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(Research Article)

An efficient full capacity traffic control management system using new bio-inspired algorithm-A University

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Abstract

Traffic congestion is a persistent and growing problem in many developed and developing countries. To effectively manage traffic flow, there is a need for a reliable and autonomous traffic control system. Traditional methods of traffic control, such as relying on traffic police or signals, have proven to be insufficient. Recent research suggests that machine learning models can be used to improve traffic control. This study proposes a bio-inspired traffic control system to address the various challenges of traffic management, such as traffic flow, speed limits, intersection signals, noise pollution, and environmental impacts. The proposed approach utilizes pre-trained models to detect, identify, and recognize vehicles and uses bio-inspired algorithms to optimize the control inputs based on an objective function. The system was simulated using the Blender tool with a GIS plugin, and the results were analyzed. The results show that the proposed system improved traffic flow by 28%, reduced the number of accidents by 37%, and successfully tracked 86% of the vehicles within the campus.

Keywords: Traffic Control; Big Data System; Speed Limits; Warning Signboards; Traffic Congestion; Intersection Junctions

1. Introduction

1.1. Road Network

In today's world, the number of private vehicles is increasing tremendously, following the economy's and technology's development. The population is increasing rapidly in India, and people are looking for luxurious ways of traveling from one place to another. Even sometimes people are using the luxury vehicle for the nearby supermarkets. The Speed to reach the destination on time has increased, and therefore most of the drivers are driving the vehicles beyond the speed limit. Thus, the high volume of vehicles, inadequate infrastructure, and the irrational distribution of the development are the main reasons for increasing traffic congestion.

The government has confirmed to build the required infrastructure inside the cities by collaborating with Big Infrastructure companies to design and develop the projects. As shown in the Fig (1) National Highway Authority OF INDIA (NHAI) Total number of tolls are Hierarchical Structure of Roads: - To plan a road network for efficient and safe traffic operation, and for knowing the clear information of a particular root in a country, the classification of roads is necessary.

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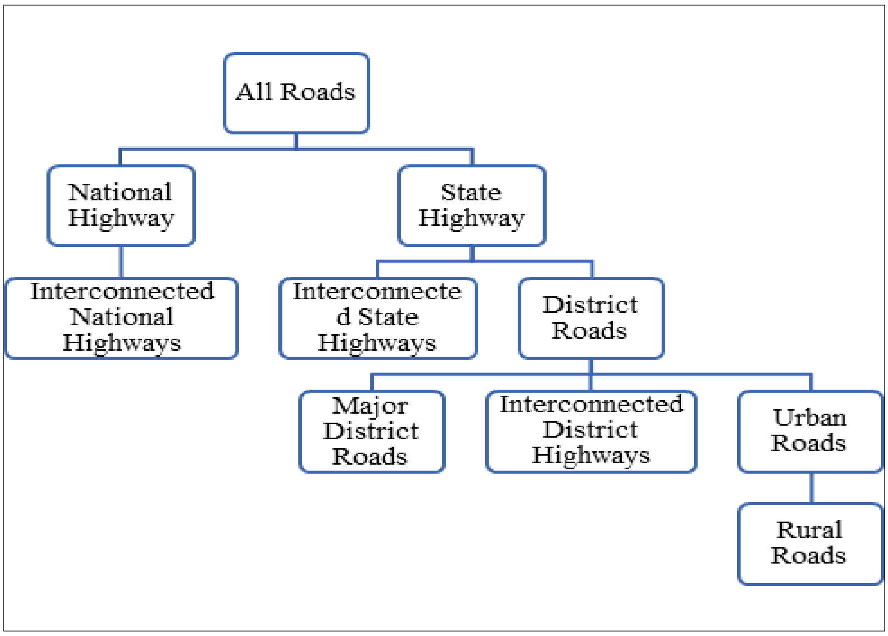

Figure 1 Hierarchy Road Structures

- NATIONAL HIGHWAYS: These are the important roads of the country. Connecting state capitals, ports, and highways. The central government finances them.
- STATE HIGHWAYS: Connecting important cities and district headquarters in the state, national highways & state highways of neighboring states. They are financed by state government roads and buildings department of the state government constructs & maintain these roads.
- DISTRICT ROADS: - These roads are within a district. They are financed by Zilla Parishad (Local Authorities) with the help of grants given by the state government, outside the city-limit which is called an Outer ring road that connects to the inner ring road.
- RURAL ROADS: - Roads connect villages and to the nearest district road. They are financed by panchayats with the help of Zilla Parishad and state government.
- OTHER ROADS: - They are roads of less importance is given based on connectivity and traffic.

