

# Urban Traffic Optimization Using AI

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**Abstract:** Urban traffic is a problem in modern cities. It makes our travel time longer we use fuel and the air gets polluted. The old way of controlling traffic signals does not work well because it cannot adapt to the changing traffic. This paper talks about a way to manage urban traffic using Artificial Intelligence. It uses real time traffic data learning to predict traffic congestion and reinforcement learning to control traffic signals. We use a kind of computer network called Long Short- Term Memory to understand traffic patterns over time. Another kind of network called Deep Q-Network helps to adjust the traffic signals. We tested this system using a simulator called SUMO to see how well it works in traffic conditions. The results show that this system reduces the number of cars waiting in line and the time they wait compared to the way of controlling traffic signals. The new approach is good, for traffic management systems because it is scalable and efficient.

**Keywords:** Artificial Intelligence, Traffic Signal Optimization, Deep Learning, Reinforcement Learning, Intelligent Transportation Systems, Smart City.

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## I. INTRODUCTION

Urban traffic congestion is a problem in cities that are growing really fast. This is because more people are buying cars the population is. Cities are not being planned very well. When traffic is congested for a time it causes a lot of problems like delayed travel, wasted fuel and harm to the environment. This affects how well the economy does and the health of the people. The usual way traffic lights are controlled is by using a fixed schedule. This means that each traffic light stays green for the amount of time no matter how busy the road is. This system is easy to set up. It does not work well because it cannot adapt to changes in traffic. Traffic is always changing, during busy and quiet times of the day.

Some new ways of controlling traffic were developed to make the old system better. These include systems like SCOOT and ALINEA which try to optimize traffic flow by looking at what's happening in real time. However, these systems are limited because they rely on math models and do not have information about what is happening on the roads. They also cannot manage the way traffic works in cities. When traffic is not managed well across intersections it causes problems like long waiting times some lanes being

used more than others and more pollution. These old math-based systems are not good at predicting traffic problems before they happen so they mostly just react to problems that're already there. Urban traffic congestion and traffic management systems, like SCOOT and ALINEA need to be improved to make cities better places to live. Urban traffic congestion is an issue that affects everyone who lives in a city and uses traffic management systems.

The development of Intelligent Transportation Systems and the latest progress in Artificial Intelligence have created chances for changing the way we manage traffic into systems that are controlled by data and work on their own. Some computer models, like Long Short-Term Memory networks are really good at understanding how traffic changes over time and finding patterns that're not straightforward, which helps us predict when traffic will be bad in the short term. At the time techniques like Q-learning and Deep Q-Networks allow traffic controllers to learn the best ways to time traffic signals by interacting with the traffic in real time. These systems that use Artificial Intelligence to adapt to changing conditions have consistently shown that they can do better than methods in reducing the time people wait in traffic and improving the flow of traffic.

With all the new technology many systems that are already in use still focus on either predicting traffic or optimizing signals but not both at the same time. They are missing a system that combines both parts. To fix this problem this paper suggests a framework for optimizing urban traffic that uses Artificial Intelligence. This framework includes getting data from Internet of Things sensors in time using Long Short-Term Memory networks to predict traffic congestion and using Deep Q-Networks to control traffic signals in a way that adapts to changing conditions. By changing the length of time traffic signals stay green based on both the traffic and what it will be like in the future the system we are proposing aims to greatly reduce the average time people wait in traffic shorten the lines of cars waiting at intersections and use less fuel. In the end this approach that combines methods provides a solution that is efficient works well and helps achieve the goals of creating smart cities that are sustainable and have intelligent systems, for moving people around.

## II. RELATED WORK

Traffic management is something people have been studying for a time. It has changed a lot over the years from systems that always did the same thing to systems that can adapt and use artificial intelligence to make things better. A time ago people came up with ways to control traffic lights that could adjust to the traffic at the time. For example, the Split Cycle Offset Optimization. Scoot for short used measurements of the traffic to decide when to change the lights. Another system, called ALINEA used feedback to control how many cars could get on the highway at the time to prevent traffic jams. These systems were better than the way of doing things, which was to just have the lights change at the same time every day. They were not perfect because they relied on models that were created ahead of time and did not have very good ways of sensing what was happening on the road.

