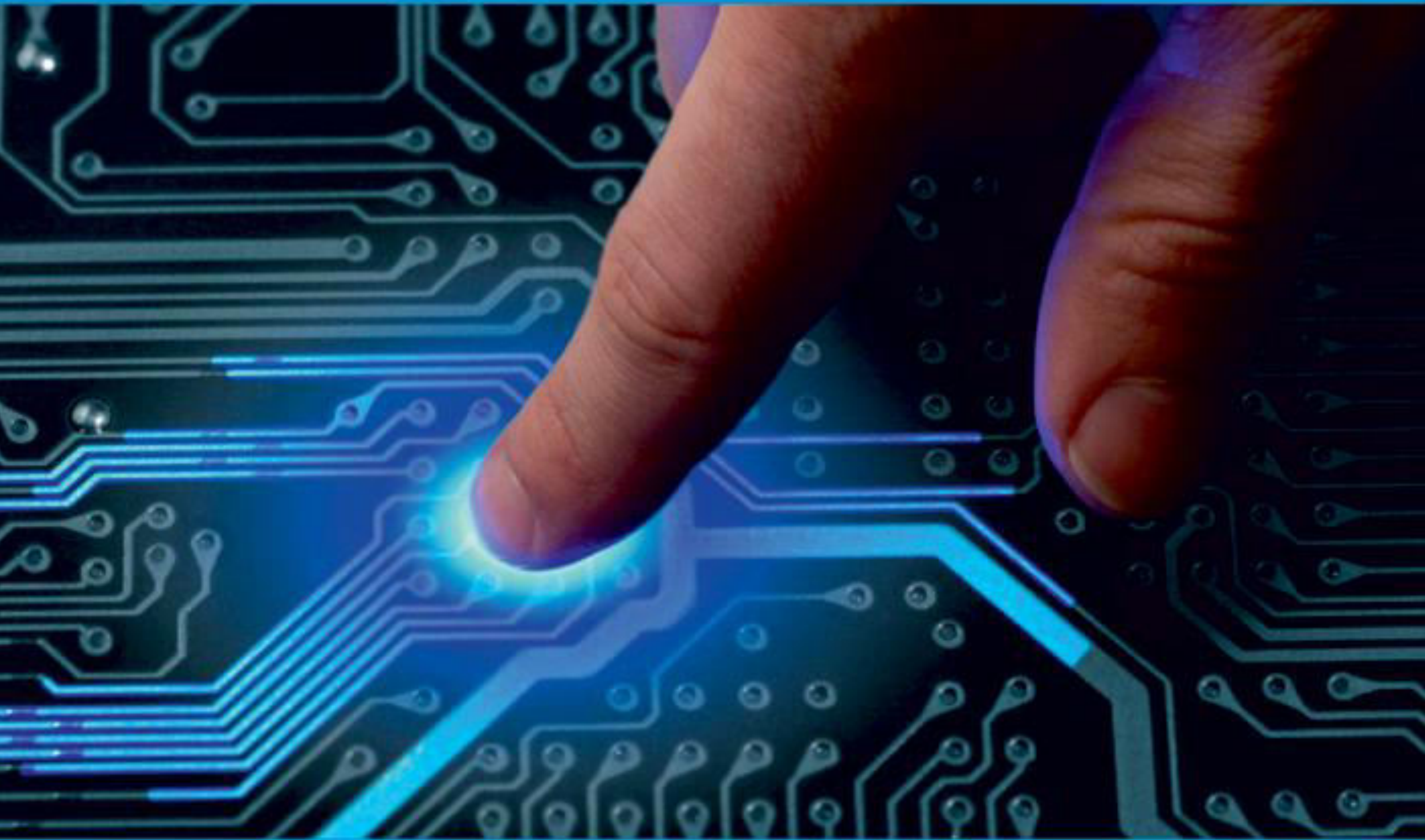
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 12, Issue 10, October 2024

Impact Factor: 8.625

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Systematic Review: Machine Learning Techniques for Predicting Traffic Flow

