

Implementation of AI in Traffic Management: Need, Current Techniques and Challenges

S.Faiza Nasim, Asma Qaiser, Nazia Abrar and Umme Kulsoom

NED University of Engineering and Technology, Pakistan

Corresponding authors: S.Faiza Nasim (e-mail: sfaizaadnan@gmail.com)

Abstract—In recent years, technology, including Artificial Intelligence (AI), has advanced in every industry conceivable. Artificial Intelligence has been a keen area of interest in solving everyday human problems. One such application area is Traffic Management, which has required extensive human involvement since the beginning. Still, researchers from all over the world are working to introduce the use of Artificial Intelligence in managing road traffic in major cities to eliminate the issue of traffic congestion. Artificial Intelligence (AI) has emerged as a promising solution for addressing the persistent challenges of traffic management in major cities. Several attempts have been made in this regard, and different techniques are being worked upon to date, but the world is still far from observing the widespread use of AI in major cities. This paper analyzes why Artificial Intelligence is needed for traffic management, what techniques have been developed so far, and the common challenges hindering the widespread application of AI in traffic management.

Index Terms—Artificial Intelligence (AI), Blockchain, Internet of Things (IoT), Traffic Congestion, Machine Learning (ML) and Neural Network.

I. INTRODUCTION

With the advent of the 21st century, Artificial Intelligence has been in the spotlight. Many technical personnel from all fields have been trying to implement AI in nearly every walk of life to improve human living conditions [1-5]. One major area of interest in this regard is Traffic Management.

With the huge spike in population, globalization, and advancement in automobile technology, more people are opting to have their own car, creating traffic congestion issues mainly in metropolitan cities. Urban regions have always struggled with traffic congestion [6], which occurs when demand exceeds available road space. Traffic congestion is one of the biggest problems that the world is facing right now, which is worsening every day with the increase in the number of vehicles on the roads [7]. This brings upon itself a plethora of related issues like air pollution [8], sound pollution [9], stress on city infrastructure, reduction in overall productivity, energy wastage in terms of fossil fuels [10], and mental stress across the city population. So efficient traffic management is the need of the hour and Artificial Intelligence can be very helpful in this matter to manage the traffic management infrastructure with minimal human involvement [11].

Considering the severity of the traffic congestion issue, researchers and engineers from all over the world have proposed different working models and systems which can be installed in the city Centre to tackle this issue[12,13]. Different techniques are being considered to this day and few commercial solutions are also available in the market from different solution providers [14, 15].

Furthermore, [24] suggested that the greater rates of growth in population, urbanization, and changes in density of population

are factors that result in difficulties for the network of roads in comparison with the requirements for effective movement of people and goods, as well as the creation of a viable transportation network in South African cities. These problems not only delay city infrastructure development but also cause automobile accidents, traffic congestion, and an increase in journey times, fuel consumption, and carbon emissions.

However, congestion in traffic is seen as a significant issue that impedes safe street transit in South African cities. While a few traffic-control initiatives have been implemented, such as the Gautrain and the Bus Rapid Transit System (BRT) in Pretoria and Johannesburg, and the MyCiTi move structure in Cape Town, certain regions of the urban areas continue to face transportation challenges. During the peak hours of the day, metropolitan areas with no public transit framework may experience significant traffic congestion. Hence, there's an obligation to examine alternate roadways that might alleviate Johannesburg's traffic congestion. As a result, it is believed that there's a need to examine alternate roadways that might alleviate Johannesburg's traffic congestion.

A lot of investigation has been done on the use of AI in transportation systems in recent years, especially on how it may be used to anticipate traffic flow on roads and its applicability in alleviating traffic congestion. However, little progress has been made in areas of reducing congestion at signalized road junctions, particularly when the vehicles at these crossings are autonomous cars [24].

Autonomous cars are the years to come of road travel, with solid data indicating that they will help decrease congestion on the roads by a minimum of 50%. It will also help to eliminate or reduce the use of gap approval theory in un-signalized roadway intersections, as well as reduce major road accidents



because autonomous vehicles can react faster than non-autonomous vehicles in hazardous situations due to their computational intelligence.

