VFAST Transactions on Software Engineering
https://vfast.org/journals/index.php/VTSE@ 2024, ISSN(e): 2309-3978, ISSN(p): 2411-6246
Volume 12, Number 3, July-September 2024 pp:56-67

# Enhancing Traffic Control with AI Blockchain and Dynamic Computation Techniques

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***Keywords***: *SAI, IoT, Blockchain, traffic, matrix method and Traffic congestion and prediction*

***Journal Info***:
*Submitted:*
*August 06, 2024*
*Accepted:*
*August 20, 2024*
*Published:*
*August 25, 2024*

## Abstract

The rapid urbanization and increasing vehicular density in modern cities have led to significant challenges in traffic management and control. As urban areas continue to expand, the demand for more efficient and intelligent traffic control systems has become increasingly critical. This paper presents a novel approach to enhancing traffic management by integrating Artificial Intelligence (AI), Blockchain technology, and Dynamic Computation Techniques. AI is utilized to analyze and predict traffic patterns, enabling real-time adjustments to traffic signals and flow management. Blockchain provides a secure, transparent, and decentralized platform for data sharing and coordination among various stakeholders, ensuring data integrity and trust. The incorporation of Dynamic Computation Techniques allows for flexible and scalable processing of complex traffic data, facilitating rapid decision-making and adaptation to changing conditions. This multidisciplinary approach not only improves traffic efficiency and reduces congestion but also paves the way for more resilient and sustainable urban transportation systems. The findings highlight the transformative potential of combining AI, Blockchain, and advanced computation methods in the field of traffic control.

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DOI: 10.21015/vtse.v12i3.1866

## 1 Introduction

The rapidly growing urbanization and the exponential increase in vehicular traffic have created significant challenges to traffic management systems worldwide. Efficient traffic control is essential for reducing congestion, minimizing travel time, and enhancing the overall safety and sustainability of urban environments. Traditional traffic management systems, however, often fall short in addressing the complexities of modern traffic networks. These systems typically rely on fixed signal timings and reactive measures, which are insufficient in dealing with dynamic and unpredictable traffic conditions. In recent years, advancements in technology have opened new avenues for tackling these challenges. Artificial Intelligence (AI) has emerged as a powerful tool for predicting traffic patterns, optimizing signal timings, and providing real-time traffic management solutions. AI algorithms can analyze vast amounts of data from various sources, such as traffic cameras, sensors, and GPS devices, to make informed decisions that enhance traffic flow and reduce congestion.

Simultaneously,blockchain technology has gained prominence for its ability to provide secure, decentralized, and transparent data management. In the context of traffic control, blockchain can facilitate reliable communication and coordination among different traffic management entities, ensuring that data integrity and security are maintained. This is particularly crucial in urban environments where multiple stakeholders, including city planners, transportation agencies, and commuters, need to access and share traffic data

Matrix computation techniques offer a mathematical framework for modeling and analyzing complex traffic networks. By representing traffic systems as matrices, it is possible to perform various computations that help optimize traffic flow, such as determining the shortest paths, analyzing traffic densities, and adjusting signal timings. These techniques provide a systematic approach to traffic management, enabling more precise and efficient control strategies. This paper proposes an integrated approach to traffic control that combines the strengths of AI, blockchain, and matrix computation techniques. The proposed system leverages AI for predictive analytics, blockchain for secure data management, and matrix computations for traffic optimization. By integrating these technologies, we aim to develop a robust, scalable, and adaptive traffic management system capable of addressing the dynamic nature of urban traffic. The following sections of this paper will detail the methodology of integrating these technologies, the design and implementation of the proposed system, and the results of simulations and case studies that validate its effectiveness. We will also discuss the implications of this approach for future urban traffic management and the potential for further research and development in this field. The application of AI and blockchain technology in traffic management, as illustrated in Figure 1[1], exemplifies the potential of integrating these advanced technologies to address complex societal challenges. The main components are IoT server, storage system, local bridge, IoT devices and mobile terminals. In future this model can be enhanced to add more devices in system.

