the line of sight. Crosswalks can be equipped with VANET infrastructure to signal to vehicles when pedestrians are about to cross.

5) Road condition alerts: VANETs can provide real-time information about road conditions, such as icy roads, potholes, or flooding. Vehicles can receive these alerts and adjust their speed and driving behavior accordingly to avoid accidents caused by adverse road conditions.

6) Driver assistance systems: VANETs can complement existing driver assistance systems by providing additional data from surrounding vehicles. For example, adaptive cruise control systems can use VANET data to maintain safe distances between vehicles in congested traffic.

7) Traffic management and congestion reduction: VANETs can help reduce traffic congestion by providing real-time traffic information to drivers, allowing them to choose less congested routes. This can prevent situations where heavy traffic leads to rear-end collisions and other accidents.

8) Data collection and analysis: VANETs collect vast amounts of data about vehicle movements and traffic conditions. This data can be analyzed to identify accident-prone areas and develop targeted safety improvements.

9) Security and privacy considerations: Implementing VANETs requires robust security measures to protect the integrity and privacy of communication. Encryption and authentication mechanisms are essential to ensure that malicious actors cannot interfere with VANET communication.

It is important that the successful implementation of VANETs for collision prevention requires coordination among vehicle manufacturers, infrastructure providers, and government agencies [6]. Additionally, public awareness and acceptance of these technologies play a very important role for the prevention of vehicle collision. Rather than VANET, fuzzy Logics are utilized to prevent vehicle collisions involves creating a decision-making system that assesses the risk of collision based on various input parameters and takes appropriate actions to avoid or mitigate the collision [7]. Here is a step-by-step guide on how to implement a collision prevention system using Fuzzy Logic:

1) Identify input parameters: Determine the input parameters that are relevant for assessing collision risk. These parameters could include:

- Distance to the vehicle in front.
- Relative speed with respect to the vehicle in front.
- Lane change intentions of nearby vehicles.
- Road conditions (e.g., wet, slippery).
- Driver reaction time.
- Braking distance.
- Vehicle acceleration.
- Traffic density.

2) Define fuzzy sets: Create fuzzy sets for each input parameter. Fuzzy sets represent the linguistic terms used to describe these parameters. For example:

- Distance: Very Close, Close, Moderate, Far, Very Far
- Relative Speed: High, Moderate, Low
- Lane Change Intentions: Aggressive, Cautious, None
- Road Conditions: Slippery, Normal

3) Membership functions and fuzzy rules: Assign membership functions to each fuzzy set. Membership functions define how each input value belongs to the fuzzy sets. These functions can be triangular, trapezoidal, or Gaussian, depending on the shape of the data distribution. Define a set of fuzzy rules that describe how the inputs relate to the output, which is the "collision risk." For example: If distance is very close or relative speed is high and lane change intentions are aggressive, then collision risk is High.

4) Fuzzy inference system: Implement a Fuzzy Inference System (FIS) that processes the fuzzy rules and input values to determine the collision risk level. Common methods for combining fuzzy rules include the Mamdani or Sugeno models.

5) Defuzzification: Convert the fuzzy output (e.g., "High," "Moderate," "Low") into a crisp value that represents the actual collision risk level. Methods like centroid or weighted average are used for defuzzification.

6) Set thresholds: Establish threshold values for the collision risk levels. For example, you may define a "High" risk threshold that triggers collision avoidance actions.

7) Decision and actions: Based on the determined collision risk level and predefined thresholds, the system should decide on appropriate actions to prevent collisions. These actions may include:

- Visual and audible warnings to the driver.
- Activating automatic emergency braking systems.
- Steering interventions.
- Adjusting vehicle speed or acceleration.

8) Testing and validation: Rigorously test and validate the fuzzy logic-based collision prevention system under various conditions to ensure its effectiveness and safety. Integrate the fuzzy logic-based collision prevention system into vehicles or traffic management infrastructure as needed. Continuously collect data and update the fuzzy logic system to improve its accuracy and adapt to changing road conditions and traffic patterns. Ensure that the system complies with all relevant regulatory standards and safety requirements.

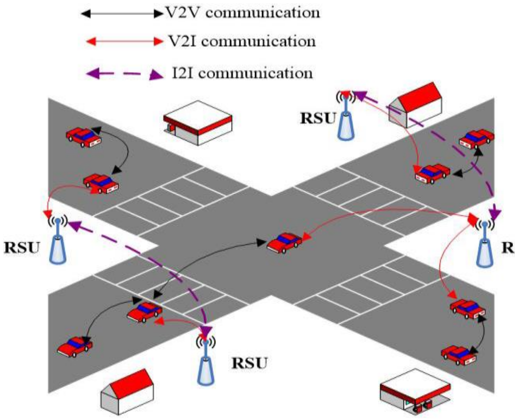

Fig. 1. Communication diagram for VANET.