According to extant literature evaluations, the application of artificial neural networks (ANN) in traffic flow prediction is not innovative. Previous related research, however, ignored the use of artificial intelligence in the domain of road junctions, particularly signalized road crossings. This conference paper attempted to shed as much as possible light on this element of road intersections. This study is primarily concerned with: Signalized Road Intersections. Using Artificial Neural Networks to Reduce Traffic Congestion at Signalized Road Intersection

But the fact that requires our attention is that irrespective of all the development and advancement in the field of AI and its use with electronic control systems to solve complex problems, especially in the area of traffic management, World is still very far to see widespread deployment of such systems in the practical world. Although there are many reasons behind this, core issues are the capital investment required to design and implement such systems, the need for prior infrastructure, complexity, and ethical issues. However, it is important to note that the implementation of AI in traffic management must be done responsibly and with consideration for potential ethical and privacy concerns [22].

II. LITERATURE REVIEW

This section highlights the designs and principles of working on the different AI-based traffic management systems proposed by different creators and researchers.

- Huang et al designed an AI-based traffic management system based on the Neural Network technique called YOLO [16]. This system collects data from CCTV[20] cameras installed on the roads and processes it through an algorithm to calculate traffic density by categorizing each class of vehicle, such as car, bike, bus, etc. Then this system decides which traffic signal needs to be turned green and for which duration based on the traffic density on the road.

- One of the most important study in traffic management system is proposed by uddin et al. Their research based on an AI-based traffic management system with added IoT functionality [18]. This system also uses a camera to detect the real-time traffic situation on the road and then process this data with the NVIDIA ML algorithm to calculate the traffic density and turn the traffic signal on/off accordingly, also the traffic violating vehicle can also be detected and the traffic regulating authorities can be informed about the offender and a text message will also be sent to the offender via the MQTT. [15]

- Soman et al proposed a digital image processing based smart traffic management system that uses CCTV cameras to collect data and then calculate traffic density at intersections with the help of “openCV” [19] platform. This helps in deciding the timings for different traffic signals.

- Gandhi et al proposed a traffic management based on AI & image processing. A single pole-mounted camera rotates and takes the image of the road periodically to gather data

[17]. Then these images are converted to gray scale and techniques of canny edge detection and image enhancement are used to compare the taken image with the reference image of the empty road to calculate the timer values of traffic signal with the greater traffic density. This system also distinguishes the lane with ambulances or fire safety vehicles via sound sensor [18] and liberates that lane on priority.

- Sharma et al presented a comprehensive, integrated Smart Road Traffic Management System (SRTMS). This paper suggests integrating different sensors in the vehicle from the factory to detect driving patterns and habits. The traffic situation is determined by the communication of the vehicle with different objects on the road, for example, poles, traffic lights [17], other vehicles, etc. All the communications will be done via blockchain [21] to minimize the data breach. The whole system will be able to manage traffic efficiently, detect accidents on the road, and inform the traffic authorities about an incident and offender.

- Degas et al presented the use of artificial intelligence approaches to urban traffic management problems in order to improve the performance of present signal design selection systems. In specifically, the architecture of a smart traffic management system is described in terms of the many layers of gathering information, the interpretation and analysis of data, decision, and control. The features of the presented hybrid modules are explained, as are the artificial intelligence technologies applied. Finally, current research in the topic is described [25].

- Iyer et al in their research, examine the uses of AI in the sphere of public transportation on the path to developing a sustainable society. For this analysis, four subsystems of the Intelligent Transportation System are considered: traffic management, public transportation, safety management, manufacturing, and logistics. In addition, the research aggregated several AI applications from various cities and organizations and provided them with a point of reference for future leaders [26]. Their study will help the industrial and transportation industries discover innovative ways to use AI as an answer in their respective fields. Prior to implementation, businesses might weigh the benefits and drawbacks of the proposals and take a careful step toward creating a sustainable society [26].

- Sukhadia et al proposed, a smart congestion governance system uses artificial intelligence to oversee and regulate the course of transportation, as well as automated administration and execution, to make a difference in the face of travel scenarios in large centers with substantial traffic concerns [27].

