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Smart Traffic System Using Infrared Sensors-based IoT

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Abstract

One of the main problems in the intersection or cities of Iraq is that all people suffer from long waits, unexpected accidents, and environmental pollution at a time when developed cities seek to reduce it. Holy Karbala is one of the most important intersections in the middle of Iraq, it is always crowded due to the anniversary of millions of pilgrims (visitors). It was the proposed case study. Therefore, relying on cloud and Internet of Things (IoT) technologies, this study designed and implemented an intelligent traffic control network based on an intelligent programming control algorithm by utilizing sensors to improve the existing traffic network. This article presented a variety of challenges that it addressed. The results showed that a green signal takes three seconds to travel from one traffic light system to another. All five recommended scenarios were implemented, as described in the research details (TLS1, TLS2, TLS3, TLS4, and ring state) as the system is characterized by efficient response, ease of implementation, and satisfactory results with low cost (two types of microcontrollers (48 $) and infrared (IR) sensors ($3.54 per piece)) and without the difficult challenges associated with the curriculum as in the previous studies.

Keywords: Intelligent Control Traffic, IR Sensor, Cloud and IoT, Soft Computing.

1 Introduction

Growth in traffic (GIT) is a common issue that cities encounter due to population growth and urban progress. Traffic congestion, auto accidents, and rule violations at busy Traffic Light Signals (TLSs) are all included in the GIT. Every day, researchers strive for and create new technologies to make living more comfortable. People are leaving their homes with aspirations for a better future that will improve their standard of living and trends. People frequently deal with higher wait times and unexpected traffic congestion issues regularly; these issues are caused by inadequate ongoing traffic regulation. The traffic light control system has a one-year history (1868). when the first model was, implemented in "London". At this time, this technique could be found in all (Yogeshwar et al., 2020). The static control concept has been used in traffic management to control car movement. It does not mean controlling their movement in, relation to density, but rather static control in the system. Intelligent Traffic Control Network (ITCN) is a new concept appeared in recent years and it's still undergoing development. It depends on a fixed control system applied to TLSs. Many researchers have conducted, research regarding traffic control, focusing, on their knowledge of reducing pollution

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and accidents, that are expected to occur as a result, of the density of cars at traffic intersections (Ghazal et al., 2016; Zhuang et al., 2018; Mahjri et al., 2019; Firdous et al., 2019; Oliveira et al., 2019). Around the world, numerous algorithms and techniques for creating and implementing smart traffic light management systems have been proposed. Every ingenious solution that is given addresses a particular issue. Some of these traffic control strategies rely on digital camera components, or they depend on each road's comparison threshold value, or they use a complex traffic control algorithm like fuzzy logic (FL) (Kulkarni & Waingankar, 2007; Kamijo et al., 2000; Valera & Velastin 2005; Younes & Boukerche 2018; Mabrouk & Zagrouba 2018; AlRikabi et al., 2019; ALRikabi et al., 2020). The proposed control system was adopted for one of the most important intersections in the city of Holy Karbala / Iraq. A smart algorithm was applied to schedule the flow of vehicles within the traffic intersection of the highest density.

The rest of the article is structured as follows: Section 2 reviews some related studies. Section 3 explains the adopted methodology. Section 3.1 highlights the smart control systems, and then Sections 3.2 and 3.3 define cloud and IoT traffic management systems. Section 3.4 describes the hardware components. Section 3.5 focuses on the most significant software needs. 3.6 describes in detail the proposed system implementation and operation with all suggested scenarios with smart traffic are explained. Section 4 delivers the results and discussion. Finally, Section 5 presents a summary of the research, and the most important outcomes of the objective presented.

2 Related Work

There are several issues with traditional Traffic Light controllers. One of them is traffic congestion, no one has realized how to quantify the amount of this jam, particularly utilizing time delay (T_D). Another issue, that is even when there is no traffic, the waiting, continues (Vahedha, 2013). Both economic-development and population growth are variables that contribute to traffic congestion.