Fig. 1 shows the schematic diagram of the communication among vehicle to vehicle, vehicle to infrastructure, and infrastructure to infrastructure. Some road-side units (RSU) have been placed for providing the direct communication between vehicles and infrastructure [8]. This communication can prevent the vehicle collision and able to control the speed of the vehicle based. Controlling vehicle speed offers numerous advantages in terms of safety, fuel efficiency, environmental impact, and overall road network efficiency. Here are some key advantages of controlling vehicle speed:

- Improved Road Safety: Reduced speed leads to shorter stopping distances, allowing drivers more time to react to unexpected situations and avoid collisions. Lower speed reduces the severity of accidents and the risk of fatalities and injuries in the event of a crash.
- Reduced Traffic Congestion: Maintaining a consistent and appropriate speed helps to smooth traffic flow and reduce congestion. Traffic jams caused by abrupt stops and starts are less likely when drivers adhere to speed limits.
- Lower Fuel Consumption: Vehicles tend to be most fuel-efficient at moderate speeds. Lowering speed reduces fuel consumption and greenhouse gas emissions. Slower speeds can lead to better fuel economy, saving drivers money and reducing the environmental impact of transportation.
- Noise Reduction: Lower speeds result in quieter traffic, reducing noise pollution in residential areas and along roadways. Quieter vehicles contribute to improved quality of life for nearby residents.
- Extended Vehicle Lifespan: Driving at lower speeds puts less stress on a vehicle's components, leading to less wear and tear and potentially extending the lifespan of the vehicle.
- Enhanced Pedestrian and Cyclist Safety: Slower vehicles are less likely to cause severe injuries to pedestrians and cyclists in the event of a collision. Reduced speed allows drivers to better detect and respond to vulnerable road users.
- Improved Air Quality: Lower-speed driving typically results in reduced emissions of pollutants, which can lead to improved air quality in urban areas. Reduced emissions contribute to better public health outcomes.
- Increased Reaction Time: Lower speeds give drivers more time to react to unexpected events, such as sudden braking or the emergence of a hazard in the roadway.
- Enhanced Driver Comfort: Maintaining a reasonable and consistent speed can lead to a more comfortable and less stressful driving experience.
- Compliance with Legal Requirements: Adhering to posted speed limits and regulations helps drivers avoid fines and legal consequences. It promotes a culture of safety and respect for traffic laws.
- Reduced Severity of Accidents: In the event of a collision, lower-speed impacts are generally less severe, leading to fewer fatalities and less damage to vehicles and infrastructure.
- Improved Predictability: Consistent speed among vehicles on the road makes it easier for drivers to anticipate the behaviour of other road users, reducing the likelihood of accidents.

Controlling the speed of a vehicle using Fuzzy Logic is a complex but effective approach that leverages fuzzy sets and rules to achieve smooth and adaptive speed control. The controlling the speed of a vehicle using Fuzzy Logic involves defining linguistic variables and fuzzy sets, creating a rule base, and using adaptive control to make speed adjustments based on real-time inputs [9]. This approach is valued for its ability to handle complex and uncertain systems while providing smooth and human-like control of vehicle speed. Additionally, the system can initiate automatic emergency braking systems, adjust vehicle speed, and coordinate with traffic management systems to optimize traffic flow and prevent congestion. The major objectives of the current article are as follows:

- To propose a fuzzy based mechanism involves developing a controller that can adjust a vehicle's speed based on inputs and conditions in a manner that is consistent with human-like decision-making.
- The system is effective in real-time scenario and able to analyze the risk assessment during travel.
- The proposed system can collect the data from vehicles and analyze the data for decision-making.
- The system prioritizes the most critical situations.

The remainder of the essay is structured as follows. Section II presents past work conducted by several researchers. Section III provides a proposed system with fuzzy logic and deep learning algorithms. Section IV explains about the dataset used to analyze the speed of the vehicle. Section V shows the experimental results and discussion about the outcomes generated. Conclusion of the paper discussed in the Section VI.

II. LITERATURE REVIEW

There are several research has been conducted for the detection and identification of collisions of road accidents. IoT and machine learning approaches are combined in the smart vehicle collision prevention system that Yu et al. [10] presented. The technology uses roadside infrastructure and sensors built into cars to gather data about the surroundings in real-time. In order to analyze the data and forecast potential collision scenarios, machine learning algorithms are used. The system provides timely alerts and warnings to drivers, and in critical situations, it automatically activates emergency braking systems to prevent collisions [11].

W. Yang [12] clarified a system for Li-Fi-based information transfer in the VANET in 2017. This method of information gathering and gearbox for vehicle conditions was introduced. Less research has been done on Li-Fi, which is a more recent topic. Framework developed an IOT system with a vast array of communication vehicles. The organisation of virtual machines completed the dissemination of information. The current major challenges are to the usage of transmission capacity and the postponement of information handling. The driving goal acknowledgment module initially controlled the front vehicle's driving objective. Second, via vehicle-to-vehicle (V2V) communication, the front vehicle transmits its driving intention and other driving boundaries to the following vehicle. The proper admonition pace of the proposed framework, according to the results of the reproduction test, was 97.67%, which was 6.34% greater than that of the framework with a fixed chance to crash (TTC) edge. The suggested framework proved effective for providing the accompanying vehicle with early notification in a variety of front vehicle operating states.