- Okwu et al describes yet another AI approach for predicting traffic flow [28]. Using Jordan's neural network, the authors created a basic recurrent neural network that can be used for short-term forecasting. The inclusion of a context layer distinguishes it from traditional feedforward networks. The context layer functions as a memory box, storing prior information. The data that has been saved at (t-1) is then sent back into the hidden layer together with the input at (t). This assists the network in predicting the subsequence; as a result, it is frequently referred to as "Jordan's Sequential Network." The input data was traffic volume from Ireland's road traffic control. The outcome is the predicted traffic flow to reduce

error, the network in question undergoes training as a network of feed-forward neural networks with a back propagation

- performs better when the total amount of neurons in the layer that is hidden is double that of the input neurons. Also, using a rate of learning of a value of and a decreasing number of iterations, flow accuracy is predicted to be between 92 and 98%. Because this model is a first order system, it offers erroneous predictions while computing higher order dynamics. [29] It was recommended that the network be linearized often at each operational point live to make algorithm calculation easier. Elman Network is another sort of recurrent network. ATOS Academic Community also created a Pattern-Based Strategy (PBS). Supervised learning, whereby labelled data is utilized with a proper output, is the initial type of recognition of patterns. Second, unsupervised learning uses unlabeled data to locate a pattern and determine the proper output; and semi-supervised learning uses little-supervised data with a large amount of unlabeled data for pattern recognition analysis. [30] Similarly, modern rideshare services like Uber and Didi Chuxing, among others, have raised the possibilities of enormous data collection. AI can use this data to efficiently estimate passenger demand, avoiding empty cars and therefore reducing congestion and energy usage [31].

- Luo et al proposes a deep learning model that takes into account Multi-View, Spatial, and Temporal (DMVST) Network. The authors gathered large-scale ridesharing demand information from DiDi Chuxing in the Chinese city of Guangzhou. They used a combination of Local CNN, which captures local areas in relation to their surroundings, and a long-short-term memory networks (LSTM), which models temporal aspects. The results showed that the proposed model outperformed others [31].

- Similarly, Xu, Ying et al used a Multi-layer Perceptron Neural Network to forecast taxi demand in Tokyo, Japan. They gather data from the Taxi Probe system, in which cabs are outfitted with sensors that capture information (e.g., taxi location) [32]. The results revealed that using 4 hours of historical demand data with fifty neurons in the layers that were concealed improved forecast accuracy. distinguishes it from traditional feedforward networks. The context layer functions as a memory box, storing prior information. The data that has been saved at (t-1) is then sent back into the hidden layer together with the input at (t). This assists the network in predicting the subsequence; as a result, it is frequently referred to as "Jordan's Sequential Network." The input data was traffic volume from Ireland's road traffic control. The outcome is the predicted traffic flow to reduce error, the network in question undergoes training as a network of feed-forward neural networks with a back propagation technique. But the scientists demonstrated that the network performs better when the total amount of neurons in the layer that is hidden is double that of the input neurons. Also, using a rate of learning of a value of and a decreasing number of iterations, flow accuracy is predicted to be between 92 and 98%. Because this model is a first order system, it offers erroneous predictions while computing higher order dynamics. [29] It was recommended that the network be linearized often at each operational point live to make algorithm calculation easier. Elman Network is another sort of recurrent network. ATOS Academic Community also created a Pattern-Based

technique. But the scientists demonstrated that the network

Strategy (PBS). Supervised learning, whereby labelled data is utilized with a proper output, is the initial type of recognition of patterns. Second, unsupervised learning uses unlabeled data to locate a pattern and determine the proper output; and semi-supervised learning uses little-supervised data with a large amount of unlabeled data for pattern recognition analysis. [30] Similarly, modern rideshare services like Uber and Didi Chuxing, among others, have raised the possibilities of enormous data collection. AI can use this data to efficiently estimate passenger demand, avoiding empty cars and therefore reducing congestion and energy usage [31].