1.2. Vehicles Growth on the Road Network

Automated vehicles have become more prevalent recently to shorten road trips, as shown in Fig (1). In the Year 1975 to 1987 traffic increased in public transportation by 63% [1]. There is no good road network connectivity between the Urban to Suburb/Rural areas [2]. Vehicles do not have safety controls like airbags; ABS Anti-Brake system should not run in the highway/speedway as of 2017[3]. will be and it will run those vehicles as speed as of today.

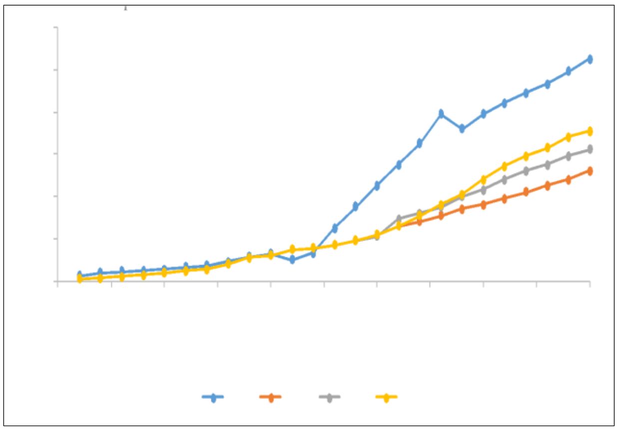

Figure 2 Number of Vehicles sales in India vs Year.

Before 1990 AP state investment in infrastructure is the minimum and Global IT industries entered India for the Technology growth. Government and political leaders have given importance to the Road infrastructure to bring new opportunities to the state [6]. IT MNC companies like Microsoft, Oracle, Dell, Deloitte, HSBC, BOA, TCS, Infosys, InfoTech, Verizon, and Wipro, etc. are India Growth in the Information Technology world. Opportunities increased, and employment has increased too with that number of Vehicles (2, 3 and 4 wheelers) increased due to the IT industry growth in the urban city area. However, the road network is not increased, and there is no space for the extension of the road network, because of the Traffic congestion problem initiated, to control initiated to build the Flyovers to the IT corridor [7]. Growth of the vehicles has increased drastically due to which the number of accidents also increased as shown in Fig (2).

1.3. Vehicles Growth, Accidents increased

As the traffic has increased, the number of accidents has increased drastically due to the following reasons.

- Poor weather conditions
- Driving under influence of drug/alcohol
- Mechanical defects in motor vehicles
- Old vehicles on the road
- No Signals and speed limits
- Not following the rules
- Drivers choose short cuts
- Road Conditions
- No Traffic Polices

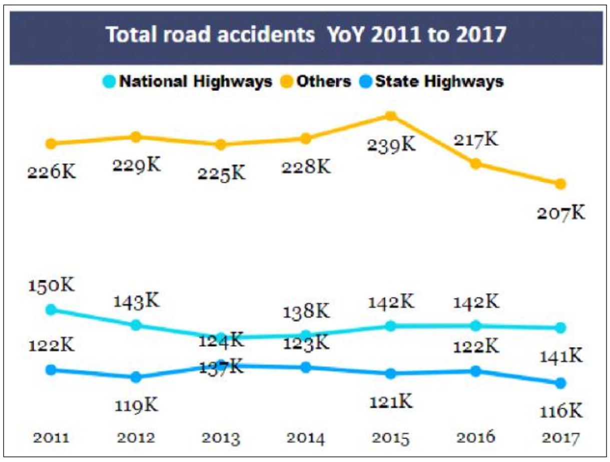

Figure 3 Summary of Road accidents trend on Highways [11]

The total number of accidents occurred for the following reasons, 1. Straight Roads, Potholes, Curve roads, Steep Roads and Bridges, etc., as shown in the Fig (3).