According to (Vidhya & Banu, 2014), congestion on road networks is a phenomenon that happens as the number of road users increases. This leads to slower speeds, longer route times, and longer wait times. Therefore, utilizing smart control models to handle traffic density has piqued the interest of many studies. According to a model study, the Smart Traffic Management System (STMS) that uses Radio Frequency (RF) Identification was dependent (Lanke & Koul, 2013). which proposed to overcome the disadvantages of the traditional traffic system such as high-implementation costs, reliance on, environmental conditions, and so on. The suggested approach tries to handle traffic congestion effectively at a low cost. The suggested system is not enhanced by a robust communication network such as GSM (Global System for Mobile). TranSyT (Transport Systems Tracker) modeling software was suggested for identifying the Optimal, Fixed, Signal, Plan (OFSP) (Tian & Zhang, 2017). Additionally, the traffic simulation software PTV Vissim was suggested for verifying and checking the TranSyT model and assisting in the decision of the OFSP to put up an adaptive, frame signal, plan and optimize, evaluate the plan basing, PTV Vissim, with VS- PLUS platform. It was proved via software that the late for the required time in ASC was significantly less than that in static, time regulation. While (Nilsson & Como, 2017) distribution rule is based on the generalized, ratio and centered on a Dynamic Traffic Signal (DTS) management class. It yields a differential Inclusive for which there is confirmation of the existence, as well as the authenticity of continuous solutions by an extension of the reflection principle in the particular, case of phases that are orthogonal to each other. The Generalized Proportional Allocation controller is defined as decreasing a specific entropy, function, which is utilized as a Lyapunov Function (also called Lyapunov's second method for stability) for the closed, system to demonstrate stability. In 2017, an oriented group signal control system could make judgments based on their intersecting traffic experience (Jin & Ma, 2017). The control problem is developed utilizing the automated stochastic control technique of the Multiagent system, in which each signal group is modeled as a smart agent. The developed technique is designed to operate with the existing signaling network. A genetic algorithm (GA) is used to optimize parameters off-line. Based on simulation results, the presented Adaptive Group based Control System (AG-CS) outperforms the upgraded GBVA-CS, owing to its adaptive, response capabilities and real-time learning to changes in traffic requirement. Under consumer equilibrium traffic, a new approach to adjust the signal meter at the target area was used. The model- -optimization was created as a multi-dimensional search issue to minimize the product of whole travel, time (T_t) associated with the urban, street, network, and variation of journey time per unit travel distance. A genetic, algorithm was created to generate model solutions (Gheni et al., 2024). To build the logic frame additional for the functional unit available in the area to manage traffic signals, protocol-simulation management developed in the "Paramics" Provides a software platform that works on good management and adopts an accurate realistic micro-simulation system. Its findings revealed that mobility improvements can be achieved by combining the researcher presented an algorithm that focuses on the time of the signal to start traffic. The available energy and the rate of low and high movement are adopted. In addition to the delays, throughout, as well as the average and variance of T_t per distance (AL-Nabi et al., 2024). Simulated a traffic control system based on an Infrared (IR) transmitter/ receiver sensor unit and an at mega 32 microcontroller processing unit. Based on sensor data, the system determines the vehicle numbers and takes the necessary actions to successfully clear the path. Nevertheless, it has several limitations, including not being manually controlled. These problems can be resolved manually. Many smart control models have been introduced recently to reduce the complexity of the earlier techniques. Shanmugasundar et al., (2020) developed a control model for an Internet of Things traffic control system based on utilizing an Arduino, a microprocessor, and an IR sensor. The autonomous start signal programmed via the control unit is based on density sensors, in addition to the possibility of manual control of the signal. A digital camera has been added to the proposed control model to overcome traffic jam problems (Abdul-hamza et al., 2023). The proposed system also achieved synchronization at 4- line intersections and implement balance between number of cars at each line and passing color. After implementing the suggested control system, the average waiting time (WT) was improved for every traffic intersection and decreased to an average of five to six minutes. (Dzulkefli et al., 2020) demonstrated a Density Traffic System circuit using an Arduino board and an infrared sensor on a breadboard. Using the Arduino UNO microcontroller creates a model that is ideal for implementing embedded control systems. Consequently, several of them—like the kind of components employed, cost, and complexity control method—were emphasized in earlier research. By offering a low-cost traffic system smart control model that is simple to use and anticipated to be efficient.

3 Method

The proposed system presents a design, and an implementation of an intelligent traffic control model focused on density traffic based on the field of cloud and soft computing systems. The following objectives are represented an important context of this article.

3.1. Smart Control Method

An intelligent control algorithm is proposed to avoid complex methods and high costs. Adopted a control system to compare road density with a threshold value of designing to make action decisions. It is designed and implemented using IR sensors and two types of microcontrollers.

3.2. Cloud in Traffic Management

The cloud network infrastructure was necessary for the effective and real-time processing, management, and analysis of massive amounts of data. To assess the framework, traffic infrared sensor calculations from a dispersed setting are transmitted via the ESP32 microcontroller to the cloud.