- Luo et al proposes a deep learning model that takes into account Multi-View, Spatial, and Temporal (DMVST) Network. The authors gathered large-scale ridesharing demand information from DiDi Chuxing in the Chinese city of Guangzhou. They used a combination of Local CNN, which captures local areas in relation to their surroundings, and a long-short-term memory networks (LSTM), which models temporal aspects. The results showed that the proposed model outperformed others [31].

- Similarly, Xu, Ying et al used a Multi-layer Perceptron Neural Network to forecast taxi demand in Tokyo, Japan. They gather data from the Taxi Probe system, in which cabs are outfitted with sensors that capture information (e.g., taxi location) [32]. The results revealed that using 4 hours of historical demand data with fifty neurons in the layers that were concealed improved forecast accuracy.

III. METHODOLOGY

This section analyzes the need of AI in traffic management and challenges that are being faced to implement it.

A. WHY IS AI NEEDED IN TRAFFIC MANAGEMENT?

After the huge increase in the population and extensive usage of private means of transportation in the last 20 years, major cities across the world are dealing with the issue of traffic congestion daily, especially metropolitan cities. Following are some key problems that arise from the aforementioned issue:

B. AIR POLLUTION

The biggest and significant problem which arises due to traffic congestion is air pollution. As we know that many manufacturers are introducing their lineups of electric vehicles (EVs) but still the major percentage of vehicles across the globe run on hydrocarbon fuels which release toxic/greenhouse gasses into the atmosphere, worsening the already bad situation of the atmosphere [23].

C. STRESS ON CITY INFRA-STRUCTURE

Traffic congestion puts pressure on city infra-structure in several ways. It can increase wear and tear on roads and highways, leading to the need for more frequent repairs and maintenance. Additionally, traffic congestion can increase travel times and make it difficult for emergency vehicles to reach their destinations quickly [18]. This can have serious implications for public safety.

a) *REDUCTION IN PRODUCTIVITY*

In addition to harming the environment, traffic congestion has serious negative effects on the economy, particularly in terms of lost productivity. Due to traffic congestion it takes longer for goods to be transported and people to get to work.

b) *ENERGY WASTAGE*

Traffic congestion is a significant reason for energy wastage on the planet. Increased idling of vehicles in the congestion leads to the burning of more fuel which strains the already scarce source of fossil fuels. Businesses may incur higher operating costs as a result of traffic congestion. Greater fuel usage and transportation costs result from longer delivery times. Businesses may also need to set aside funds to handle logistics and find alternate ways to reduce delays, which can have a negative impact on production.

c) *SOCIAL EFFECT*

There are many social side effects of traffic congestion. Many studies have shown that the dwellers of metropolitan cities experience frustration and mental stress due to traffic congestion. Reduced social interactions and reduced access to opportunities also add up to the issue.

B. WHAT ARE THE CHALLENGES IN WIDESPREAD APPLICATION OF AI BASED TRAFFIC MANAGEMENT SYSTEMS?

After discussing the need for Artificial Intelligence based traffic management systems & current proposed designs and development of AI-based traffic management systems, we need to ponder upon the fact that, why we are lacking real-world practical use cases of AI in traffic management.

a) *CAPITAL INVESTMENT*

Out of the many challenges that are hindering the widespread adoption of smart traffic management systems, the core reason is the high cost of technology. AI systems require data to process. To collect data related to traffic high-end CCTV cameras and proximity sensors are required which are very costly. In addition to that, processing a large amount of data requires heavy-duty computer hardware which also adds up to the cost.

b) *ABSENCE OF INFRASTRUCTURE*

To implement an Artificial Intelligence based system, certain civil infrastructure is required, for example, road intersections are required to be made labeled and marked to help the computer vision algorithms to identify the roads. Many third-world metropolitan cities lack the basic infrastructure to install such systems. Also, the road networks require to be built according to certain standards across the city to help train Artificial Intelligence algorithms for efficient working [22].

c) *COMPLEXITY*

AI-based traffic management systems can be complex, and it can be difficult to design and implement them in a way that

works well in the real world. Although there are many systems that researchers have proposed in recent years, most of them are simulation models or they work in a highly simulated and controlled environment.