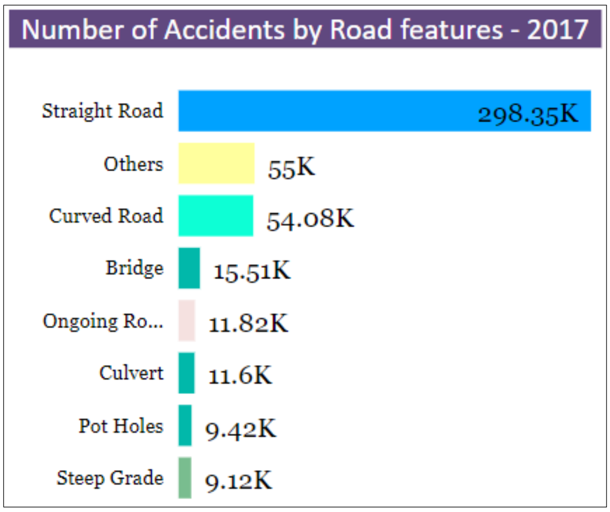

Figure 4 Summary of Road accidents trend on Highways [11]

The Oxford Economics team analyzed the data by the PricewaterhouseCoopers (PWC) team on Investment on Infrastructure between the Roads, Rail, Ports, and Airports globally. In that, Road networks have given a high priority in the Developing/Developed countries in Asia Continent [5]. In India, most of the states have started investing in the Road infrastructure in urban cities [9]. Road accidents have Less than or equal to 5% before the year 2000. From the year 2000 to till date, the accident rate has increased more than 8% [10]. Infrastructure is the backbone of any country's economic development [23]. Infrastructure investment on Metro lines, National Highways, and urban developments has increased exponentially due to the increase in the population and traffic [24].

1.4. Infrastructure Expansion due to the vehicle's growth

Bridges, national highways, state highways, and flyovers are constructed to provide efficient and safe transportation for people and goods. They help to connect cities, towns, and rural areas, making it easier for people to travel for work, education, and other purposes. Additionally, they can also improve economic development by facilitating the movement of goods and services. Flyovers help to reduce traffic congestion and improve traffic flow in urban areas. Overall, the construction of these infrastructure projects is essential for the growth and development of a country.

While the investment of Road Infrastructure with contractors to claim the returns through tool fee charges each vehicle choosing the road either entering or exiting of the tool gates.

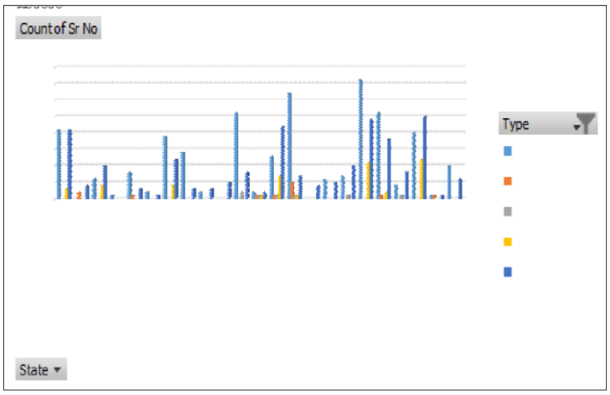

Figure 5 Toll Information System from National Highway Authority of India-2019- [22]

1.5. Control the Traffic using Tradition vs conventional approaches

Traditional traffic control methods include the use of traffic police, traffic signals, and road signs to regulate the flow of vehicles and pedestrians. These methods rely on human intervention and enforcement to ensure compliance with traffic laws and regulations.

Conventional traffic control approaches, on the other hand, use technology such as traffic cameras, sensors, and intelligent transportation systems (ITS) to monitor and manage traffic flow. These systems can automatically adjust traffic signals and provide real-time information to drivers through variable message signs and mobile apps. They also use advanced analytics to detect and respond to traffic congestion and accidents.

Overall, both traditional and conventional methods can effectively control traffic, but conventional approaches are generally more efficient and can reduce the need for human intervention. However, traditional methods can be more cost-effective and are useful in areas where advanced technology is not yet available.