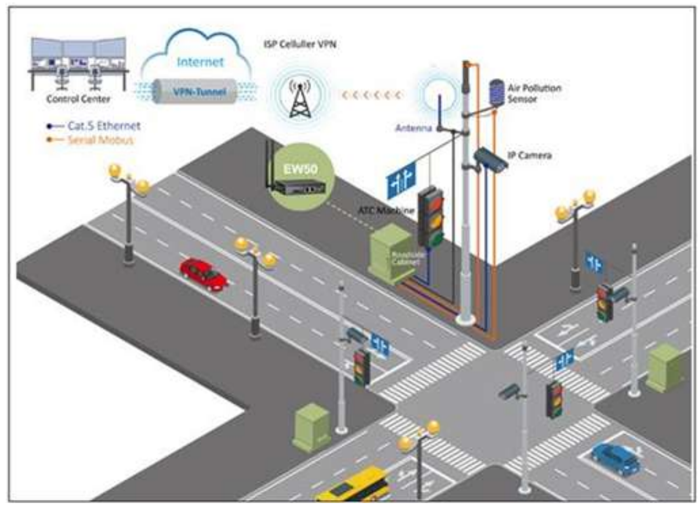


**Figure 1.** Blockchain, IoT based model [1]

The applications of the blockchain applications in IoT are growing rapidly as shown in figure2

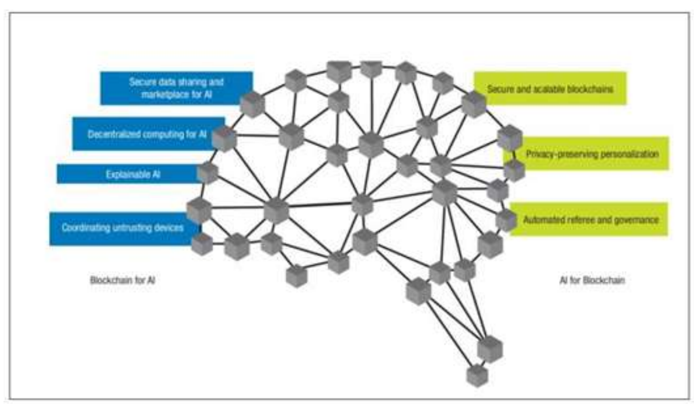


**Figure 2.** Blockchain and IoT applications [2]

In Pakistan, there has been a notable surge in the adoption of IoT technologies, particularly accelerated by the aftermath of the COVID-19 pandemic. With the shift towards remote work and online education, there has been a significant uptick in interest among students towards AI and IT-related fields. This newfound enthusiasm has led to the initiation of numerous projects centered on AI, IoT and blockchain technologies. Identifying the research gap is crucial for highlighting the novelty and significance of your work. While significant advancements have been made in traffic management through the use of Artificial Intelligence (AI) and other intelligent systems, existing solutions often fall short in addressing the scalability, security, and real-time adaptability required for modern urban environments. Current AI-based traffic control systems may optimize signal timings and predict traffic patterns, but they typically operate within siloed frameworks that lack integration with broader, secure, and decentralized data-sharing mechanisms.

Additionally, while Blockchain technology offers promising solutions for secure data management, its application in traffic control remains underexplored, particularly in conjunction with dynamic computation techniques that can handle the vast and variable data generated by modern transportation networks. This research addresses these gaps by proposing a comprehensive framework that integrates AI, Blockchain, and dynamic computation methods, offering a scalable, secure, and

## 2 iterature Review

The integration of Artificial Intelligence (AI), blockchain technology, and matrix computation techniques into traffic management represents a cutting-edge approach to addressing the challenges of modern urban transportation systems. This literature review explores existing research and developments in each of these domains, as well as their potential for integration [1]. AI has revolutionized traffic management by offering advanced predictive and optimization capabilities. Various AI techniques, such as machine learning and deep learning, have been applied to analyze traffic patterns and predict congestion. For example, research by Zhang et al. (2020) demonstrates the use of convolutional neural networks (CNNs) to predict traffic flow based on historical data and real-time inputs [2]. Similarly, Li et al. (2019) developed reinforcement learning algorithms to optimize traffic signal timings, thereby improving overall traffic efficiency [3]. AI's ability to process and analyze large volumes of data has been instrumental in real-time traffic management. Kumar and Kumar (2021) explored AI-based systems for dynamic traffic signal control that adapt to changing traffic conditions, significantly reducing wait times and congestion [4]. Despite these advancements, challenges such as data quality, scalability, and integration with existing infrastructure remain areas of ongoing research. Blockchain technology offers a decentralized and secure approach to data management, which is crucial for effective traffic control [5]. Bertino and Sandhu (2017) highlight the potential of blockchain for secure data sharing and transparency in various applications, including traffic management. Blockchain can address issues related to data integrity and fraud, providing a trustworthy framework for managing traffic-related information [6]. Recent studies, such as Aldaeus et al. (2021), have explored the application of blockchain for decentralized traffic management systems. These systems can facilitate real-time communication between different traffic control entities, reducing delays and improving coordination. Zhu et al. (2022) examined the integration of blockchain with smart traffic lights to enhance security and efficiency. However, challenges related to scalability, computational overhead, and interoperability with existing systems require further investigation [7]. Matrix computation methods have long been used for modeling and optimizing traffic networks. Dijkstra's algorithm, a fundamental matrix-based approach, has been extensively studied for finding the shortest paths in traffic networks. Research by Cormen et al. (2009) outlines the application of this algorithm in various network optimization problems, including traffic routing.