D) *ETHICAL & SOCIAL ISSUES*

AI-based traffic management systems rely on data from various sources such as cameras, GPS, and sensors, which raise concerns about data collection and privacy, also there is a lack of trust and understanding of the technology among the general public and decision-makers, which makes it harder to implement and maintain these systems.

E) *PRIVACY CONCERNS*

AI structures need rights to many data sources it may include a personal data from different device, a surveillance cameras, a GPS information all these increases the concerns and alarms about their privacy and security. Matching the requirements for information gathering with confirming one's privacy rights is important. It needs to implement a vigorous information security measures and safeguarding the transparency in information procedure to advance community trust.

IV. RESULTS

Table I describes the summary of numerous sensors and techniques/algorithm used in mentioned papers.

TABLE I
SUMMARY OF RESOURCES USED IN THE PROPOSED SYSTEMS
DISCUSSED [17] [18]

S.NO	Paper Name	Sensors	Algorithm/Technique
1	Smart control of traffic light using Artificial Intelligence	Camera	Neural Network, YOLO
2	Ai Traffic Control System based on Deep stream and IOT using NVIDIA Jetson	Camera	NVIDIA ML, SSD, IoT, MQTT
	Nano		
3	Traffic Light Control and Violation Detection Using Image Processing	Camera	Image Processing, "openCV"
	Smart Traffic Light Controller Using Image Processing	Camera & Sound Sensor	Image processing
4	The role of Blockchain, AI and IOT for smart road traffic management system	Speed, GPS, Camera, etc	AI, Blockchain & IoT

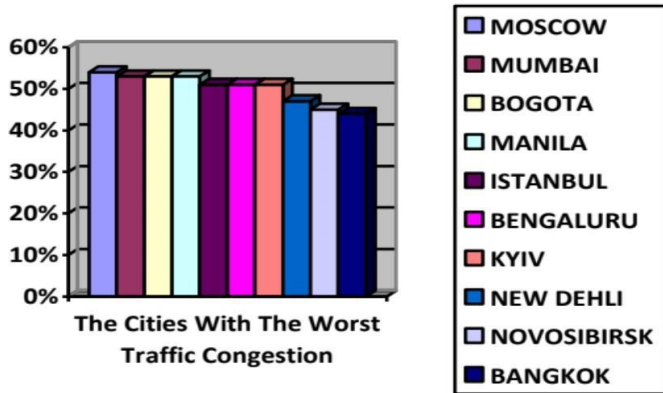


FIGURE 1. DETAILS OF THE EXTRA TRAVEL TIME (IN %) AS COMPARED TO THE AVERAGE UNCONGESTED CONDITIONS. [6]

V. DISCUSSION & CONCLUSION

This paper highlights the problems caused by the absence of AI-based traffic management in detail. Conventional traffic management techniques are not keeping up with the huge increase in the volume of traffic. This paper also presents a brief highlight of some of the proposed AI based systems in this regard that can be implemented. Another issue which requires our attention is the challenges that are being faced to implement such systems in the real world. Artificial Intelligence (AI) has the potential to play a significant role in traffic management by providing real-time traffic data, predicting traffic patterns, and optimizing traffic flow. AI-powered traffic management systems can also help reduce congestion, improve safety, and make transportation more efficient.