O. Heety et al. [13] introduced a comprehensive audit of past works by ordering them dependent on dependent on remote correspondence, especially VANET. In ITS for-information security, an RC5 encryption method was introduced. Quartus Prime was used to the RC5 recreation. The primary function was to ensure that it would function with the ITS framework and the FPGA framework for the protection of customer data. Additionally, this paper included a detailed analysis of the unresolved problems and test results obtained while integrating the VANET with SDN.

By suggesting a V2V conspiracy that can locate vehicle clients in the natural world, V. Singhal et al. [14] introduced the utilisation of significant resources is successfully lessened in an LTE arrangement. The suggested solution eliminates a significant portion of V2V traffic disclosure and management, which primarily involves cars and travellers in VANET. The focus of the investigation is on collisions between street vehicles and trains at railway level automated crossings on single-line rail-street segments. Another investigation goal is to determine how using different risk factors may affect predicted danger factors in order to reduce the risk of street vehicle-train collisions at crossings.

J. Huang et al. [15] introduced a combination control system of adaptive cruise control (ACC) and collision avoidance (CA), which considers a driver's social style. First, a survey was conducted to identify the different types of drivers. The relevant driving social data were then collected through driving test system tests, serving as the format data for the online ID of each driver type. It developed a new technology integrating an IoT network of distant devices with an Intelligent Transport technology that was sent in accordance with the benchmarks released by ETSI inside the Technical Committee on ITS. A correspondence message structure based on auto ontologies, the SAE J2735 message set, and the serious explorer data framework events mapping that links to the social diagram was introduced by K. Alam et al. in study [16]. Finally, we provide usage details and test results to demonstrate the practicality of the suggested framework and to include various application scenarios for various customer groups.

According to D. Asljung et al. [17], the choice of this danger measure has a substantial impact on the conclusions generated from the data. This tactic can be applied to validate the security of a vehicle with the right precautions. All of this while maintaining a high level of legitimacy and a low level of information requirement compared to cutting-edge factual tactics. A model-based computation was presented by M. Brännström et al. [18] to determine how the driver of a vehicle can regulate, brake, or accelerate to avoid colliding with a subjective object. In this computation, a straight vehicle model was used to represent the vehicle's motion, and a square shape was used to represent the vehicle's edge. The item's assessed border was represented by a polygon that was allowed to alter in size, shape, location, and orientation under test conditions.

M. Earthy et al. [19] introduced a plan and trial approval of a nonlinear model prescient regulator that is fit for taking care of these mind-boggling circumstances. Via cautiously choosing the vehicle model and numerical encodings of the vehicle and snags, we empower the regulator to rapidly figure inputs while keeping up a precise model of the vehicle's movement and its vicinity to deterrents. T. Butt et al. [20] looked at a variety of perspectives, including the protection of an individual, conduct and activity, correspondence, information and picture, thoughts and emotions, area and space, and affiliation, to examine the protection issues and factors that are fundamental to consider for maintaining security in SIoV conditions. In addition, the study discusses the square chain-based solutions for saving security for SIoV. The Social Internet of Vehicle (SIoV) is one application of SIoT in the automotive sector that has contributed to the development of the present intelligent vehicle framework (ITS).

Y. Chen et al. [21] proposed an agreeable driving methodology for the associated vehicles by coordinating vehicle speed forecast, movement arranging, and powerful fluffy way following control. The framework vulnerabilities are considered to upgrade the collaboration between the self-ruling vehicle and the close by vehicle. With the driving data got from the associated vehicles method, the repetitive neural organization is utilized to anticipate the close by vehicle speed. The literature work can be explained in terms of the Table 1.