3.3. IoT in Traffic Management

Smart developed countries that keep pace with the progress of infrastructure and that attempt to eliminate the problems of congestion, such as pollution, have adopted the use of IoT for the benefit of these goals. All the traffic intersections in the proposed system are linked to a central appointment and control system via the Internet of Things.

3.4. Hardware Components

The Implementing circuit of the proposed control method is based on electronic components, which are as follows:

3.4.1. Arduino-MEGA-2560 Microcontroller

Two main benefits of the Arduino board are its short response time and user-friendly client interface. These open-source boards are easy to purchase and provide as they are considered reliable technology with reasonable cost (Laith Abdul Raheem Al Anzy, Abdullah & Aquraishi, 2023). Such sufficient inputs to enable the control system unit to decide on traffic flow was one of the conditions for putting the proposed system into practice.

3.4.2. ESP32 WI-FI Microcontroller

Utilization of the Arduino cloud platform is regarded as essential for implementing the proposed system using an Arduino.

3.4.3. Infrared (IR) Sensors

IR sensor is the key concern with many proposed traffic management control models. The importing density value is based on a smart algorithm proposed by the researcher to facilitate the task of the traffic control system for vehicles. Sensors are safely planted along the roads within a coverage system suitable for the work environment, as shown in Figure 1.

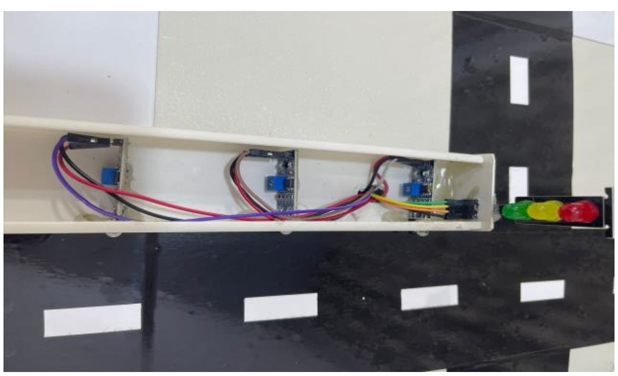


Figure 1: IR Sensors

3.4.4. LED

For minimizing energy consumption output sources, light-emitting diodes are used as traffic light signals. It works in three modes which are the starting signal (green light), waiting signal (yellow light), and stopping signal (red light).

3.4.5. (16X2) LCD Display

Display the internet connection status with its IP as shown in Figure 2.

Figure 2: Internet Connection Status Using (16X2) LCD Display

3.5. Software Requirements

Arduino is considered one of the basic systems prepared to deal with microcontrollers in the C++ programming language, as it is equipped with sufficient libraries to help the researcher implement projects with a unique structure, programming, and rules that support the programming language C++. Powerful cloud and IoT platforms depended on implementation to monitor and control the proposed method.

3.6. System Implementation and Operation

The suggested workstation with a control system unit is seen in Figure 3. Using an intelligent algorithm, the departure of cars from the busiest traffic intersection was scheduled according to a threshold value determined by the number of sensors in use (TH). In each road, equal numbers of IR sensors (S_{ji}, where j is the road number and i is the sensor number within the road) are connected to apply the principle of computational density for each of the roads within the traffic intersection. The control system unit processes the digital signals it receives from the ($\sum i$ Sji) traffic environment. The suggested control model's appropriate action decision is made using the density comparison approach.