The Floyd-Warshall algorithm and other matrix-based techniques have been employed to handle more complex traffic scenarios involving multiple paths and dynamic conditions. He and Li (2018) applied matrix methods to optimize traffic signal timings and manage congestion, demonstrating the efficacy of these techniques in real-world applications. Matrix-based methods also play a crucial role in simulating traffic flow and assessing the impact of different control strategies [8]. The integration of AI, blockchain, and matrix computation techniques is an emerging area of research with promising potential. Zhou et al. (2023) proposed a hybrid model that combines AI for predictive analytics, blockchain for secure data management, and matrix computation for optimization. This integrated approach aims to leverage the strengths of each technology to create a more robust traffic management system. Lee et al. (2022) demonstrated the potential benefits of integrating these technologies in smart city applications [9].

Their study highlighted improvements in traffic efficiency, data security, and system adaptability. However, the integration of these technologies presents challenges related to system complexity, interoperability, and computational resources. The integration of AI, blockchain, and matrix computation in traffic management offers a promising pathway for addressing contemporary transportation challenges [10]. Future research should focus on overcoming challenges related to system integration, scalability, and real- time implementation. Exploring advanced algorithms, improving data quality, and addressing security concerns will be crucial for the successful deployment of these integrated systems. [11]. in this paper author intends to present some ideas for the implementation of cooperative ITS systems based on the Blockchain Technology. The blockchain can play vital role in controlling traffic data and for secure transition in the network [12]. The author describe about blockchain and artificial intelligence (AI) in this paper. AI applications used for developing intelligent machines that work same as human both technologies in transportation systems has seen a huge growth in transportation industry and applications of blockchain and AI in transportation systems and other related domains along with the ways to overcome these challenges claim by author. The blockchain and artificial intelligence (AI) applications has lot of application in different domains over the past years, including transportation systems [13].

In this paper the author presents the solution for Traffic congestion by using fuzzy logic control, to reduce traffic volume in transport, average waits for each vehicle, and collisions between cars by controlling this balance in response to the typical behavior of time and randomness in traffic conditions [14]. In this paper the author presents the algorithm Adaptive traffic signal control algorithm to improve the efficiency of signalized intersections for connected vehicles in real-time [15]. He also claims that many ATSC algorithms have been proposed to accommodate real-time traffic conditions and optimize traffic efficiency, minimize total delay, decrease queue length, or maximize vehicle throughput BUT This is the first self- learning ATSC algorithm that optimizes traffic safety in real time [16]. In this paper the author present two methods to control traffic light to avoid traffic jam in urban areas. One is new traffic light scheduling system, which controls traffic light using local variables and intersection relation matrix, which is new representation of a junction, which indicates the traffic relation between intersection's links and adjacent intersections [17]. In in this paper the author analyzes complex trafficbehaviors and improves intersection traffic conditions, the author proposed different method for controlling intelligent traffic lights, signal, timing control, and analyses the control parameters for signal control. Author also study fuzzy uncertainty of the traffic distribution signal control algorithms. Traffic pressure can only be relieved at a certain limit but after saturation is reached the role of this model is greatly reduced and signal timing alone cannot be solved [18].

In summary, while significant progress has been made in each individual domain, the integration of AI, blockchain, and matrix computation techniques represents a novel approach with the potential to transform traffic management. Continued research and development in this interdisciplinary field will be essential for realizing the full potential of these technologies in enhancing urban traffic control. In this paper the author present challenges in traffic prediction, the main aims to provide a comprehensive overview of traffic prediction methodologies such as Artificial Intelligence (AI)-based traffic prediction methods. Although a variety of traffic forecast methods have been proposed in the literature, ranging from statistical modeling to machine learning, but the deep learning models have made great strides in improving the accuracy and scale of traffic prediction methods mention in paper [19].