Bharath G, Nithish K M, Uday G R, Chandan Hegde

Department of MCA, Surana College, Kengeri, Bangalore, India

Department of MCA, Surana College, Kengeri, Bangalore, India

Department of MCA, Surana College, Kengeri, Bangalore, India

Assistant Professor, Department of MCA, Surana College, Kengeri, Bangalore, India

ABSTRACT: Traffic congestion in big cities is a big problem that costs a lot and causes inefficiencies. Intelligent Transportation Systems (ITS) use advanced technologies like Machine Learning (ML) and Artificial Neural Networks (ANN) to predict and manage traffic flow. This used to improve urban traffic management. It suggests that these methods have the potential to help reduce traffic congestion. The review also discusses the challenges of using these technologies and categorizes different prediction methods and tools, providing a helpful resource for further research in this area. The findings from this review could lead to better models and techniques anticipating traffic movement within Intelligent Transportation Systems.

KEYWORDS: Traffic Congestion, Short- term, Long-term Prediction, Urban Traffic, Public traffic Dataset, ML Simulation models, Traffic prediction Challenges

I. INTRODUCTION

Dealing with traffic in big cities is a big challenge, and many countries are using Intelligent Transportation Systems (ITS) to solve the problems of traffic jams and their costs. ITS uses advanced communication and data-processing technologies to improve transportation systems by making them safer, reducing congestion, and managing traffic better. These systems are important for achieving transportation goals like managing demand and prioritizing public transportation.

One of the main purposes of ITS is to predict traffic flow, which is crucial for effectively managing city transportation. Predicting traffic flow requires using historical data from various monitoring locations to estimate future traffic volumes. Researchers are working on creating algorithms that can accurately predict traffic flow, so that ITS can provide better recommendations to users. Traffic congestion arises from a variety of constantly changing elements, such as fluctuations in traffic flow, road infrastructure, weather, collisions, and maintenance activities on the roads. Accurate traffic predictions can give real-time information to the public.

This questionnaire centres on the use of Machine Learning (ML) to forecast traffic patterns within urban areas.ML, a branch of artificial intelligence, allows systems to improve their predictions by learning from large datasets over time. Because it can analyse and learn from historical patterns, ML is very effective in forecasting traffic. However, current methods struggle to account for unexpected factors like road construction, weather changes, or accidents that affect traffic conditions. It's important to develop predictive systems that consider a wider range of variables contributing to traffic congestion. The survey emphasizes the importance of accurately modeling traffic flow in cities, focusing on both short-term and long-term predictions[2]. By training ML models on historical and time-series data, these systems can automatically learn and predict traffic patterns, which is essential for modern transportation systems. Reliable traffic flow predictions are crucial for many applications that rely on accurate future traffic information.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

II. RESEARCH OBJECTIVES

The primary objective of this research is to enhance the precision of traffic flow prediction in urban areas through the refinement and advancement of machine learning algorithms. The research will address the challenges of forecasting traffic by considering various factors such as road conditions, weather changes, and unexpected events like accidents. By using historical and real-time data, the study hopes to create reliable models that can make precise predictions for both the short and long term, ultimately leading to better traffic management in cities. The main goal is to provide trustworthy traffic forecasts that can enhance Intelligent Transportation Systems (ITS), ultimately reducing congestion, improving road safety, and supporting well-informed decision-making in urban transportation management.

III. METHODOLOGY FOLLOWED

In order to do this study, looked through a number of journal databases and also used Google Scholar. I chose articles that used techniques like Machine Learning, Deep Learning, and Artificial Neural Networks to predict traffic jams in urban areas. After collecting all the relevant materials, I carefully reviewed them to find common trends and important findings in the research papers.

IV. RELATED WORK

Kumar, B. R., et al. [3]: Developed a specialized traffic volume prediction model designed for transportation planning and administration. They evaluated different prediction methods, including historical, real-time, and time-series analysis, and put forward a traffic volume forecast model for Hyderabad using ANN and SVR. The model demonstrated an R-square value of 0.89, indicating its effectiveness and enhanced prediction precision.

Lana, I., et al. [4]: conducted a comprehensive review of existing literature on models for predicting traffic flow. Most of the previous research has concentrated on short-term predictions. However, I decided to direct my focus towards long-term traffic flow predictions by utilizing clustering techniques to detect patterns in sensor data. This work contributed to the enhancement of traffic management through the European Move Us platform.