TABLE I. KEY FACTORS OF THE LITERATURE

References	Author & Year	Input Features	Methodology	Output
[10]	Yu et al. (2018)	The design is implemented by using four motors and single speed transformation.	4-IWD electric racing cars are investigated by using GDYNOPT an optimal control software package.	Optimal racing lines, suspension, and steering wheel angles.
[11]	Mateichyk et al. (2023)	Parameters related to energy and connections between system inputs.	The Mamdani type and Sugeno type fuzzy derivation models were proposed based on logical derivation rules.	The Mamdani model provides the accuracy 98.8% with improved energy efficiency.
[12]	W. Yang et al. (2020)	In V2V communication, the front vehicle transmits its driving intention and other driving boundaries to the following vehicle.	The proposed module is integrated with two modules, FCW and driving intention recognition module to establish the V2V communication.	The timely warning ratio at the beginning of the braking is 93.3%.
[13]	O. Heety et al. (2020)	Quartus Prime was used to the RC5 recreation.	In ITS for-information security, an RC5 encryption method was introduced.	The test results obtained while integrating the VANET with SDN.
[14]	V. Singhal et al. (2020)	The considered only crossing data where vehicles cross the railway lines.	The investigation is on collisions between street vehicles and trains at railway level automated crossings on single-line rail-street segments.	It reduces the risk of street vehicle-train collisions at crossings.
[15]	J. Huang et al. (2020)	A survey was conducted to identify the relevant driving social data which is collected through driving test system tests.	It developed a new technology integrating an IoT network of distant devices with an ITS technology.	The results enhance the comfort and driver adaptability.
[16]	K. Alam et al. (2015)	They have utilized SIoV simulator for connectivity platform and recognized customized communication properties.	They mapped the VANET components in IoT-A model for better integration with social internet of vehicles (SIoV).	The workload model dynamic adapts the SIoV subsystem.
[17]	D. Asljung et al. (2017)	A large driving dataset is considered that contains around 250000 km driving data.	The process of finding the estimated distance between collision of vehicles was identified and threat measures are considered.	The collision data is considered such as BTN and TTC for the estimation of distance.
[18]	M. Brännström et al. (2010)	The computation used a vehicle model that was used to represent the vehicle's motion, and a square shape model represent the vehicle's edge.	A model was proposed to determine how the driver of a vehicle can regulate, brake, or accelerate to avoid colliding with a subjective object.	The shape, size, and location were identified under test conditions.
[19]	M. Earthy et al. (2020)	It takes figure inputs during vehicle's movement and its vicinity to deterrents.	They introduced a plan and trial approval of a nonlinear model prescient regulator that is fit for taking care of these circumstances.	The results showed the emergency double lane changer for finding out the longitudinal forces to avoid collision.
[20]	T. Butt et al. (2019(	The consideration of square chain-based solutions for saving security for SIoV as an input.	They looked at a variety of perspectives to examine the protection issues and factors that are fundamental to consider for maintaining security in SIoV conditions.	They recognized the ITS framework for SIoV and considered various aspects of security.
[21]	Y. Chen et al. (2020)	The driving data got from the associated vehicles method; the repetitive neural organization is utilized to anticipate the close by vehicle speed.	It proposed an agreeable driving methodology for the associated vehicles by coordinating vehicle speed forecast, movement arranging, and powerful fluffy way following control.	The framework vulnerabilities are considered to upgrade the collaboration between the self-ruling vehicle and the close by vehicle.

III. PROPOSED SYSTEM

The vehicle speed can be controlled by using a Fuzzy Logic system involves developing a controller that can adjust a vehicle's speed based on inputs and conditions in a manner that is consistent with human-like decision-making [22] [23]. Fig. 2 shows the proposed methodology of the system and described the data flow generated for the intelligent vehicles. Here's a proposed system for controlling vehicle speed using Fuzzy Logic:

1) Data collection and sensors: Equip the vehicle with sensors such as radar, lidar, cameras, and GPS to collect real-time data about the vehicle's surroundings and conditions. Data may include information on:

- Road conditions (e.g., wet, dry, icy).
- Traffic density.
- Vehicle speed.
- Distance to the vehicle in front.
- Lane markings.
- Weather conditions.
- Traffic signs and signals.

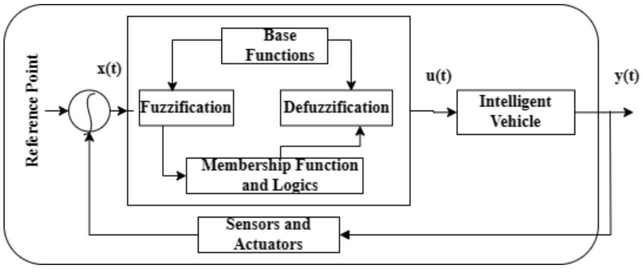

Fig. 2. Proposed methodology.

2) Fuzzy logic controller: Develop a Fuzzy Logic controller that takes the collected sensor data as inputs and calculates the optimal vehicle speed [24]. The controller consists of several components:

- Fuzzification: Convert the crisp sensor data into fuzzy variables using linguistic terms (e.g., "close," "moderate," "far").
- Fuzzy Rules: Define a set of fuzzy rules that capture the relationship between the input variables and the output (vehicle speed). These rules are often expressed in the form of "IF [antecedent] THEN [consequent]." For example:
- IF (Traffic is Heavy) AND (Distance to the Vehicle in Front is Short) THEN (Reduce Speed).
- Fuzzy Inference System: Implement the fuzzy inference system that combines the fuzzy rules and input data to determine the appropriate speed adjustments.
- Defuzzification: Convert the fuzzy output into a crisp value representing the recommended vehicle speed.

3) Speed adjustment algorithm: Develop an algorithm that takes the output from the Fuzzy Logic controller and adjusts the vehicle's speed accordingly. This may involve controlling the throttle, brakes, and transmission.

4) Real-time operation: Integrate the Fuzzy Logic controller into the vehicle's onboard computer or control system for real-time operation. The system continuously processes incoming sensor data and adjusts the vehicle's speed accordingly.

5) User interface: Create a user interface for drivers to interact with the system. Drivers may have the option to set speed preferences, override the system, or receive alerts and notifications.

6) Safety mechanisms: Implement safety mechanisms to ensure that the vehicle operates safely even in the presence of fuzzy logic errors or sensor failures. These mechanisms may include emergency braking systems and fail-safe procedures.

7) Testing and validation: Rigorously test and validate the system in controlled environments and under various real-world conditions to ensure safety and effectiveness.

8) Compliance with regulations: Ensure that the system complies with all relevant regulations and safety standards for autonomous and semi-autonomous vehicles.

9) Continuous improvement: Continuously collect data and monitor the system's performance. Use this data to fine-tune the Fuzzy Logic controller and improve speed adjustment decisions.