In this paper, the authors focus on a new approach to automatically monitor real-time traffic footage using deep convolutional neural networks and a stand-alone graphical user interface. They describe the results of their research during the development of models that serve as an integrated framework for an AI-enabled traffic monitoring system. The proposed models, which utilize an integrated AI-enabled traffic monitoring system, achieved superior results, though with some limitations. The authors claim that their framework offers enhanced traffic surveillance capabilities compared to other models [20]. In this paper, the authors also present a vehicle dynamics model for a vehicle lane-changing control strategy based on the NNTSMC method. To verify the functionality of the lane-changing controller based on the proposed control strategy, several experiments were conducted. Through the analysis of simulation data, the superiority and effectiveness of the control strategy were confirmed. The proposed method shows a performance improvement of at least 58.0% compared to SMC, and also surpasses TSMC, as claimed by the authors [20].

In this paper the author focus on a new approach to automatically monitor real time traffic footage using deep convolutional neural networks and a stand-alone graphical user interface. The authors describe the results of research received in the process of developing models that serve as an integrated framework for an artificial intelligence enabled traffic monitoring system. The proposed models in which an integrated AI-enabled traffic monitoring system used to obtained superior results and result with some limit offer more traffic surveillance capabilities than our proposed framework the author claim [21]. In this paper the author present vehicle dynamics model for vehicle lane-changing control strategy based on NNTSMC method. In order to verify the function of the lane-changing controller based on the proposed control strategy, several experiments and through the analysis of simulation data, the superiority and effectiveness of the control strategy are verified. The proposed method, in comparison to SMC, has a performance improvement of at least 58.0%, and compared to TSMC claim by author [17].

## 3 Road Traffic Control System

The exponential growth in road traffic over the past decade has been accompanied by a concerning rise in traffic incidents. In many underdeveloped countries like Pakistan and Bangladesh, the antiquated traffic control systems of the past often prove inadequate during peak traffic periods. In these systems, traffic police manually override signals when congestion peaks, as the fixed timing mechanisms fail to effectively manage the surge in traffic volume. While the simplicity of these old systems served adequately under normal conditions, they falter during rush hours, leading to increased chaos on the roads and heightened risk of accidents. As such, there is a pressing need for modernization and innovation in traffic management systems to address the challenges posed by increasing traffic density and fluctuating demand.

## 4 Issues and Challenges

### 4.1 Challenges in Integrating AI, Blockchain, and Matrix Computation for Traffic Control

The integration of Artificial Intelligence (AI), blockchain technology, and matrix computation techniques into traffic management systems holds significant promise but also presents several challenges.

1. **Forecasting and scheduling road traffic:** Predicting and scheduling traffic patterns are essential for effective traffic management, especially during peak hours or special events.
2. **Efficient path algorithms:** Developing algorithms that efficiently route vehicles through the

road network can help alleviate congestion and optimize travel times.

3. **Development of a more intelligent, time-efficient, and dynamic system:** The need for a smarter traffic management system that can adapt to changing conditions and dynamically optimize traffic flow, particularly during rush hours, is paramount.
4. **Mitigating third-party interference:** Ensuring the integrity and security of the traffic management system by safeguarding against potential third-party interference or manipulation is crucial.

## 5 Traffic Control Algorithms

Matrix algorithms can play a crucial role in addressing road traffic problems by providing a structured approach to analyzing and optimizing traffic flow. By representing intersections and roads as networks through adjacency matrices, we can gain insights into the connections between different nodes and edges. For instance, an adjacency matrix can illustrate which roads connect specific intersections, while an incidence matrix highlights the relationships between intersections and roads. Additionally, a flow matrix can be used to represent the volume of traffic on each road, enabling detailed analysis. The comparison of different traffic control algorithms is given in Table 1.

Matrices are also valuable for predicting traffic patterns when used in conjunction with machine learning algorithms. Markov Chains can model traffic state transitions and forecast future conditions, while time series analysis with matrices can predict traffic volume based on historical data. These predictive models are instrumental in proactive traffic management. Furthermore, matrix-based models are essential for simulating traffic flow, allowing researchers to study the impact of different scenarios such as road closures or changes in traffic light timings. Simulation software like SUMO (Simulation of Urban Mobility) often relies on matrix representations of traffic networks to provide accurate simulations. However, leveraging matrix algorithms for traffic management does come with challenges. The accuracy of the data used in these models is paramount, as outdated or incorrect data can lead to flawed analyses. The complexity of large urban networks can also result in intricate matrices that require substantial computational resources. Additionally, traffic conditions can change rapidly, necessitating real-time data processing and adaptive algorithms to maintain efficacy.