REFERENCES

- [1] Nasim, Syeda Faiza, Muhammad Rizwan Ali, and Umme Kulsoom. "Artificial intelligence incidents & ethics a narrative review." *International Journal of Technology, Innovation and Management (IJTIM)* 2, no. 2 (2022): 52-64.
- [2] Feroze, S. Atruba, and S. Faiza Nasim. "Genetic Testing of Huntington's Disease by Facial Examination of a Mankind using AI Programs." In *2022 3rd International Conference on Innovations in Computer Science & Software Engineering (ICONICS)*, pp. 1-9. IEEE, 2022.
- [3] Islam, Noman, Asadullah Shaikh, Asma Qaiser, Yousef Asiri, Sultan Almakdi, Adel Sulaiman, Verdah Moazzam, and Syeda Aiman Babar. "Ternion: An autonomous model for fake news detection." *Applied Sciences* 11, no. 19 (2021): 9292.
- [4] Nasim, S. F., S. Fatimah, and A. Amin. "ARTIFICIAL INTELLIGENCE IN MOTOR IMAGERY-BASED BCI SYSTEMS: A NARRATIVE." *Asian Journal Of Medical Technology* 2, no. 2 (2022): 55-64.
- [5] Qaiser, Asma, Saman Hina, Abdul Karim Kazi, Saad Ahmed, and Raheela Asif. "Fake News Encoder Classifier (FNEC) for Online Published News Related to COVID-19 Vaccines." *Intelligent Automation & Soft Computing* 37, no. 1 (2023).
- [6] Ramana, Kadiyala, Gautam Srivastava, Madapuri Rudra Kumar, Thippa Reddy Gadekallu, Jerry Chun-Wei Lin, Mamoun Alazab, and Celestine Iwendu. "A Vision Transformer Approach for Traffic Congestion Prediction in Urban Areas." *IEEE Transactions on Intelligent Transportation Systems* 24, no. 4 (2023): 3922-3934.
- [7] Roy, Sneha, Drew Cooper, Alex Mucci, Bhargava Sana, Mei Chen, Joe Castiglione, and Gregory D. Erhardt. "Why is traffic congestion getting worse? A decomposition of the contributors to growing congestion in San Francisco-Determining the Role of TNCs." *Case Studies on Transport Policy* 8, no. 4 (2020): 1371-1382.
- [8] Cory-Slechta, Deborah A., Alyssa Merrill, and Marissa Sobolewski. "Air pollution-related neurotoxicity across the life span." *Annual review of pharmacology and toxicology* 63 (2023): 143-163.
- [9] Kumar, Adarsh, Tripti, Deep Raj, Subodh Kumar Maiti, Maria Maleva, and Galina Borisova. "Soil pollution and plant efficiency indices for phytoremediation of heavy metal (loid) s: two-decade study (2002–2021)." *Metals* 12, no. 8 (2022): 1330.
- [10] Abbasi, Kashif Raza, Muhammad Shahbaz, Jinjun Zhang, Muhammad Irfan, and Rafael Alvarado. "Analyze the environmental sustainability factors of China: The role of fossil fuel energy and renewable energy." *Renewable Energy* 187 (2022): 390-402.
- [11] Dash, Bibhu, and Pawankumar Sharma. "Role of artificial intelligence in smart cities for information gathering and dissemination (a review)." *Academic Journal of Research and Scientific Publishing* 4, no. 39 (2022).
- [12] Anbaroglu, Berk, Benjamin Heydecker, and Tao Cheng. "Spatio-temporal clustering for non-recurrent traffic congestion detection on urban road networks." *Transportation Research Part C: Emerging Technologies* 48 (2014): 47-65.
- [13] Dadashova, Bahar, Xiao Li, Shawn Turner, and Pete Koeneman. "Multivariate time series analysis of traffic congestion measures in urban areas as they relate to socioeconomic indicators." *Socio-Economic Planning Sciences* 75 (2021): 100877.
- [14] Dadashova, Bahar, Xiao Li, Shawn Turner, and Pete Koeneman. "Multivariate time series analysis of traffic congestion measures in urban areas as they relate to socioeconomic indicators." *Socio-Economic Planning Sciences* 75 (2021): 100877.
- [15] Noor, Md Asaduzzaman, Sultana Ashrafi, Md Abdul Fattah, Syed Riad Morshed, and Saima Rahman. "Assessment of traffic congestion scenario at the CBD areas in a developing city: In the context of Khulna City, Bangladesh." *Transportation Research Interdisciplinary Perspectives* 11 (2021): 100435.
- [16] Huang, Rachel, Jonathan Pedeem, and Cuixian Chen. "YOLO-LITE: a real-time object detection algorithm optimized for non-GPU computers." In *2018 IEEE international conference on big data (big data)*, pp. 2503-2510. IEEE, 2018.
- [17] Gandhi, Mihir M., Devansh S. Solanki, Rutwij S. Daptardar, and Nirmala Shinde Baloorkar. "Smart control of traffic light using artificial intelligence." In *2020 5th IEEE international conference on recent advances and innovations in engineering (ICRAIE)*, pp. 1-6. IEEE, 2020.
- [18] Uddin, Md Imran, Md Shahriar Alamgir, Md Mahabubur Rahman, Muhammed Shahnewaz Bhuiyan, and Md Asif Moral. "AI traffic control system based on deepstream and iot using nvidia jetson nano." In *2021 2nd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)*, pp. 115-119. IEEE, 2021.
- [19] Soman, Renjith, and K. Radhakrishnan. "Traffic Light Control and Violation Detection Using Image Processing." *Traffic* 8, no. 4 (2018).
- [20] Chidhambaram, S., R. S. Mukilan, R. Shivabalaji, K. Vigneshwaran, and R. Dhivya Praba. "Smart Traffic Light Controller Using Image Processing."
- [21] Sharma, Ashish, Yogesh Awasthi, and Sunil Kumar. "The role of blockchain, AI and IoT for smart road traffic management system." In *2020 IEEE India Council International Subsections Conference (INDISCON)*, pp. 289-296. IEEE, 2020.
- [22] TomTom, T. "Traffic congestion ranking: Tom tom traffic index." (2019).
- [23] Wang, Peng, Ruhan Zhang, Shida Sun, Meng Gao, Bo Zheng, Dan Zhang, Yanli Zhang, Gregory R. Carmichael, and Hongliang Zhang. "Aggravated air pollution and health burden due to traffic congestion in urban China." *Atmospheric chemistry and physics* 23, no. 5 (2023): 2983-2996.
- [24] Bhattacharya, Bimalendu. *Urbanization, Urban Sustainability and the Future of Cities*. concept publishing company, 2010.