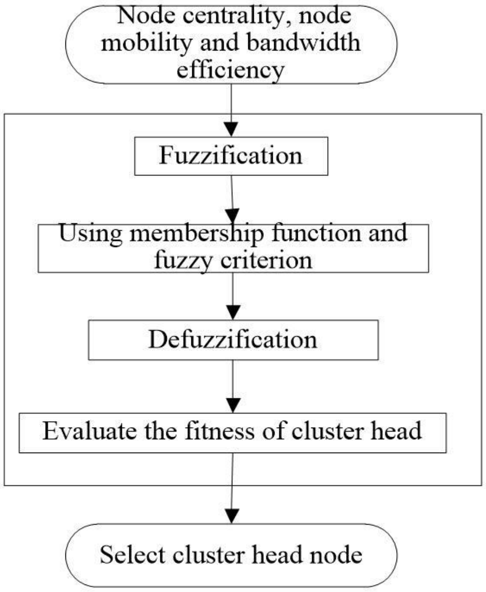

Fig. 3. Fuzzy-based data flow diagram.

Fig. 3 the fuzzy-based dataflow diagram with the set of steps used to find the cluster head node. There are several nodes available in the cluster of the vehicles and if it is stronger in terms of centrality C, then it performs more activity and can connects within a network [25]. The centrality of the cluster can be evaluated by using Eq. (1):

$$C_i(j) = \sum_{k=1}^{n} x_{i,k}(j) \tag{1}$$

where, $C_i(j)$ represents the centrality of the node i at any instance j, n is total number of nodes in a cluster and $x_{i,k}(j)$ is providing the mean value of the cluster nodes. To increase the precision of the centrality of the node can be identified with the given using Eq. (2):

$$C_i(j) = wC_i(j) + (1-w)C_i(j-t) \tag{2}$$

where, w varies with the node speed and represents the weight of the node, t represents the time factor. The fuzzy value for the input can be represented in terms of using Eq. (3):

$$C_{fuzzy-\,i}(j) = 1 - \frac{C_i}{n} \tag{3}$$

Node mobility refers to the ability of nodes (devices or entities) in a network, typically a wireless network, to change their physical positions or locations over time. Node mobility is a crucial aspect in various network types, including wireless ad hoc networks, mobile sensor networks, and vehicular networks. The node mobility can be found with the formula:

$$C_m = {}^{|x| - min_{y\varepsilon n}|y|}\Big/_{max_{y\varepsilon n}|y|} \tag{4}$$

where, x and y represent the mobility factors in x and y direction respectively and C_m indicates the mobility factor through which final velocity of the node can be identified.

IV. DATASET DESCRIPTION

In cities all throughout the world, traffic congestion is getting worse. Urban population growth, ageing infrastructure, improper and disorganised traffic signal timing, and a dearth of real-time data are all contributing issues [26]. The effects are substantial. According to INRIX, a provider of traffic data and analytics, commuters in the United States were forced to pay $305 billion in lost productivity, wasted fuel, and increased transportation costs because of traffic congestion in 2017 [27]. Cities must adopt innovative tactics and technologies to ease traffic because it is physically and financially impractical to build more highways. We choose the input data from a vehicle traffic dataset [28] with 48120 instances and four attributes (datetime, junction, vehicle, and ID).

The datetime attributes is utilized to observe the frequency of the vehicle in per minutes that pass through a road or the traffic volume. The dataset contains another attribute, named junction that contain the values of 4 distinct junctions. The vehicle attribute is providing the number of vehicles passes within an hour on a junction. Each vehicle is having unique ID that assigned by the unique number of entries. The traffic prediction dataset typically contains historical and real-time data related to traffic conditions, and it is used for developing models and algorithms to predict future traffic patterns [29] [30]. These datasets are valuable for various applications, including traffic management, route planning, prevention of vehicle collision, and urban development. There are several contributing factors play a role in this issue:

1) *Expanding urban populations:* Many cities are experiencing rapid population growth, leading to an increased number of vehicles on the road. This exacerbates congestion problems, especially during peak hours.

2) *Aging infrastructure:* In many cases, cities have infrastructure that was designed to accommodate much smaller populations. Aging roads, bridges, and public transit systems may struggle to handle the demands of modern urban life.

3) *Inefficient traffic signal timing:* Poorly synchronized traffic signals can cause unnecessary delays and exacerbate congestion. Timely and coordinated signal timing is crucial for optimizing traffic flow.

4) *Lack of real-time data:* Having access to real-time traffic data is vital for managing and mitigating congestion effectively. Without this data, city officials and commuters are left in the dark about current traffic conditions.

To address these challenges, cities are indeed exploring new strategies and technologies:

1) *Public transportation:* Investing in efficient public transportation systems can reduce the number of vehicles on the road and provide viable alternatives for commuters.

2) *Smart traffic management:* Implementing intelligent traffic management systems that use real-time data to optimize signal timing, reroute traffic, and provide information to commuters can help alleviate congestion.

3) *Ridesharing and carpooling:* Promoting ridesharing and carpooling can reduce the number of single-occupancy vehicles on the road.