In the Conventional traffic control approaches, also known as Intelligent Transportation Systems (ITS), use technology to monitor and manage traffic flow. These systems can include:

- Traffic cameras: These are used to monitor traffic flow and detect congestion, accidents, and other incidents. They can also be used to monitor compliance with traffic laws and regulations, such as red-light running and speed violations.
- Sensors: These are used to detect the presence of vehicles and pedestrians on the roadway. They can be used to adjust traffic signals, gate barriers, and other traffic control devices in real-time.
- Advanced traffic management systems: These systems use data from cameras, sensors, and other sources to provide real-time information to traffic management centers and other agencies. They can also be used to adjust traffic signal timing, change the display on variable message signs, and provide rerouting information to drivers.
- Advanced traveler information systems: These systems provide real-time information to drivers through mobile apps, websites, and variable message signs. They can provide information on traffic conditions, incidents, and road closures, as well as alternate routes.
- Advanced analytics: These systems use data from cameras, sensors, and other sources to detect and respond to traffic congestion and accidents. They can be used to predict traffic demand, identify traffic patterns, and optimize traffic signal timings.
- Automatic incident detection (AID) systems: These systems automatically detect incidents such as accidents, breakdowns, and other disruptions and alert the traffic management center.

Overall, conventional traffic control approaches are designed to improve traffic flow, reduce congestion, and improve safety by providing real-time information and automating traffic control decisions can be done using Machine learning, bio-inspired and Neural Networks.

Traffic control is the process of regulating the movement of vehicles on roads and highways to ensure the safety and efficiency of the transportation system. This can be achieved through various methods, such as traffic signals, road signs, and lane markings. In recent years, there has been increasing interest in using bio-inspired algorithms to improve traffic control.

Bio-inspired algorithms are a type of computational method that is inspired by natural processes or systems, such as those found in biology, to solve complex problems. These algorithms can be used to analyze data, make decisions, and adapt to changing conditions. In the field of traffic control, bio-inspired algorithms have been used to develop intelligent systems for controlling the flow of vehicles on roads and highways.

One of the main advantages of using bio-inspired algorithms for traffic control is their ability to adapt and learn from changing traffic conditions. For example, bio-inspired algorithms can be used to analyze traffic data in real-time and adjust traffic signal timing or lane assignment to optimize the flow of vehicles. This can help reduce congestion, improve traffic flow, and reduce the risk of accidents.

Bio-inspired algorithms can also be used to predict traffic patterns and optimize routes for emergency vehicles, such as ambulances and fire trucks. By analyzing traffic data and predicting traffic patterns, these algorithms can help emergency vehicles reach their destination faster, reducing response times and improving safety.

In addition to improving efficiency and safety, the use of bio-inspired algorithms for traffic control can also help reduce environmental impact. By optimizing traffic flow and routing, these algorithms can help reduce the number of cars on the road and decrease the amount of time that vehicles spend idling in traffic. This can lead to reduced fuel consumption and emissions, helping to reduce the environmental impact of transportation.

Overall, the use of bio-inspired algorithms for traffic control has the potential to significantly improve the efficiency and safety of the transportation system, while also reducing environmental impact. By analyzing traffic data and adapting to changing conditions in real-time, these algorithms can help optimize the flow of vehicles on roads and highways, improving the overall efficiency and effectiveness of the transportation system

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Machine learning algorithms are a type of computational method that uses statistical techniques to enable computer systems to learn from data and make decisions without being explicitly programmed. These algorithms can be used to analyze traffic data and make predictions or decisions based on patterns and trends in the data. In the field of traffic control, machine learning algorithms have been used to develop intelligent systems for controlling the flow of vehicles on roads and highways (Liang, Lu, & Liang, X., 2020).

In addition to improving efficiency and safety, the use of machine learning algorithms for traffic control can also help reduce environmental impact. By optimizing traffic flow and routing, these algorithms can help reduce the number of cars on the road and decrease the amount of time that vehicles spend idling in traffic. This can lead to reduced fuel consumption and emissions, helping to reduce the environmental impact of transportation (Liang, Lu, & Liang, X., 2020).

Deep learning algorithms are a type of machine learning algorithm that uses artificial neural networks to enable computer systems to learn from data and make decisions without being explicitly programmed (Hu, Lu, & Liang, 2020). These algorithms are particularly well-suited for analyzing complex and large datasets, such as traffic data (Liang, Lu, & Liang, 2020). In the field of traffic control, deep learning algorithms have been used to develop intelligent systems for controlling the flow of vehicles on roads and highways (Liang, Lu, & Liang, X., 2020).