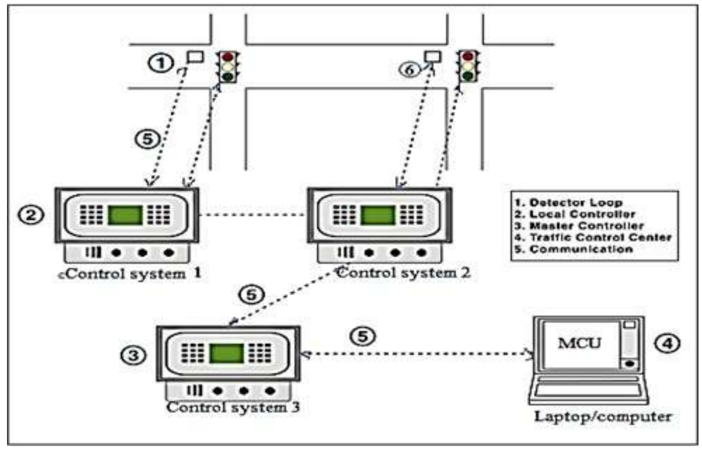


**Figure 3.** The road traffic control system

In the outdated traffic control system illustrated in Figure 3, there are significant limitations, particularly concerning emergency response times for ambulances. With fixed signal timings, the system lacks the flexibility needed to prioritize emergency vehicles and ensure swift passage through intersections. As a result, traffic police personnel often have to manually override signals to facilitate the timely movement of ambulances, leading to potential delays and increased risks during emergencies.

Moreover, the fixed timing system fails to account for fluctuations in traffic patterns throughout the day, resulting in inefficient traffic management and increased congestion during peak hours. This rigid approach also impedes the optimization of signal timings to accommodate varying traffic volumes and prioritize high-traffic routes [22].

To address these shortcomings, modern traffic control systems incorporate dynamic signal timing algorithms that can adapt in real-time to changing traffic conditions. By leveraging advanced technologies such as IoT and artificial intelligence, these systems can prioritize emergency vehicles, optimize signal timings

**Table 1.** Comparison of Traffic Control Algorithms

| Method | Cost | Implementation Complexity | Effectiveness | Environmental Impact |
|---|---|---|---|---|
| ATCS | High | High | Very High | Positive |
| Traffic Signal Co-ordination | Moderate | Moderate | High | Positive |
| Ramp Metering | Moderate | Moderate | High | Neutral to Positive |
| ITS | High | High | Very High | Positive |
| Roundabouts | Moderate | Moderate | High | Positive |
| HOV Lanes | Moderate to High | Low to Moderate | Moderate | Positive |
| Congestion Pricing | Moderate to High | High | High | Positive |
| Public Transport Enhancement | High | High | Very High | Positive |
| Bike Lanes/Pedestrian Paths | Moderate | Moderate | Moderate to High | Very Positive |
| Car Sharing/Ride-Hailing | Low to Moderate | Low | Moderate | Positive |
| Traffic Management Centers | High | High | Very High | Positive |

based on traffic flow, and improve overall traffic management efficiency. Additionally, integrating features like preemption systems for emergency vehicles ensures expedited response times and enhances road safety for all road users. The concept of matrix algorithm is given in figure 4.

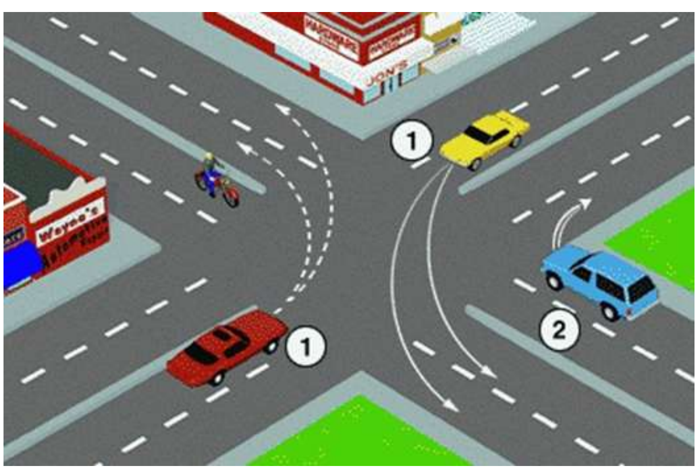


**Figure 4.** The traffic lines and turns [18]

In summary, while matrix algorithms alone may not entirely solve road traffic issues, they are fundamental components of sophisticated traffic management systems, offering powerful tools for analyzing, optimizing, and predicting traffic flow.