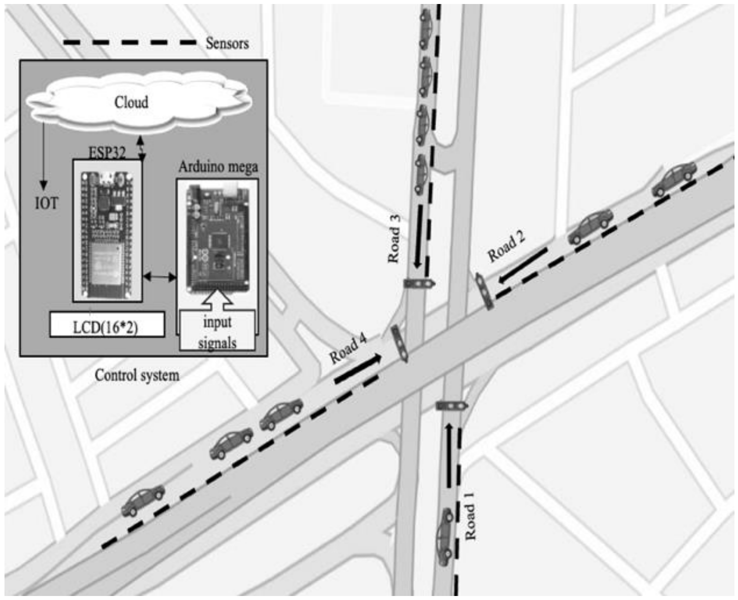


Figure 3: Proposed Traffic Intersection Environments with Control System

Figure 4 shows the flowchart of the proposed control system to manage heavy traffic. According to the control system, Digital signals for each road are received and processed within the density comparison concept so that the most crowded road is cleared. The algorithm will continue in this manner. The proposed approach will lessen people's dilemmas, lowering the number of accidents on the road every day.

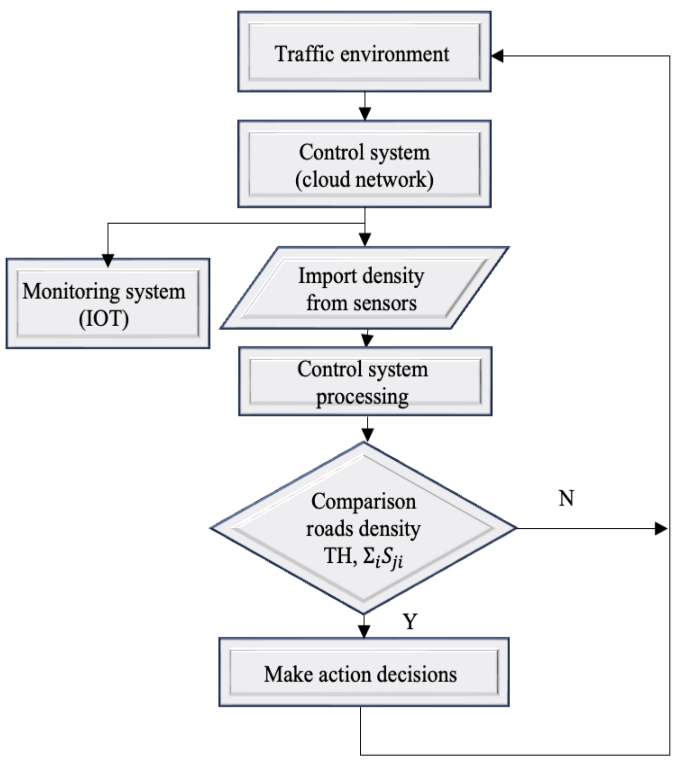


Figure 4: Flowcharts of the Proposed Smart Traffic Control Algorithm

The results are analyzed mathematically according to the equations programmed within the control unit to calculate the digital density of the cars, then a working signal is given LED blinking time. If the result of the count's density is higher, the LED will glow more than the average time or vice versa. To determine the best course of action in the context of a traffic intersection based on the processing of the control unit, the research considered five fundamental instances, which are as follows: Cases one (TLS1), two (TLS2), three (TLS3), and four (TLS4) depicts the state of the green light on road 1, which is the busiest road in terms of the number of vehicles. In contrast, instance five (Ring Status) denotes the situation where there are either an equal number of cars or none at all on the roads in the traffic environment. In this case, the traffic intersection will be managed by the traditional system, and a signal will be activated regularly.