As technology got better people started to use data to try to predict what the traffic would be like. This is important because if you can predict the traffic, you can do things to prevent jams from happening in the place. At first people used statistical models to try to make predictions. These models were not very good at capturing how complicated traffic patterns can be. Then people started to use something called learning, which is a type of artificial intelligence. This was an improvement especially when people used something called Long Short-Term Memory networks or LSTM for short. These networks are good at looking at what happened in the past and using that to make predictions about what will happen in the future. Some researchers, like Das and his team used these kinds of models to make predictions about traffic flow. They were able to make accurate predictions but sometimes their models were not able to respond quickly enough to what was happening in real time. Traffic management systems like Intelligent Transportation Systems or ITS, for short are getting better and better at using data to make predictions and prevent traffic jams.

Reinforcement learning is a good way to control traffic signals in addition to modeling. It works well because it can learn from the environment. This is how it works: there is a method called Q-learning, which allows systems to learn from their surroundings without needing a model. Then Deep Q-Networks were developed, which can handle a lot of information about traffic. Several studies have used reinforcement learning methods. Reinforcement learning methods work well. For example, IntelliLight used a system that reduced the time it takes to travel. Research by Hussain and others in 2023 also used Deep Reinforcement Learning to control traffic signals. Deep Reinforcement Learning worked better than methods in complex traffic situations.

People are also looking at how to use intelligence with cloud computing and Internet of Things sensors. Some studies, like the one by Sinha and others in 2022 have made dashboards that use intelligence and cloud computing to control traffic in time. Even though we have made a lot of progress, with reinforcement learning and traffic optimization there are still some problems to solve. A lot of systems only look at either predicting traffic or optimizing signals. They do not do both. We need a system that can predict congestion using learning and also control traffic signals using reinforcement learning. We also need to figure out how to coordinate intersections make the system work fast in time and have a backup plan in case the system fails.

## III. PROPOSED METHODOLOGY

The system starts by getting traffic data in time using Internet of Things sensors and cameras at road intersections. These devices, such as loop detectors and infrared sensors collect traffic information like the number of cars on the road the length of traffic lines and the speed of the cars. Cameras use computer programs to detect cars and determine how crowded the road is. To ensure the traffic data reaches its destination small computers like ESP32 are used to collect and send the traffic information. The raw traffic data is then cleaned up by removing errors converting it into a format and filtering out unnecessary parts. This process makes the traffic data more useful and reliable for processing. The traffic data is collected from sources, including Internet of Things sensors and cameras to get a clear picture of the traffic situation. The data is then processed to extract insights, such as traffic congestion, speed and volume. The system relies on these insights to make decisions and optimize traffic flow. The Internet of Things sensors and cameras play a role, in collecting accurate and reliable traffic data.

To improve the traffic management, this system uses a computer-based program to predict the traffic also this program uses something called Long Short-Term Memory to look at what the traffic has been like in the past and what the traffic's like now and then it makes a good guess about what the traffic will be like soon. This is helpful because traffic in cities is very hard to predict and changes a lot over time. By looking at the traffic data the program can say what the traffic will be like soon and this traffic information is sent to the part of the system that makes decisions. This allows the system to

get ready for roads before they get really bad.

The system makes decisions using a kind of computer program that learns and gets better over time. This program looks at what's happening on the road, such as how many cars are waiting and how long the lines are and it uses this traffic information to figure out what to do. It does this by trying to make the waiting times and lines as short as possible. The program gets better at making decisions by trying things and seeing what works best. Finally, the system uses these decisions to control the traffic lights in time which makes the roads work better than they would if the traffic lights were just, on a set schedule. The traffic management system uses the traffic data and the decisions to make the traffic flow smoothly.

**IV. SYSTEM ARCHITECTURE**

The urban traffic optimization system that uses intelligence is made up of many parts. This system is designed to work with the city's infrastructure and to be able to handle a lot of information at the same time. The system starts with the Data Collection and Processing layer. This layer uses traffic sensors and cameras at road intersections to get information about the traffic.