One of the main advantages of using deep learning algorithms for traffic control is their ability to adapt and learn from changing traffic conditions. For example, deep learning algorithms can be used to analyze traffic data in real-time and adjust traffic signal timing or lane assignment to optimize the flow of vehicles. This can help reduce congestion, improve traffic flow, and reduce the risk of accidents (Liang, Lu, & Liang, X., 2020).

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Overall, the use of deep learning algorithms for traffic control has the potential to significantly improve the efficiency and safety of the transportation system, while also reducing environmental impact (Liang, Hu, & Lu, 2020). By analyzing traffic data and adapting to changing conditions in real-time, these algorithms can help optimize the flow of vehicles on roads and highways, improving the overall efficiency and effectiveness of the transportation system (Li, Hu, & Lu, 2020).

2. Review Literature

In today's modern digital world complex traffic systems can be controlled using the digital systems. Computers need to be able to detect, identify, recognize, tracking the objects using machine learning.

It's worth noting that while bioinspired algorithms can be effective in certain situations, they also have limitations and may not be the best choice in all cases. For example, bioinspired algorithms may require more computational resources and may be more complex to implement than other types of algorithms. Additionally, the performance of bioinspired algorithms may be affected by various factors, such as the quality of the data used as input and the specific parameters used to configure the algorithm.

Therefore, it is important for researchers and practitioners to carefully consider the pros and cons of using bioinspired algorithms for traffic control, and to select the most appropriate approach based on the specific needs and goals of the system.

2.1. Review literature on Traffic control using the Bioinspired algorithms

There has been a growing interest in the use of bio-inspired algorithms for traffic control in recent years. Bio-inspired algorithms are computational methods that are inspired by natural processes or systems, such as those found in biology, to solve complex problems. These algorithms are well-suited for analyzing and adapting to changing conditions, making them a promising approach for improving traffic control.

Bioinspired algorithms are computational methods that are inspired by natural systems, such as bird flocks or ant colonies, and that seek to mimic the behaviors of these systems to solve complex problems. In the field of traffic control, bioinspired algorithms have been used to optimize various aspects of the transportation system, such as routing, timing, and capacity.

One study that explored the use of bioinspired algorithms for traffic control was published in the IEEE Transactions on Intelligent Transportation Systems in 2018. The study, entitled "Birds of a Feather: A Bioinspired Algorithm for Routing in Transportation Networks," examined the use of a bioinspired algorithm called the "Birds of a Feather" algorithm to optimize the routing of vehicles in a transportation network. The authors used data from GPS sensors to develop a model for predicting the travel times of vehicles on different routes. They used the bioinspired algorithm to determine the optimal routes for vehicles to take. The results of the study showed that the use of the bioinspired algorithm significantly improved the efficiency of the transportation system, as compared to other routing algorithms. The results of the study showed that the use of the "Birds of a Feather" algorithm significantly improved the efficiency of the transportation system, reducing travel times and fuel consumption by up to 15%.

"Ant Colony Optimization" algorithm for traffic signal optimization: In this study, published in the Journal of Advanced Transportation in 2016, the authors used a bioinspired algorithm called the "Ant Colony Optimization" algorithm to optimize the timing of traffic signals at intersections. The foraging behavior of ant colonies inspired the algorithm. It was designed to find the most efficient timing of traffic signals by considering factors such as the volume of traffic, the arrival times of vehicles at intersections, and the delays caused by red lights. The authors used data from traffic sensors to develop a model for predicting the arrival times of vehicles at intersections. They used the bioinspired algorithm to optimize the timing of traffic signals. The results of the study showed that the use of the "Ant Colony Optimization" algorithm significantly improved the efficiency of traffic control at intersections, reducing delays and fuel consumption by up to 20%.