4) *Congestion pricing:* Some cities have implemented congestion pricing, where vehicles are charged to enter certain congested areas during peak hours. This can incentivize commuters to use alternative transportation methods or travel during non-peak times [31].

5) *Urban planning:* Thoughtful urban planning that focuses on mixed land use, pedestrian-friendly designs, and bike infrastructure can reduce the need for car travel.

6) *Emerging Technologies:* Autonomous vehicles and connected vehicle systems hold the potential to reduce congestion by improving traffic flow and safety.

7) *Data analytics:* Utilizing data analytics and predictive modelling can help city planners and transportation agencies make informed decisions about traffic management.

In the next few diagrams, the dataset is explored in terms of distinct junction and the time series. Fig. 4 shows the training data at junction 1 for approximate one and half year. The training data indicates the increasing pattern in the frequency of traffic at junction1. Fig. 5 indicates the hourly traffic for 42 days in a time series.

Fig. 6, 7, 8, and 9 shows the vehicle frequency at junction 1, 2, 3, and 4 respectively. Figures shows a pattern that junction 1 and 2 is having higher vehicle frequency in compare to other junctions. Junction 4 is having very less frequency of the vehicles.

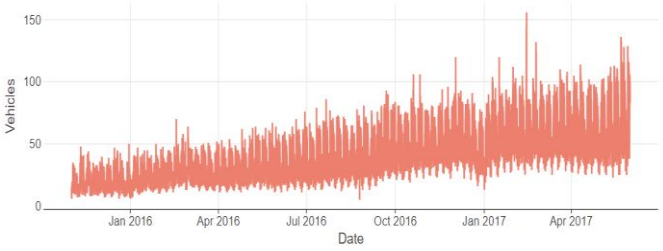

Fig. 4. Training data at junction 1.

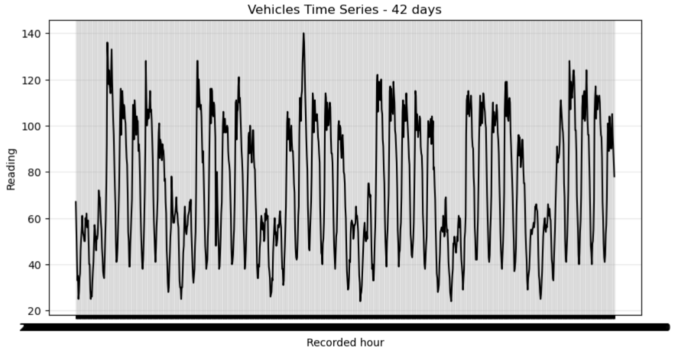

Fig. 5. Vehicle frequency time series for 42 days.

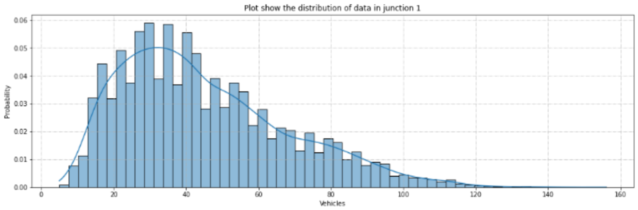

Fig. 6. Vehicle frequency time series at junction 1.

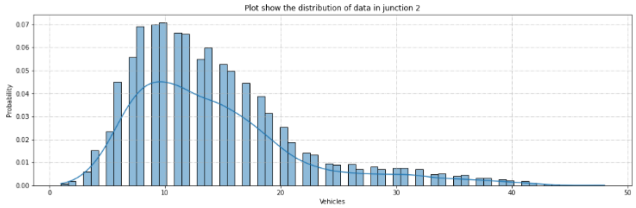

Fig. 7. Vehicle frequency time series at junction 2.

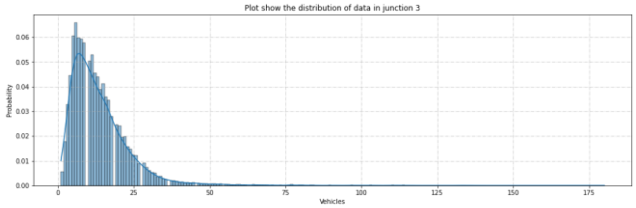

Fig. 8. Vehicle frequency time series at junction 3.

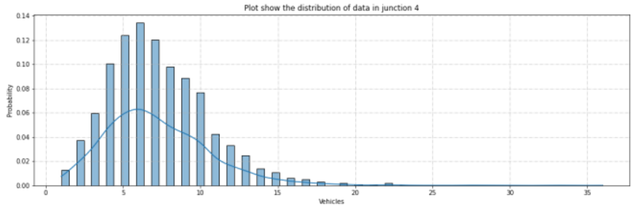

Fig. 9. Vehicle frequency time series at junction 4.

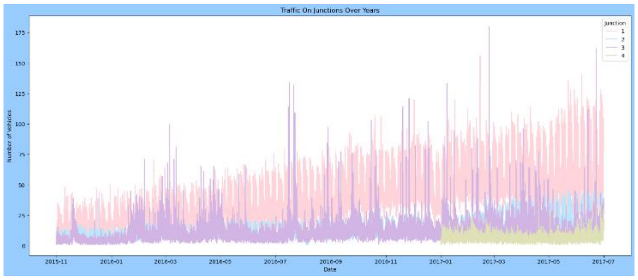

Fig. 10. Traffic position at junction.