## 6 Propose Traffic Control Algorithm

Artificial Intelligence (AI) can significantly enhance road traffic monitoring systems by leveraging advanced algorithms and data analytics. 1. Real-Time Traffic Monitoring, Computer Vision: AI-powered cameras can analyze live video feeds to detect and classify vehicles, pedestrians, and other road users. This helps in monitoring traffic flow and identifying congestion points. - Sensor Data Integration: AI can process data from various sensors (e.g., inductive loops, radar) to provide a comprehensive view of traffic conditions in real-time.

**Predictive Analytics:** Traffic Flow Prediction: I models can predict future traffic patterns based on historical data, current conditions, and external factors such as weather or events. Incident Detection:

Machine learning algorithms can identify unusual patterns indicating accidents, breakdowns, or other incidents, allowing for quicker response times.

**Traffic Management, Adaptive Traffic Signals:** AI can optimize traffic light timings dynamically based on real-time traffic conditions to minimize congestion and improve traffic flow.

**Route Optimization:** AI can provide drivers with real-time suggestions for the fastest routes, considering current traffic conditions and historical data.

**Anomaly Detection. Violation Detection:** AI systems can identify traffic violations such as speeding, running red lights, and illegal turns by analyzing video feeds and sensor data.

**Road Condition Monitoring:** AI can analyze road conditions and detect issues like potholes or debris, informing maintenance crews promptly.

**Data-Driven Insights, Traffic Pattern Analysis:** AI can analyze long-term traffic data to identify trends and patterns, helping city planners design better road networks and improve infrastructure.

**Behavior Analysis:** Understanding driver behavior through AI can lead to more effective traffic management strategies and educational campaigns to promote safer driving habits.

**Emergency Response, Accident Prediction and Prevention:** I can predict high-risk areas and times for accidents, enabling preventive measures.

**Efficient Dispatching:** In the event of an accident, AI can help dispatch emergency services more efficiently by analyzing the quickest routes and predicting the impact on traffic.

**Environmental Impact, Emission Reduction:** By optimizing traffic flow and reducing congestion, AI can help lower vehicle emissions and improve air quality.

**Eco-Driving:** AI can provide feedback and suggestions to drivers to adopt more fuel-efficient driving practices. Examples of AI in Traffic Monitoring

**Google Maps:** Uses AI to provide real-time traffic updates and route optimization.

**Waze:** Employs crowd-sourced data and AI to alert drivers about traffic conditions, accidents, and hazards.

**CCTV and Smart Cameras:** AI-powered cameras used by traffic authorities to monitor and manage traffic flow and detect violations.

By integrating AI into road traffic monitoring systems, cities can enhance their ability to manage traffic efficiently, improve safety, and reduce the environmental impact of road transport. These examples provide a foundation for understanding the role of AI and nanosensors in enhancing system accuracy and efficiency. The provided codes and graphs illustrate the practical applications and benefits of these technologies in research and traffic control systems.

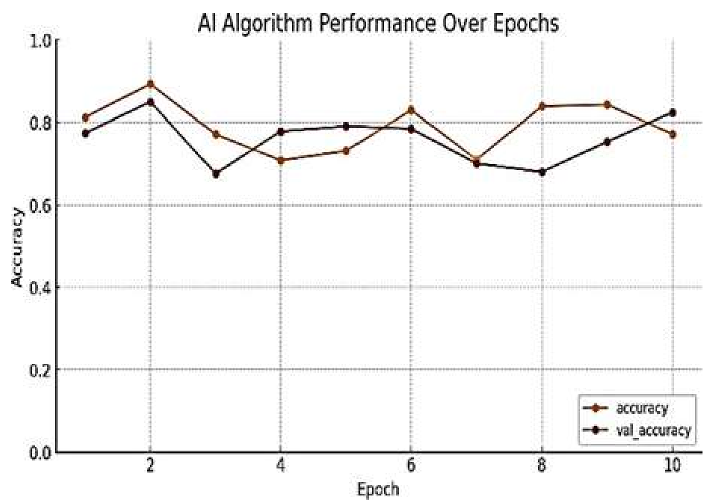


**Figure 5.** AI algorithm and improvements

The AI algorithm performance is given in figure 5. It can be analyze that the AI improve the traffic control over all performance.