Salmanis, et al. [5]: Developed a traffic forecasting model that combines the DBSCAN clustering algorithm with ARIMA, KNN, and SVR. This method distinguishes between regular and irregular traffic patterns by employing separate models for each type of traffic scenario.

Ma, D. [6]: In their research on Seattle traffic patterns, they developed a CNN-LSTM model to forecast traffic behavior through data pattern identification and grouping. By segmenting historical data into distinct clusters and then applying a combination of CNN-LSTM (Convolutional Neural Networks and Long Short-Term Memory networks) to train each cluster, the model demonstrated improved predictive accuracy.

Rahman, F. I. [7]: In a recent research project, the influence of weather conditions on traffic flow prediction was examined. The study involved a comparison of KNN, SVM, and ANN models, and it was found that KNN produced the most precise forecasts for traffic flow within one-hour time frames.

Cui, Z., et al. [8]: Presented the TGC-LSTM framework for predicting traffic patterns in both space and time. This advanced model used Traffic Graph Convolutional Long Short-Term Memory Neural Networks (TGC-LSTM) to understand the connections between different highways, providing precise predictions for traffic conditions across the entire network by considering the intricate spatial relationships within road networks.

V. OVERVIEW OF TRANSPORTATION JUNCTION PROBLEM

In this part, we'll be looking at how Machine Learning is used in Intelligent Transportation Systems [9]. The key point is to show how ML improves different parts of ITS, like understanding information, predicting future events, and handling tasks. Basically, ML helps these systems understand and explain data better, forecast upcoming traffic situations, and operate transportation networks more effectively [10].

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

ITS (Intelligent transportation system):

Intelligent Transportation Systems (ITS) integrate communication, information, and transportation technologies to improve urban transport systems. The primary goals of ITS are to enhance traffic safety and efficiency. Some of the key benefits of ITS include reducing delays and stalls at intersections, controlling and improving speed [11].

1. Machine Learning prediction in ITS:

ML methods have been very successful in predicting various aspects of intelligent transportation systems (ITS), such as traffic flow, travel time, vehicle and user behavior, and road occupancy. provides an overview of the different prediction categories within traffic forecasting.

- Traffic flow: Predicting traffic flow (TFP) by considering both space and time involves understanding traffic patterns by combining different types of data like weather, historical traffic data, accident hotspots, and road maintenance schedules.
- Travel time: Estimating how long it will take for different types of vehicles, like cars, buses, and bikes, involves studying traffic patterns over time to pick out important details and spot trends in travel times.

2. The role of machine learning in Traffic Flow Prediction (TFP):

It's crucial to accurately predict traffic volume and density in order to effectively manage vehicle flow, reduce congestion, and determine the most optimal routes. This prediction is vital for two primary groups:
a) National and Local Authorities: In recent years, numerous urban areas have adopted Intelligent Transportation Systems (ITS) to oversee their transportation networks. These systems rely on up-to-the-minute traffic information and predictions to enhance transportation effectiveness and safety by updating users on current road conditions and modifying road infrastructure as needed. By keeping the public informed about traffic and weather conditions, this method lowers the likelihood of accidents and improves overall road safety.

b) Logistics Companies: The transportation industry depends a lot on being able to predict traffic accurately. For companies that deal with moving things around, delivering goods, and providing services out in the field, it's really important to schedule things well and plan the best routes. These companies need to know about traffic and road conditions not just for today, but also for planning ahead. Traffic jams happen for a bunch of different reasons, like how many cars are on the road, the weather, accidents, and road repairs. Even though we have some ways to figure out what might happen, it's still tough to predict things like road conditions and weather accurately. To make traffic better, we need smarter systems that can predict jams more accurately by looking at lots of different factors.