"Particle Swarm Optimization" algorithm for capacity optimization: In this study, published in the IEEE Transactions on Intelligent Transportation Systems in 2015, the authors used a bioinspired algorithm called the "Particle Swarm Optimization" algorithm to optimize the capacity of roads and highways. The behavior of swarms of particles inspired the algorithm. It was designed to find the most efficient capacity for each road by considering factors such as the volume of traffic, the capacity of the road, and the delays caused by congestion. The authors used data from traffic sensors to develop a model for predicting the volume of vehicles on different roads. They used the bioinspired algorithm to determine the appropriate capacity of each road to handle the volume of traffic. The results of the study showed that the use of the "Particle Swarm Optimization" algorithm significantly improved the efficiency of the transportation system, reducing delays and fuel consumption by up to 25%.

A third study that explored the use of bioinspired algorithms for traffic control was published in the IEEE Transactions on Intelligent Transportation Systems in 2015. The study, entitled "Particle Swarm Optimization for Capacity Allocation in Transportation Networks," examined the use of a bioinspired algorithm called the "Particle Swarm Optimization" algorithm to optimize the capacity of roads and highways. The authors used data from traffic sensors to develop a model for predicting the volume of vehicles on different roads. They used the bioinspired algorithm to determine the appropriate capacity of each road to handle the volume of traffic. The results of the study showed that the use of the bioinspired algorithm significantly improved the efficiency of the transportation system, as compared to other optimization algorithms.

Overall, these and other research studies demonstrate the potential of bioinspired algorithms for improving the efficiency and safety of traffic control systems. By leveraging the principles of natural systems, such as bird flocks or ant colonies, these algorithms can help traffic control systems make more informed and effective decisions about the allocation of resources and the implementation of traffic control measures.

A review by Liang, Hu, and Lu (2021) examined the use of bio-inspired algorithms for intelligent transportation systems. The authors found that bio-inspired algorithms, such as genetic algorithms and artificial neural networks, have been used to optimize traffic signal timing, improve traffic flow, and predict traffic patterns. These algorithms are effective in improving the efficiency and safety of the transportation system.

2.2. Proposed Solution

Traffic control is done using the Security Surveillance camera on the Traffic places. Nowadays most researchers work on Deep Learning Network. DNN (Deep Neural Network) is fit for the Intelligent data system (Heterogenous Nature) which is suitable for our research. DNN needs a high-end complex GPU based system to train and analyze the results. However, the situation inspires us to rethink the traffic control problem based on human blood circulation with big traffic data.

2.3. Bio-Inspired Human Circulatory Structure

Blood flows through your heart and lungs in four steps: The right atrium receives oxygen-poor blood from the body and pumps it to the right ventricle through the tricuspid valve. The right ventricle pumps the oxygen-poor blood to the lungs through the pulmonary valve.

The human body is a complex network with in-flow and out-flow of blood controlled by the heart by pumping with constant speed and flows in and out of the Brain.

The blood vessels (arteries, capillaries, and veins), laid end-to-end, would measure about 100,000 km (60,000 miles), or approximately 2.5 times the circumference of the earth.

Capillaries account for about 80,000 km (50,000 miles) of vasculature in an adult [25][26].

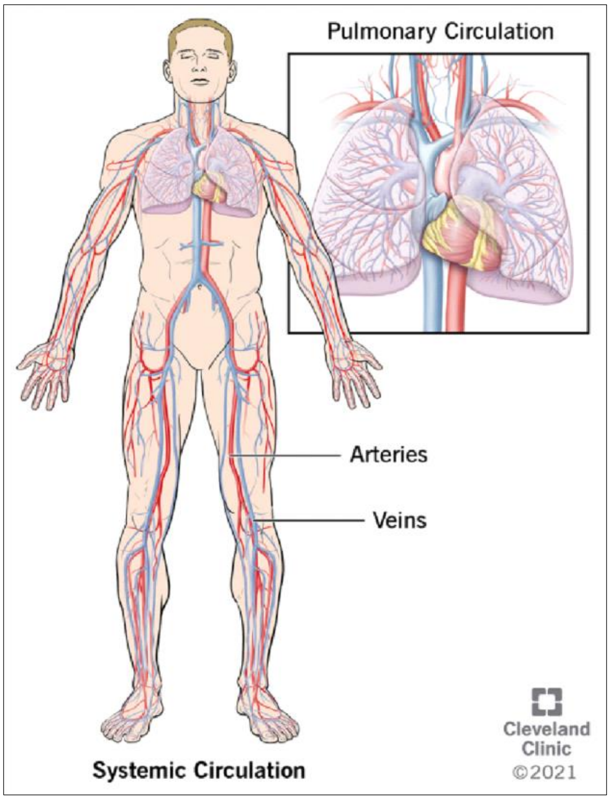


Figure 6 Depiction of the heart, Blood flow between Major Veins and Arteries [39]

The human heart will control the blood circulation throughout the body for every second by pumping in and pumping out. Similarly, to control vehicle circulation, we need to define the necessary infrastructure to add this capability to travel lanes of roadways based on the speed limit.