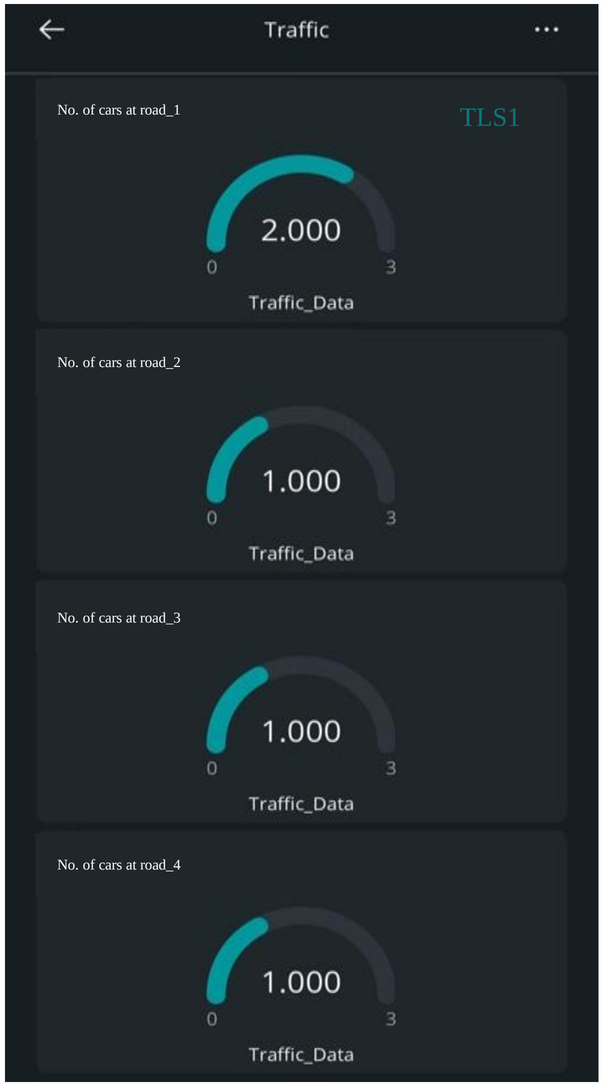
One of the most important features of the proposed method is reducing waiting time at traffic intersections, which constitutes an easy excuse for committing traffic violations. Therefore, attention to time is important because it is the most valuable commodity in our time. It limits the violation of rules and laws by people trying to reach their intended destination.

4 Results and Discussion

The quality of life at present is generally linked to the financial and environmental status of countries, as it gives a measure of the progress of countries and the well-being of their people. We notice that traffic crowding has increased in countries around the world, and this is a problem that affects the economic aspect of all countries. Including the above financially and environmentally. The presented traffic control system method assists, in better, time-based tracking, and thus has some benefits over another system such as high accuracy and efficiency while avoiding the usage of expensive devices and complex methods.

The proposed control traffic system is based on using low-power transmission sources (IR sensors), that are arranged with designed threshold values along each side of the road to the control system units. The control system built using software mind is an Arduino-Mega-2560 microcontroller and Wi-Fi ESP32 microcontroller. The proposed algorithm monitors the system operation status via a cloud platform.

The five examples that were previously highlighted as possibly occurring in traffic were the focus of this study. Figure 5 displays the preliminary findings, and it is important to note that there are more cars on road number one than there are on the other roads combined. The control system made an action decision to traffic light of road 1 of 100% density (First case / TLS1) based on input sensing data (as shown in Figure 5, a) and as a result of the comparison principle.



(a)

(b)

Figure 5: First Case / TLS1, (a) Cloud Platform, and (b) Traffic Environment

During the testing or getting results period of the proposed method, the response time is found three seconds to make an action decision from the control system, that is emptying the densest road with the number of vehicles. Figure 6 shows the cloud platform of the remaining three cases which are TLS2, TLS3, and TLS4.