By doing this work at the intersection the system can respond quickly. Send the information to the central processing systems in real time. The main work of the system happens in the AI Server and Cloud Platform layer. This layer gets the information from the Edge Processing Unit. Combines it with information that has been collected in the past. This information is stored safely in the cloud. The cloud platform can handle a lot of information. Can do the complex work that is needed for artificial intelligence. It also allows for monitoring of the traffic across intersections.

The Traffic Prediction and Optimization layer is where the artificial intelligence engines are. The two parts of these layers are the Traffic Prediction Model and the Optimization Algorithm. The Traffic Prediction Model uses deep learning algorithms to predict what the traffic will be like. The Optimization Algorithm uses strategies to figure out the best way to control the traffic signals. These models look at the information from the AI server. Use it to predict when there will be traffic jams and to determine how long the traffic signals should stay green. The information from these models is used to make decisions about how to optimize the traffic signals. The system also has an Adaptive Signal Control and Feedback layer. This layer looks at the traffic in time and evaluates how well the system is working. It also has a feedback loop that can detect problems with the traffic and send alerts. This feedback is sent back to the AI server, which uses it to make adjustments, to the traffic signals in time. The urban traffic optimization system that uses intelligence is always working to make the traffic flow better. The Traffic Prediction and Optimization layer is a part of this system. The urban traffic optimization system uses intelligence to make the traffic flow better.