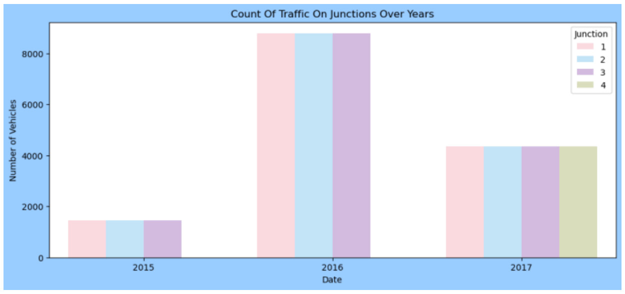

Fig. 11. Traffic count over years.

Fig. 10 shows the traffic positions and patterns for all junctions. Fig. 11 shows the traffic count for three years where 2016 shows the highest traffic in a year. Fig. 12 shows the co-relation among all attributes of the dataset.

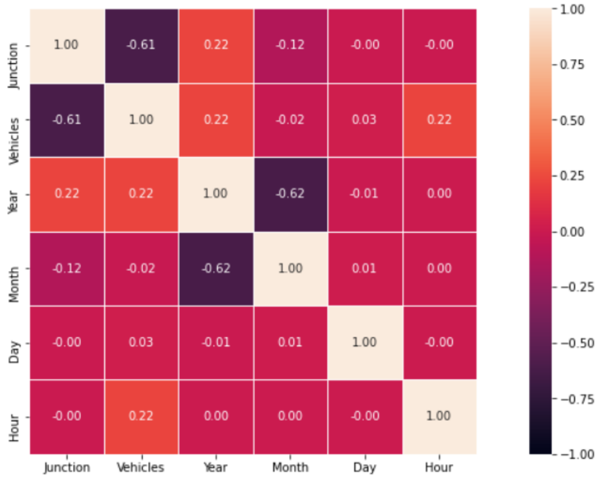

Fig. 12. Heatmap for the dataset attributes.

V. RESULTS AND DISCUSSION

The experimental results show the distinct parameters for predicted the traffic frequency and the speed control models. Fig. 13 and Fig. 14 show the results with recurrent neural network (RNN) before and after RNN predictions. The predicted series before RNN is very low and not able to make a pattern for the traffic data. While after applying RNN algorithm, the predicted data make a pattern out of it and establish a relation between initial series, target series, and predictions.

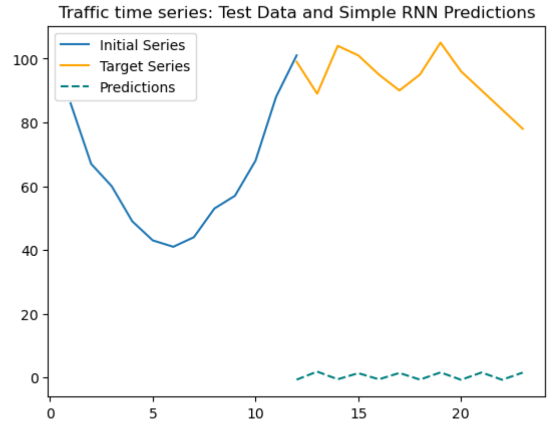

Fig. 13. Traffic data before RNN prediction.

Fig. 15 indicates the tag data at distinct junctions and its distributions in hour, day, and month.

Fig. 16, 17, 18, 19 shows the root mean square error (RMSE) values comparison of custom or proposed model with distinct models such as Gated Recurrent Unit (GRU), Long Short-Term Memory (LSTM), Convolution Neural Network (CNN), and Multilayer Perceptron (MLP) at junction 1, 2, 3, and 4 respectively. The RMSE evaluate the average difference between predicted and actual values as shown in the Eq. (5).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \hat{x}_i)^2}{N}} \tag{5}$$

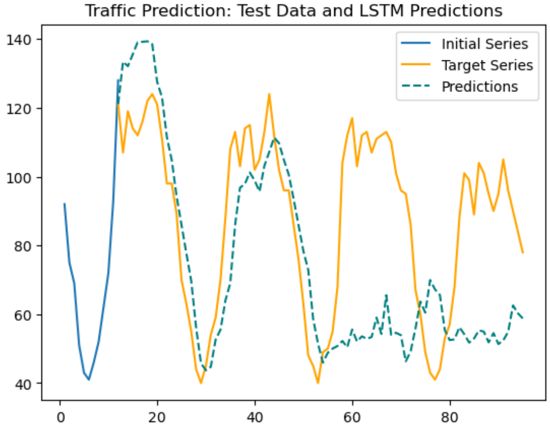

Fig. 14. Traffic data after RNN prediction.