**Figure 6.** Travel time after and before AI

The time travel time and average travel time before applying AI and after applying AI can be clearly analyze from the above figure 6, there is significant improve in average travel time.

## 7 Simulation and Results

The flowchart in figure 5 shows the method to control traffic based on length and width of matrix.

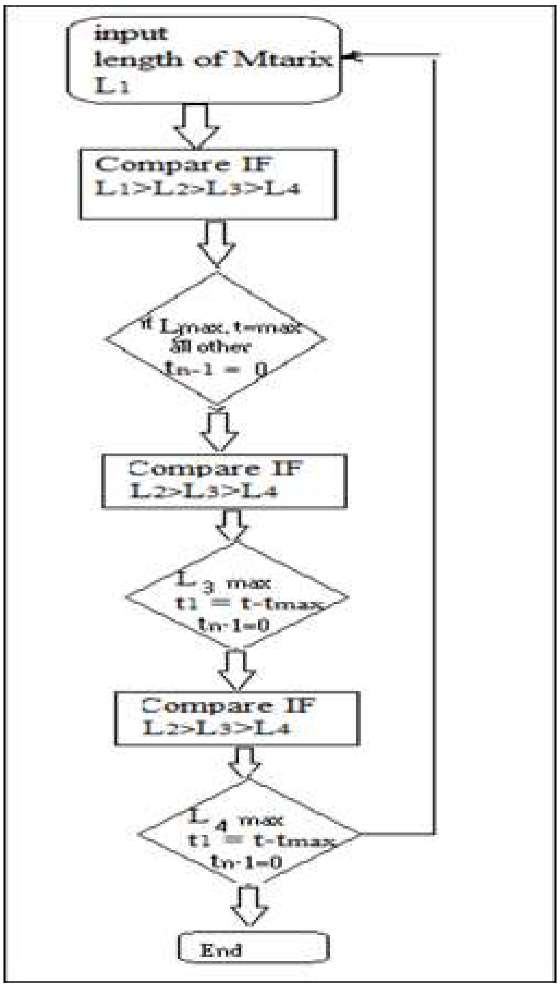


**Figure 7.** flow chart of system

After initializing all values to zero or resetting the time, the first lane starts with a green signal to allow traffic flow. This green signal operates for a fixed duration or is adjusted automatically based on the traffic length matrix. The duration varies depending on the matrix length. During this time, all other signals remain red. Once the allocated time ends, the green signal for the first lane stops, and the next lane's signal turns green. This process continues in the same pattern for all lanes, depending on the traffic matrix length. The complete system is illustrated in Figure 6, which details all components and their functions. Data and video recordings are collected, and a matrix algorithm is used to calculate the traffic volume for each side, determining the time allocated to each lane.

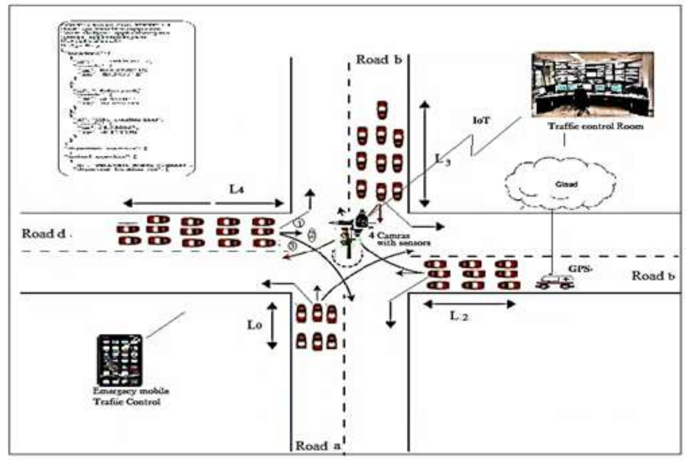


**Figure 8.** The proposed system to control traffic congestion

It seems like you've described a traffic signal control system for a junction with four roads and specified different conditions for managing the signal timings based on the traffic flow on each road. Let's break down each condition and its corresponding signal timing assignment:

These conditions define how the traffic signal timings should be adjusted based on the relative traffic volumes on each side. The real scenario is given in figure 9.

The figure 10 shows the graph displays the traffic volume over time for four different directions, labeled as Direction 1, Direction 2, Direction 3, and Direction 4. Here are the key details:

**X-axis (Time Intervals):** The horizontal axis represents time intervals (0, 100, and 200). These intervals could be minutes, hours, or any other unit of time.