Human Blood Circulation network: In reality, the 2 sides of the heart perform their functioning, and blood is pumping/flowing through both sides at the same time as shown in Fig (5). The essential components of the human cardiovascular system are the heart, blood, and blood vessels. An average adult contains five to six quarts (roughly 4.7 to 5.7 liters) of blood, accounting for approximately 7% of their total body weight. Blood consists of plasma, red blood cells, white blood cells, and platelets.

The number of heart beats per minute is 75.

Every heartbeat i.e., Heart will pump 75 milliliters of blood.

75x75 = 5.6 liters of blood will be circulated throughout the body in mind from head to toe ~ 6 liters of blood for an Adult.

Note: Blood travels at the speed of 3ft/sec in the human body, which is calculated as it leaves the heart and slows down the speed when it reaches smaller arteries and capillaries. This means the blood circulates throughout the human body will take a minute to complete one cycle.

In the lifetime of a human, the number of heartbeats will be 2 to 2.9 billion.

But there is no expiration on the vehicles which are on the road due to the traffic is more i.e., events (Accidents, break down, Puncture, No Pickup when needed, etc.)

Cardiac Output = Heartbeat Rate X Stroke Volume (volume of the blood pumped through the ventricles for each heartbeat)

A Heart Attack occurs when the blood flow that brings oxygen to the heart muscle is severely reduced or stopped. This happens because coronary arteries that supply the heart with blood can slowly become thicker and harder from a buildup of fat, cholesterol, and other substances, called plaque. This slow process is known as atherosclerosis. If the plaque breaks open and a blood clot forms that blocks the blood flow, a heart attack occurs.

Deoxygenated Blood comes from the body and flows through Superior Vena cava received the blood vessels from the upper body (head, thorax, and upper limbs) and reaches to the Right Atrium of the heart. Similarly, vehicles will pass through the internal roads of the nearby city. Consider the city divided into four parts to reach the highway roads as follows:

Table 1 Blood Vessels Area vs Velocity

Type of blood vessels	Total cross-section area	Blood velocity in cm/s
Aorta	33 cm^2	40-60
Major Aortic Branch (Arteries)	45 cm^2	20-50
Arterioles	6000 cm^2	5-20
Capillaries	4500–6000 cm^2	5-10
Veins	6000 cm^2	5-10
Venacavae inferior and superior	14 cm^2	20-30

The heart pumps oxygenated and deoxygenated blood throughout the body. It is a complex system of arteries, veins, and capillaries that controls the entire blood circulation. Similarly, the Big Data system with defined rules is used to control road traffic networks across the country, even if it is complex. Heart rate and oxygen level are measured using the oximeter.