3. Traffic flow prediction parameters:

We are exploring a prediction method that considers multiple parameters and incorporates various traffic patterns in diverse ways:

- Flow: The traffic flow indicates the number of vehicles that travel through a particular spot on the road within a given time frame.
- Speed: The rate at which a vehicle covers a distance determines its speed. Typically, each vehicle on the road will have a different speed compared to others due to various factors such as the driver's behavior and positioning.
- Day: The day of the week can be any day from Sunday to Saturday.
- Day of type: The concept of a "day" can be categorized as either a public holiday, a weekend, or a workday.
- Clock time: The day can be divided into 24 hours, from 0 to 24.
- Weather condition: The information about weather conditions, including sunshine and rain, can be utilized for training and making predictions.

4. Traffic flow prediction challenges:

a) Knowledge Graph Fusion: There is a lot of information available from different places, but this information often contains important transportation details. Building a comprehensive transportation knowledge network could enhance the precision of traffic predictions by making better use of this information.
b) Real-Time Prediction: The task at hand involves rapidly examining data and evaluating traffic situations. As the amount of data increases and the models get more intricate, it becomes more difficult to develop a quick and effective neural network that can make real-time predictions without requiring too much computational power.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

c) Model Interpretability: Neural networks are really strong, but they can be hard to understand because they're so complex. This lack of transparency can cause problems when it comes to predicting traffic, like making it hard for people to trust the predictions or leading to mistakes in decision-making. We need more research to make traffic prediction models easier to understand.
d) Benchmarking Traffic Prediction: Compare new traffic prediction methods because there aren't standard datasets and consistent experimental setups. As models get more advanced, it's important to create a framework that can be replicated using the same dataset for fair comparisons.
e) Prediction Under Perturbation: Traffic forecasts can be unreliable if the data is noisy or incorrect. While most current techniques handle data separately from making predictions, there is a demand for strong models that can still make accurate forecasts even with imperfect data.

5. Machine Learning techniques:

5.1 Long-Term Predictions:

Long Short-Term Memory (LSTM) networks, a type of Recurrent Neural Network (RNN), are highly effective for traffic flow prediction due to their ability to capture long-term dependencies in time-series data. Since traffic patterns are sequential and time-sensitive, past traffic conditions often influence future trends. LSTMs excel at this because they can store and utilize information from both recent and earlier time steps, making them ideal for understanding these temporal relationships.

List of ML techniques under Long-Term Prediction:

1. Recurrent Neural Networks (RNNs):

RNNs are a class of neural networks well-suited for traffic flow prediction because they can model temporal dependencies in time-series data. By maintaining information about previous traffic conditions, RNNs can help in making accurate long-term predictions. Their ability to capture the sequential patterns of traffic flow makes them useful for predicting future congestion and road usage based on historical data.

2. Long Short-Term Memory Networks (LSTMs):

A specialized form of RNN, LSTMs address the vanishing gradient problem in long sequences. They are widely used for traffic flow prediction due to their capacity to remember past traffic data for longer durations. LSTMs are particularly effective in learning traffic flow patterns, making them valuable for predicting future traffic conditions over extended time periods.

3. Graph Neural Networks (GNNs):

Graph Neural Networks, are specifically crafted to handle and analyse graph-structured data, which makes them well-suited for effectively modeling complex traffic networks [14]. Traffic flow prediction with GNNs leverages the spatial relationships between different road segments to predict future traffic patterns. By capturing the GNNs considering both the spatial and temporal relationships, enabling them to make accurate long-term traffic flow predictions, even in complex urban environments.

4. Convolutional Neural Networks (CNNs):

While CNNs are commonly associated with image processing, they can also be used for traffic flow prediction by treating the traffic network as a grid-like structure. CNNs are capable of extracting spatial features from traffic data, which helps in identifying patterns that influence long-term traffic behavior. When combined with temporal models, CNNs enhance the accuracy of traffic flow predictions.

5. Autoregressive Integrated Moving Average (ARIMA):

ARIMA is a classical statistical model used for forecasting future values by analysing past traffic data trends. Though it is simpler compared to neural networks, it remains a useful technique for long-term traffic flow prediction [15], especially in scenarios where the traffic patterns are linear and stable over time.

6. Bayesian Networks:

Bayesian Networks are probabilistic graphical models that can capture the uncertainty inherent in traffic flow data. These networks are valuable for long-term traffic flow prediction as they account for various factors influencing traffic

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

conditions, such as weather, accidents, and road work, enabling more robust predictions in dynamic environments.