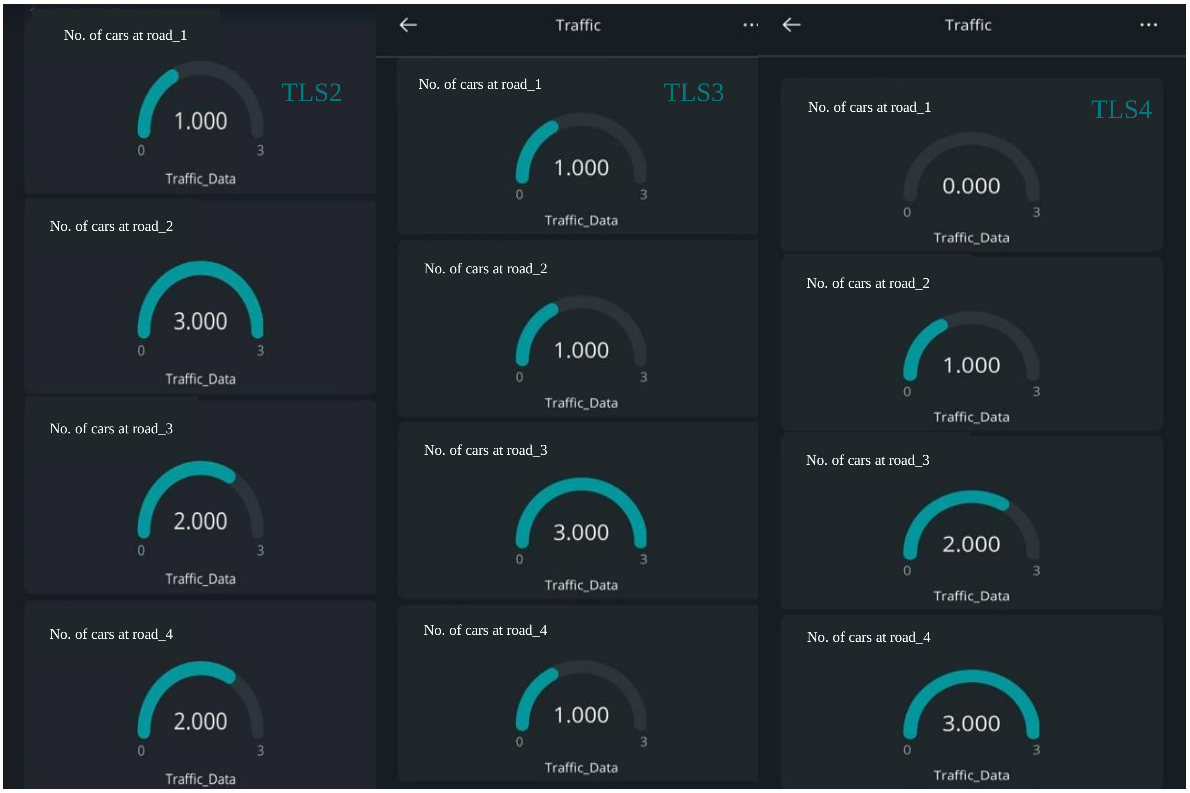


Figure 6: Traffic Light Signals Status (2,3, and 4) Cloud Platform

Table 1 shows the density of each road concerning the decision action of each traffic light signal case as shown by the cloud platform Figure 6.

Table 1: Importing Current Density from the Proposed Model System

Case	Road number	Density
TLS2	1	33.33%
	2	100%
	3	66.67%
	4	66.67%
TLS3	1	33.33%
	2	33.33%
	3	100%
	4	33.33%
TLS4	1	00.00%
	2	33.33%
	3	66.67%
	4	100%

Figure 7 depicts one of the scenarios likely to occur inside junctions: equal vehicle density or the absence of cars within intersections (night condition). So, for the ring case, the traditional traffic signal management approach is dependent.

(a)

(b)

Figure 7: Fifth Case/Ring Status, (a) Cloud Platform, and (b) Traffic Environment

The study presented several issues in determining the best frame layout. Firstly, it was shown that it takes three seconds for the green signal to move from one road to another, depending on the density of the roads. Secondly, it was found that all the proposed cases were implemented across the components of the system with high efficiency and without going through the difficulties of the methods suggested in other research.

5 Conclusion

The recommended intelligent traffic system does away with the shortcomings of the current conventional system, including traffic congestion, fuel, and time wastage, and the need for more traffic officers to manage intersections, among other issues. The objectives of the suggested control traffic system have been set up with effective administration. It featured a control system and traffic environment. On either side of the road are placed low power transmission sources (IF sensors), which are positioned within the intended threshold value for the control system units. Wi-Fi ESP32 microcontrollers and Arduino Mega-2560 microcontrollers are examples of control systems that were created with software in mind.

The proposed algorithm monitors the system operation status via a cloud platform. The project presented several issues in determining the best frame layout. Firstly, it was shown that the response time is three seconds for the green signal to move from one road to another, depending on the density comparison principle. Secondly, it was found that all the proposed scenarios were implemented based on the units of the proposed system with high efficiency and without going through the difficulties of the methods suggested in other research. Automated traffic management and monitoring are critical for highway usage and upkeep.

In this study, we presented an intelligent and efficient method for managing and monitoring vehicle intersections within Holy Karbala City. The expected results showed a quick response and high accuracy in determining the density of the intersection that is densest with the number of cars. We want to develop our framework in the future by including both knowledge, discovery, and data, mining approaches, refining our spatial indexing mechanism, and focusing more on our application layer to accommodate additional, features. It is also conceivable to envision the future by contemplating linking a smart network of control and monitoring to more than one traffic intersection inside Holy Karbala city, depending on the optimization strategies.

Authors' Contributions: The Article Conceptualization, methodology, software, validation, formal analysis, investigation, data curation, writing original draft preparation, and funding acquisition by Zahraa Talib author. The article administration, writing review and editing, and supervision have been done by Dr. Laith Ali Abdul Rahaim author.

Availability of Data and Materials: The datasets created during the current investigation are accessible from the corresponding author upon reasonable request.

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Conflict of Interest: Authors declare no conflict of interest.

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