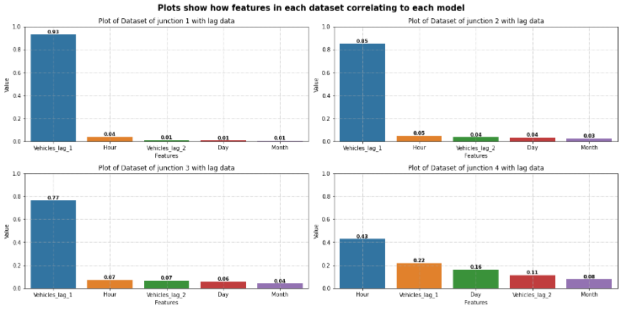

Fig. 15. Vehicle frequency time series.

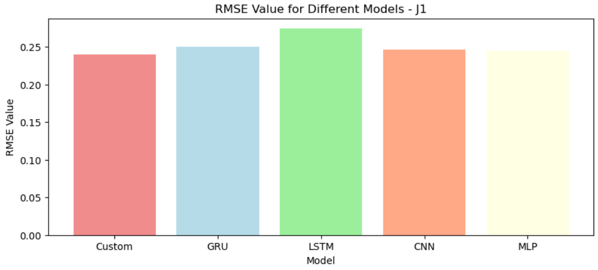

Fig. 16. RMSE comparison for distinct model at junction 1.

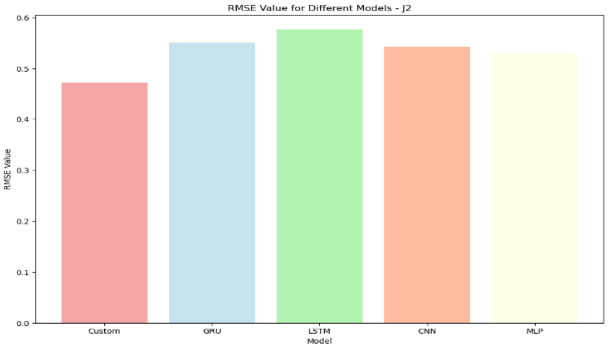

Fig. 17. RMSE comparison for distinct model at junction 2.

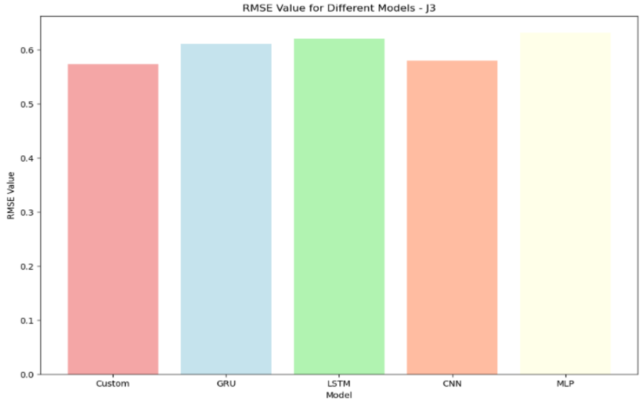

Fig. 18. RMSE comparison for distinct model at junction 3.

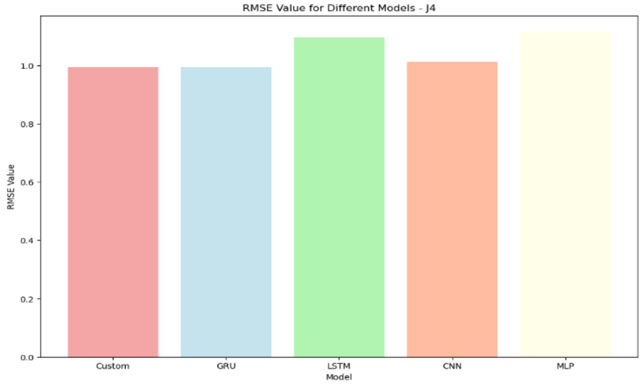

Fig. 19. RMSE comparison for distinct model at junction 4.

where, x_i represents the actual values, $\hat{x}_i$ indicates the predicted values for N number of rows. Table II indicates the RMSE values at different junctions that show the lowest values for the proposed model in compare to existing algorithms.

TABLE II. COMPARISON OF RMSE VALUES AT JUNCTIONS

Model	RMSE J1	RMSE J2	RMSE J3	RMSE J4
Proposed Model	0.2395	0.4719	0.5727	0.9939
LSTM	0.2739	0.5760	0.6201	1.0962
MLP	0.2441	0.5303	0.6310	1.1148
CNN	0.2458	0.5428	0.5793	1.0124
GRU	0.2498	0.5509	0.6103	0.9930

VI. CONCLUSION

The development of an algorithm for controlling the speed of a vehicle using Fuzzy Logic offers a promising approach to enhance road safety and driving efficiency. Fuzzy Logic, with its ability to model complex and imprecise relationships, provides an effective means to mimic human-like decision-making processes in speed control. A Fuzzy Logic-based algorithm for controlling vehicle speed has the potential to significantly enhance road safety, reduce accidents, and improve overall driving efficiency. Its ability to process complex and uncertain data in real-time makes it a valuable tool in modern vehicle control systems. However, successful implementation requires a holistic approach, including thorough testing, user acceptance, and compliance with safety regulations, to realize its full potential in improving the driving experience and road safety. In future, the system can be implemented by collecting real-time data with physical setup.

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