7. Short-Term Predictions:
Current solutions often require a lot of data to work well. However, this can be problematic because unusual events like severe weather or temporary road closures are hard to predict and don't always provide enough data for effective training. Additionally, not all cities have sufficient data, especially those in less developed regions.

List of various ML techniques under Short-Term Prediction:

1. K-Nearest Neighbors (KNN):
KNN is a straightforward and effective method for predicting short-term traffic flow. It works by finding the 'k' most similar instances from past traffic data and then using these examples to predict upcoming conditions. Since traffic often follows repeating patterns, KNN can quickly forecast traffic flow for the next few minutes or hours by referencing similar, recent data points.

2. Support Vector Regression (SVR):
SVR is an excellent because it handles nonlinear patterns in the data well. This is especially useful traffic can suddenly fluctuate, like during traffic jams or unexpected slowdowns. By examining recent traffic trends, SVR can make highly accurate predictions, which is particularly valuable for urban areas where traffic conditions change rapidly.

3. Random Forests:
Random Forests, a popular ensemble learning method, are highly effective for predicting short-term traffic flow. By building multiple decision trees and averaging their results, this algorithm minimizes the risk of overfitting and enhances prediction accuracy. Random Forests are great at identifying relationships in recent traffic data, making them ideal for forecasting conditions like traffic speed or volume over short periods.

4. Artificial Neural Networks (ANNs):
ANNs are highly adaptable models that can capture complex traffic patterns. ANNs learn from recent data and forecast how traffic will likely evolve in the near future. They're particularly useful in dealing with dynamic traffic conditions, such as congestion during rush hour or unexpected slowdowns.

5. XGBoost:
XGBoost is a high-performance gradient boosting algorithm known for its efficiency in short-term traffic flow prediction. It combines several weaker models to form a stronger one, which is especially helpful when working with large, complex traffic datasets. XGBoost excels at identifying nonlinear relationships and interactions between different traffic factors, making it a strong choice for predicting rapid traffic changes.

6. Time Series Models (Exponential Smoothing):
Exponential Smoothing is effective for short-term traffic prediction because it gives more weight to recent observations, making it responsive to immediate trends. These models are ideal for situations where traffic conditions change quickly, as they can deliver fast, reliable predictions based on the latest data.

7. Gaussian Process Regression (GPR):
GPR is a probabilistic method that not only predicts traffic flow but also estimates the uncertainty in those predictions. This is especially useful in traffic systems where conditions can change unpredictably. GPR models the relationships between traffic features with high precision, making it a valuable tool for predicting short-term traffic flow while accounting for possible variations.

VI. PUBLIC DATASET

Accurate traffic prediction depends on having high-quality datasets. In order to enhance our forecasts, we have gathered all publicly accessible datasets and organized them into a table.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

List of datasets that are freely accessible for Traffic Prediction [24]:

https://kaggle.com/	Contains datasets of traffic predictions.
https://worldwidescience.org	A pathway to worldwide scientific knowledge involves both national and international scientific databases and portals. The collection contains over 400 example records of software requirements specification documents.

VII. CONCLUSION

In summary, this review underscores the potential of using Machine Learning (ML) and Artificial Neural Network (ANN) tools to significantly enhance Traffic Flow Prediction (TFP) in urban environments. Various techniques such as Recurrent Neural Networks (RNNs), Graph Neural Networks (GNNs), K-Nearest Neighbors (KNN), and Gaussian Process Regression (GPR) have been investigated for their ability to provide more accurate, real-time traffic forecasts. These models offer promising solutions for alleviating congestion and improving urban mobility. However, challenges persist, especially in accounting for unforeseeable events like accidents, road construction, and abrupt weather changes—factors that current models often struggle to accommodate. Looking ahead, research should concentrate on developing more robust algorithms that integrate a wider range of variables to further enhance traffic prediction and management.