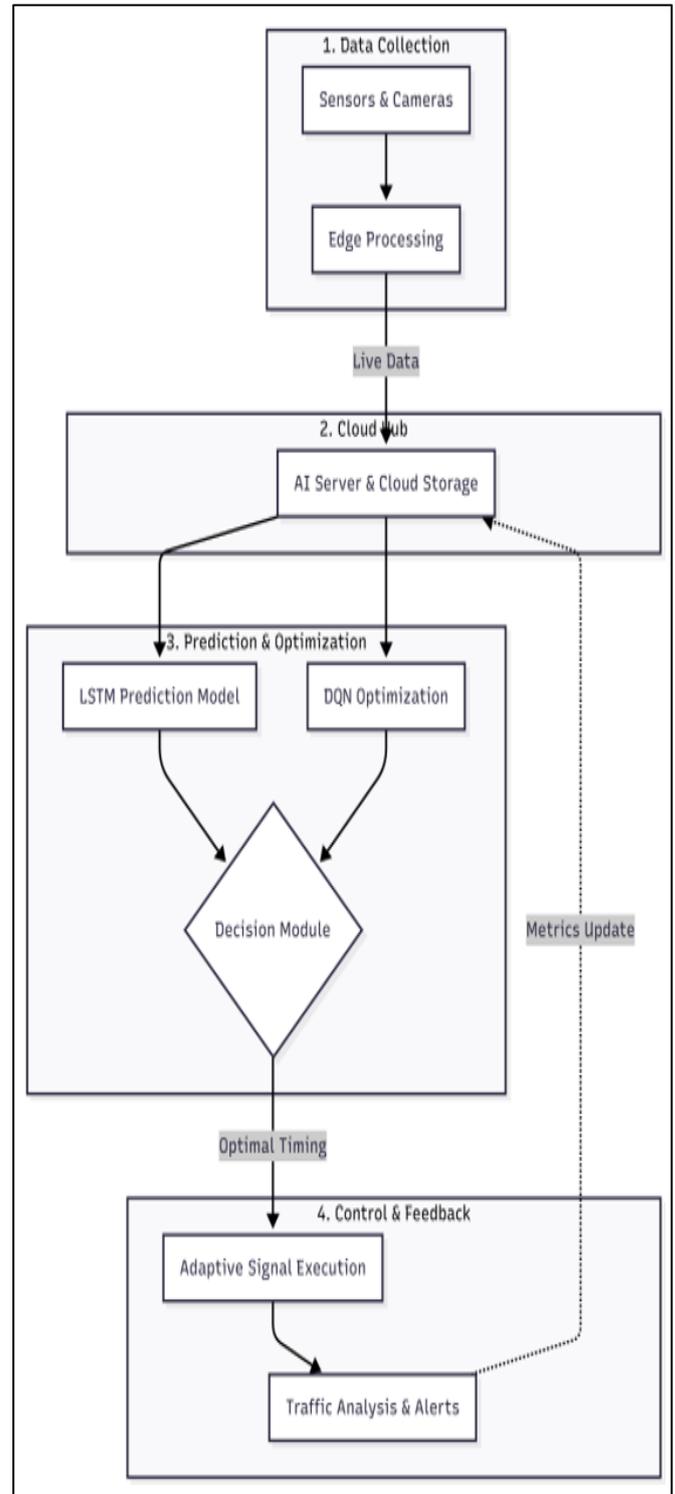


Fig 1 Architectural Workflow of the AI-Based Urban Traffic Optimization System, Illustrating the Seamless Integration of IoT Data Collection, Cloud-Based Predictive Analytics, and Dynamic Feedback Loops for Adaptive Signal Control.

**V. EXPERIMENTAL SETUP**

The setup for the traffic optimization system uses a mix of hardware and sensors to get real-time data. This system takes a look at things like how many cars are there on the road and how long the lines of cars are.

It also checks how fast these cars are going. The system uses cameras and special detectors to get all this information. These cameras are connected to computers that can find objects like cars on the road. The detectors can sense when a car is nearby. This information is then sent to a computer at the intersection that can process it away.

The software for this traffic system is written in Python because Python has a lot of tools for making systems like this traffic system. This traffic system uses something called TensorFlow to make and train the computer models that predict traffic and control the traffic lights. It also uses tools to get the traffic data ready, for the models. This includes

making sure the traffic data is consistent and finding the parts of the traffic data. This traffic system can even learn from its mistakes. Get better over time.

To make sure this traffic system works well and is safe it is tested using a simulator called SUMO. This simulator can mimic traffic and roads so it is a way to test the traffic system before it is used in the real world. The simulator can show how well this traffic system works compared to traffic light systems. This traffic system is run on a computer with a lot of memory and a special graphics card so it can handle all the traffic data from the traffic system.

Table 1 Experimental Environment and Toolchain

Component Category	Specific Technologies & Devices Used
Traffic Sensing Hardware	High-resolution surveillance cameras, Inductive loop detectors, Infrared/Ultrasonic sensors
Processing & Execution	ESP32 Microcontrollers, Edge processing units, Cloud servers
Programming Languages	Python, C++, Java
Deep Learning Frameworks	TensorFlow, Python libraries (NumPy, Pandas, Matplotlib)
Simulation Platform	SUMO (Simulation of Urban Mobility)
Computational Resources	Multi-core processor, 16 GB RAM, GPU acceleration

## VI. EXPERIMENTAL RESULTS

The urban traffic system that uses intelligence was thoroughly tested using the SUMO platform to see how well it manages traffic congestion in real time. This system was able to combine real time traffic data from sensors and edge processing units, which greatly reduced the time it took to communicate and make decisions. The traffic prediction model, which is called Long Short-Term Memory was trained using both new data to forecast traffic congestion levels. By using an algorithm instead of traditional fixed timings, the system was able to prioritize busy roads and reduce unnecessary delays in roads that are not busy.

Experiments were done to test the system under traffic conditions, including low, medium and high congestion. The adaptive signal control system, which uses Deep Q-Network reduced the time vehicles wait by 25 to 35 percent compared to systems.

The system also reduced the number of vehicles waiting in line by 20 to 30 percent during busy traffic times. This reduction is because the system can predict traffic

congestion and adjust the traffic signals before it gets worse.

The system also improved the efficiency of intersections and helped the environment. The number of vehicles that can pass through an intersection increased by 15 to 25 percent when traffic is heavy. This proves that our traffic system can work better by changing the traffic lights. The system helps vehicles spend time waiting, which means they use less fuel and produce fewer greenhouse gases. These are what we want for smart city plans and city movement.

Here are the results of comparing our AI traffic system to traffic lights in Table 2. Our system works well. Is easy to use in real life. It uses data and machine learning to handle city traffic. The system is good, at managing traffic.

The urban traffic system that uses intelligence is a good solution for managing traffic congestion. The urban traffic system is effective, in reducing traffic congestion and improving the environment. The urban traffic system is a component of smart city infrastructure and urban mobility.