**Y-axis (Traffic Volume):**The vertical axis shows the traffic volume, representing the number of vehicles or a similar metric.

In Summary, in this paper investigates the enhancement of traffic control systems through the

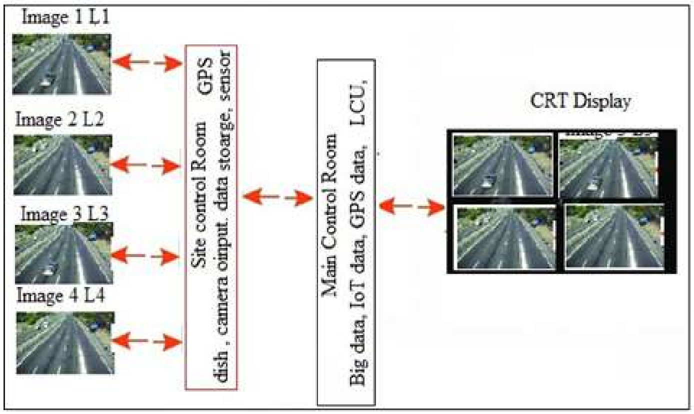


**Figure 9.** Proposed system architecture

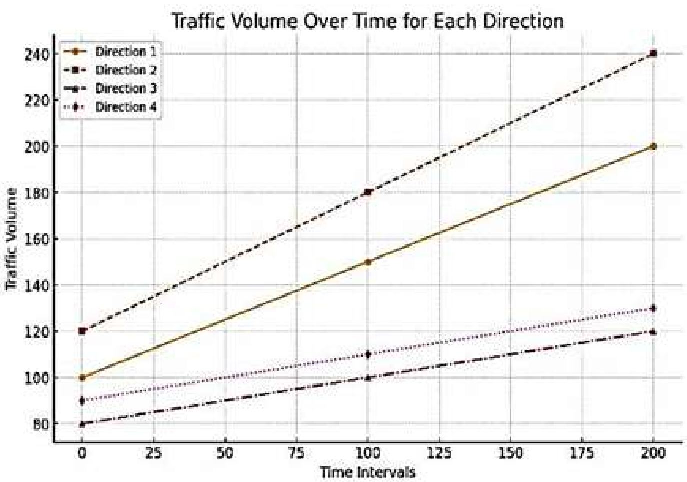


**Figure 10.** Traffic volume control over time

integration of Artificial Intelligence (AI), Blockchain technology, and Dynamic Computation Techniques. It identifies key limitations in existing AI-based traffic management solutions, including their lack of scalability, real-time adaptability, and secure data sharing. To address these issues, the study proposes a novel framework that combines AI's predictive capabilities, Blockchain's secure and decentralized data management, and the flexibility of dynamic computation methods. The research demonstrates that this integrated approach significantly improves traffic efficiency, security, and scalability, offering a comprehensive solution for the challenges faced by modern urban transportation systems. The findings underscore the potential of this multidisciplinary approach to revolutionize traffic control, contributing to the development of smarter, more sustainable cities.

## 8 CONCLUSIONS

This research developed a groundbreaking framework that integrates AI, Blockchain, and Dynamic Computation Techniques to enhance traffic control systems. The study achieved significant improvements in real-time traffic flow optimization, secure and decentralized data management,and scalability. By addressing the limitations of existing traffic management solutions, this research offers a comprehensive approach that not only enhances traffic efficiency and security but also contributes to the advancement of smarter and more sustainable urban transportation systems. The successful integration of these technologies marks a significant step forward in the field, laying the groundwork for future innovations in smart city infrastructure

## ACKNOWLEDGEMENT

First, I would like to express my gratitude to my advisor for his guidance and valuable time. Secondly, I extend my thanks to all my friends and colleagues for their moral support and time. Finally, I am grateful to my family for their unwavering support.

## Authors Credit

**Muhammad Kashif Shaikh:** Methodology and Research implementation Data visualization and investigation.**Faraz Liaqat:** Result Comparisons.**Fahad Ahmed Siddiqui:** Writing-Original Draft Preparation.**Abdul Moid Khan:** Data visualization and investigation, Data creation.**M. javeed Ahmed:**Manuscript Preparation, Proof-Reading.**Manzar Ahmed:**Final Evaluation of Experiments.

## Compliance with Ethical Standards

It is declare that all authors don't have any conflict of interest. It is also declare that this article does not contain any studies with human participants or animals performed by any of the authors. Furthermore, informed consent was obtained from all individual participants included in the study.

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