- [25] Degas, Augustin, Mir Riyanul Islam, Christophe Hurter, Shaibal Barua, Hamidur Rahman, Minesh Poudel, Daniele Ruscio et al. "A survey on artificial intelligence (ai) and explainable ai in air traffic management: Current trends and development with future research trajectory." *Applied Sciences* 12, no. 3 (2022): 1295.
- [26] Iyer, Lakshmi Shankar. "AI enabled applications towards intelligent transportation." *Transportation Engineering* 5 (2021): 100083.
- [27] Sukhadia, Aayush, Khush Upadhyay, Meghashree Gundeti, Smit Shah, and Manan Shah. "Optimization of smart traffic governance system using artificial intelligence." *Augmented Human Research* 5 (2020): 1-14.
- [28] Okwu, Modestus O., Vitalian U. Chukwu, and Onyewuchi Oguoma. "Application of artificial neural network model for cost optimization in a single-source, multi-destination system with non-deterministic inputs." In *Advances in Computational Intelligence: 15th International Work-Conference on Artificial Neural Networks, IWANN 2019, Gran Canaria, Spain, June 12-14, 2019, Proceedings, Part II* 15, pp. 539-554. Springer International Publishing, 2019.
- [29] Abduljabbar, Rusul, Hussein Dia, Sohani Liyanage, and Saeed Asadi Bagloee. "Applications of artificial intelligence in transport: An overview." *Sustainability* 11, no. 1 (2019): 189.
- [30] Kour, Shagun Preet, Parshant Sharma, and Maddassar Jalal. "Artificial Intelligence in Transport-A Survey." In *2022 IEEE 3rd Global Conference for Advancement in Technology (GCAT)*, pp. 1-6. IEEE, 2022.
- [31] Luo, Aling, Boyi Shangguan, Can Yang, Fan Gao, Zhe Fang, and Dayu Yu. "Spatial-Temporal Diffusion Convolutional Network: A Novel Framework for Taxi Demand Forecasting." *ISPRS International Journal of Geo-Information* 11, no. 3 (2022): 193.
- [32] Xu, Ying, and Dongsheng Li. "Incorporating graph attention and recurrent architectures for city-wide taxi demand prediction." *ISPRS International Journal of Geo-Information* 8, no. 9 (2019): 414.