Table 2 Quantitative Performance Comparison (Fixed-Time vs. AI-Based System)

Performance Metric	Traditional Fixed- Time System	Proposed AI-Based System	Observed Improvement
Average Vehicle Waiting Time	High (static allocation)	Dynamically reduced	25% – 35% Reduction
Average Queue Length	Severe during peak hours	Proactively managed	20% – 30% Reduction
Intersection Throughput	Static/Limited	Dynamically maximized	15% – 25% Improvement
Environmental Impact	High idle emissions	Reduced fuel consumption	Measurable Emission Drop

## VII. DISCUSSIONS

The traffic optimization system that uses intelligence is really good at making things better. It is better than the way of doing things where the traffic lights are always on the same schedule. This new system can change the traffic light times based on how many cars are on the road and if there will be traffic jams. It makes sure that people do not have to wait for a time when there are not many cars on the road. When there are a lot of cars on the road it gives them more time to go. This system is better than the one because it can change and adapt to the traffic. The old systems can only react to what's happening right now. This system uses something called the Long Short-Term Memory network to predict what will happen with the traffic. It can make changes to the traffic lights before the traffic gets really bad. It also uses computers at the intersections to make decisions really fast.

The system uses something called deep reinforcement learning to make the traffic lights work better. It is like a game where the system gets rewards, for doing things that make the traffic better. The system learned how to make the traffic lights work better by trying things and seeing what works best. This system can be used for intersections and it can be connected to the internet. Even though this system is really good it is not perfect. The traffic optimization system is really cool. It needs a lot of computer power to make the traffic optimization system work. Setting up the traffic optimization system takes a time. We have to be careful when we use the traffic optimization system in the world because a lot of things can go wrong with the traffic optimization system.

The tests we did with the traffic optimization system show that the traffic optimization system can really help with the traffic and make the city a better place. The traffic optimization system that uses intelligence is a way to reduce traffic jams and make the city a more pleasant place to live with the traffic optimization system.

## VIII. CONCLUSION

This paper is about making traffic lights work better in cities. It uses intelligence to fix the problems with the traffic lights. The old traffic lights were set to stay the same all the time or only change a bit. The new system uses Long Short-Term Memory to predict when traffic is going to get bad. It also uses Deep Q-Network to change the traffic lights in time. The Long Short-Term Memory part of the system looks at how traffic lights have been in the past and uses that to figure out when traffic is going to get congested. This helps the traffic lights system get ready, for the traffic before it gets really bad. At the time the Deep Q-Network part of the system is learning how to make the traffic lights work better. The traffic lights system is always trying to make traffic lights work better in cities using Long Short-Term Memory and Deep Q-Network. It does this by trying things and seeing what works best.

The people who made this system tested it using computer simulations. They found out that it can make

traffic lights work a lot better. It can make cars wait for amounts of time which is up to 35% less waiting time. It can also make the lines of cars which is 30% shorter. It can make the traffic flow better overall. This system is also good, for the environment. It helps cars use fuel and make less pollution. This is because the system can make the traffic lights work in a way that makes cars stop and wait often. The system shows that using intelligence to predict traffic and make traffic lights work better is a good idea. The traffic system uses traffic lights and the Long Short-Term Memory and the Deep Q-Network to make the traffic lights work better.

The future of this research is going to be about taking the proposed framework and using it in life. This means it will be used in a city with a lot of traffic. The main goal is to make the system work with intersections at the same time. This will be done by using learning methods that help the system make good decisions. The system will be able to manage traffic in a city not just one intersection. The system will also be able to find emergency vehicles like ambulances and fire trucks. When the system finds these emergency vehicles it will give them a light so emergency vehicles like ambulances and fire trucks can get to where they are going quickly. This will help people in emergency situations get the help they need faster.

The system will also use technology to talk to vehicles like ambulances and fire trucks and make sure everything is working properly with emergency vehicles like ambulances and fire trucks. This will help reduce delays and make the traffic system more reliable. The main goal of the traffic system is to make a traffic system that can work on its own and is good for the environment. This will be a change from how traffic is managed now. The traffic system will be able to learn and get better over time. This will help make cities smarter and more sustainable, with a traffic system.

## DISCLAIMERS

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