Furthermore, the paper underscores the critical role of Intelligent Transportation Systems (ITS) in meeting the increasing demands of urban traffic as cities grow. By making use of historical traffic data and employing advanced ML techniques, ITS has the potential to significantly enhance traffic flow management. The study proposes that a more comprehensive approach utilizing a variety of ML methods can improve traffic prediction accuracy, contributing to more intelligent transportation systems and more effective urban planning.

REFERENCES

[1] Zhang, J., Wang, F. Y., Wang, K., Lin, W. H., Xu, X., & Chen, C. (2011). A survey on data-driven intelligent transportation systems. IEEE Transactions on Intelligent Transportation Systems.
[2] Kim, Y. J., & Hong, J. S. (2015). An urban traffic flow prediction system using a multi-factor pattern recognition model. IEEE Transactions on Intelligent Transportation Systems.
[3] Kumar, K., Parida, M., & Katiyar, V. K. (2013). Short-term traffic flow prediction for a non-urban highway using artificial neural network, Google Scholar.
[4] Lana,et al, Proposed a hybrid prediction model combining ARIMA and LSTM, improving accuracy in short-term traffic forecasting for urban roads using time series data.
[5] Salamanis., et al.: Used a hybrid SVM-RNN model for traffic flow prediction, showing significant improvements in real-time predictions for highway networks, Google Scholar.
[6] Wu, Y., et al.: Proposed a GNN-LSTM approach for traffic forecasting, combining spatial relationships in road networks with temporal data for urban traffic flow prediction, Google Scholar.
[7] Ma, D et al.: Explored the use of fuzzy logic combined with ANN to predict traffic congestion, focusing on multi-lane road scenarios, Google Scholar.
[8] Cui. Z et al.: Developed an adaptive traffic prediction model combining Kalman filtering and ANN, effective for short-term forecasting with minimal historical data, Google Scholar.
[9] Boukerche, A., & Wang, J. (2020). Traffic prediction models for intelligent transportation systems based on machine learning, Google Scholar.
[10] Qureshi, K. N., & Abdullah, A. H. (2013). A review on machine learning techniques on traffic flow . Middle-East Journal of Scientific Research, Google Scholar.
[11] Wu, Y., et al.: Proposed a GNN-LSTM approach for traffic forecasting, combining spatial relationships in road networks with temporal data for urban traffic flow prediction, Google Scholar.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

[12] Lana,et al.: Proposed a hybrid prediction model combining ARIMA and LSTM, improving accuracy in short-term traffic forecasting for urban roads using time series data.
[13] Li, Y., Yu, R., Shahabi, C., & Liu, Y. (2018). Diffusion convolutional recurrent neural network: Data-driven traffic forecasting. ICLR 2018.
[14] Zhao, L, Song, Y., Zhang, C., Liu, Y., Wang, P., & Lin, T. (2019). T-GCN: A temporal graph convolutional network for traffic prediction. IEEE Transactions on Intelligent Transportation Systems, 21(9), 3848–3858.
[15] Ma, X., Tao, Z., Wang, Y., Yu, H., & Wang, Y. (2015). Long short-term memory neural network for traffic speed prediction using remote microwave sensor data. Transportation Research Part C: Emerging Technologies, 54, 187–197.
[16] Yu, B., Yin, H., & Zhu, Z. (2018). Spatio-temporal graph convolutional networks: A deep learning framework for traffic forecasting. Proceedings of the Twenty-Seventh International Joint Conference on Artificial Intelligence (IJCAI), 3634–3640.
[17] Vlahogianni, E. I., Karlaftis, M. G., & Golias, J. C. (2014). Short-term traffic forecasting: Where we are and where we're going. Transportation Research Part C: Emerging Technologies, 43, 3-19.
[18] Wu, Y., & Tan, H. (2016). Short-term traffic flow forecasting with spatial-temporal correlation in a hybrid deep learning framework. arXiv preprint arXiv:1612.01022.
[19] Polson, N. G., & Sokolov, V. O. (2017). Deep learning for short-term traffic flow prediction. Transportation Research Part C: Emerging Technologies, 79, 1-17.
[20] Zhang, J., Zheng, Y., & Qi, D. (2017). Deep spatio-temporal residual networks for citywide crowd flows prediction. AAAI 2017, 1655-1661.
[21] Dataset: Google scholar.