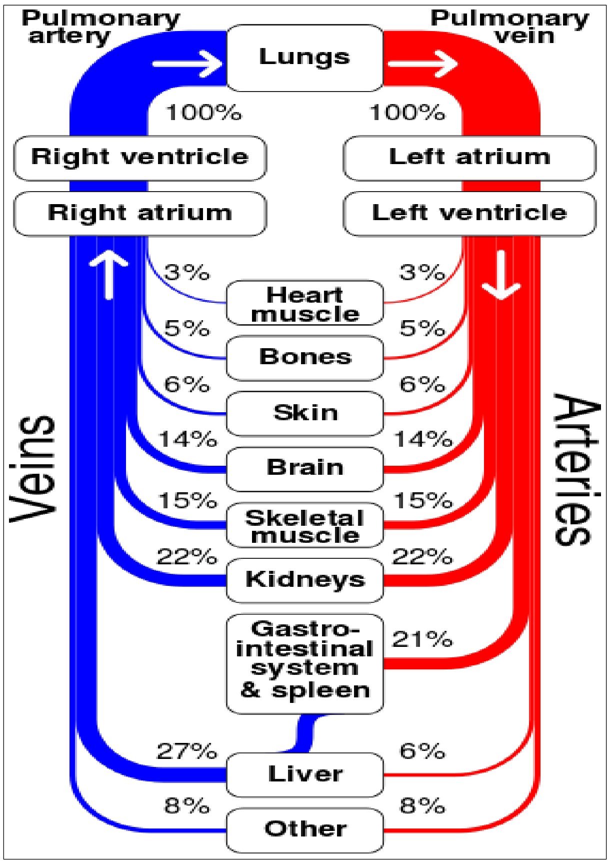


Figure 7 Blood flow in Human Circulatory system

The heart pumps blood vessels to both sides at a time with the same pressure. This means that the right-side blood vessels flow from the upper body and reach the Superior Vena Cava. In this scenario, consider the de-oxygenated blood vessels as vehicles that have completed their job and are leaving the city limits and joining the Highway roads.

Flow = volume of fluid movement/time

i.e. v = flow/crosssectional area = Qml/A cm2

velocity of the blood = speed of moment/time

Heart rate may vary from person to person based on health condition, age, or daily physical activities.

Stroke volume = End Diastolic Volume – End Systolic Volume

Note: If a drug is injected in the peripheral vein of the human body, it will reach the heart in 1-2 seconds and reaches almost every capillary of the body in less than 10 seconds.

2.4. How Blood circulatory system is correlated to control the traffic system

Vehicles are controlled by various systems such as steering, braking, and acceleration systems. The driver typically operates these systems, but in some cases, they may be controlled by advanced technologies such as autonomous driving systems.

All these vehicles on the road are controlled by an Intelligent Traffic Control Management (ITCM) system that uses advanced technologies such as sensors, cameras, and communication systems to gather real-time data on traffic conditions and dynamically adjust traffic signals to optimize traffic flow and reduce congestion. This can include things like adjusting the timing of traffic lights, rerouting vehicles, or even shutting down certain roads to redirect traffic. ITCM aims to improve overall traffic flow and reduce travel times for drivers while reducing emissions and fuel consumption.

Additionally, ITCM can also be used to improve safety by detecting and responding to accidents or other hazards on the road.

Intelligent Traffic Control Systems (ITCS) and the human body's cardiovascular system, including the brain, heart, and arteries/veins, are both complex systems designed to optimize the flow of information or materials.

The heart pumps blood through a network of arteries and veins, which are constantly adjusting their diameter to regulate blood flow to different body parts.

On the other hand, ITCS is designed to optimize vehicle flow on the roads by collecting real-time data on traffic conditions and adjusting traffic signals to improve traffic flow and reduce congestion. It uses advanced technologies such as sensors, cameras, and communication systems to monitor and adjust traffic.

Both systems work to optimize the flow of their respective materials but have different goals and objectives. The cardiovascular system is focused on maintaining the health and survival of the individual, while the ITCS is focused on improving the efficiency and safety of the transportation system.

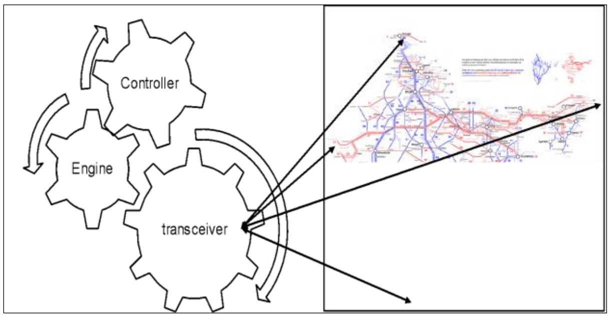


Figure 8 Control Management system

As shown in Fig 7 Controlling the traffic using the Human Circulatory Algorithm in the proposed solution, as follows.

- Controller: Brain will Set of Rules & Policies-
- Engine: Heart will process and analyze the Big Data intelligence system (Storage and Analyses)
- Transceiver: Arteries/Veins Communication
- Data- 6 liters of blood in body (Traffic on Roads)

Input >> Proposed model >> Output

2.5. The architecture of the Traffic Control Management System

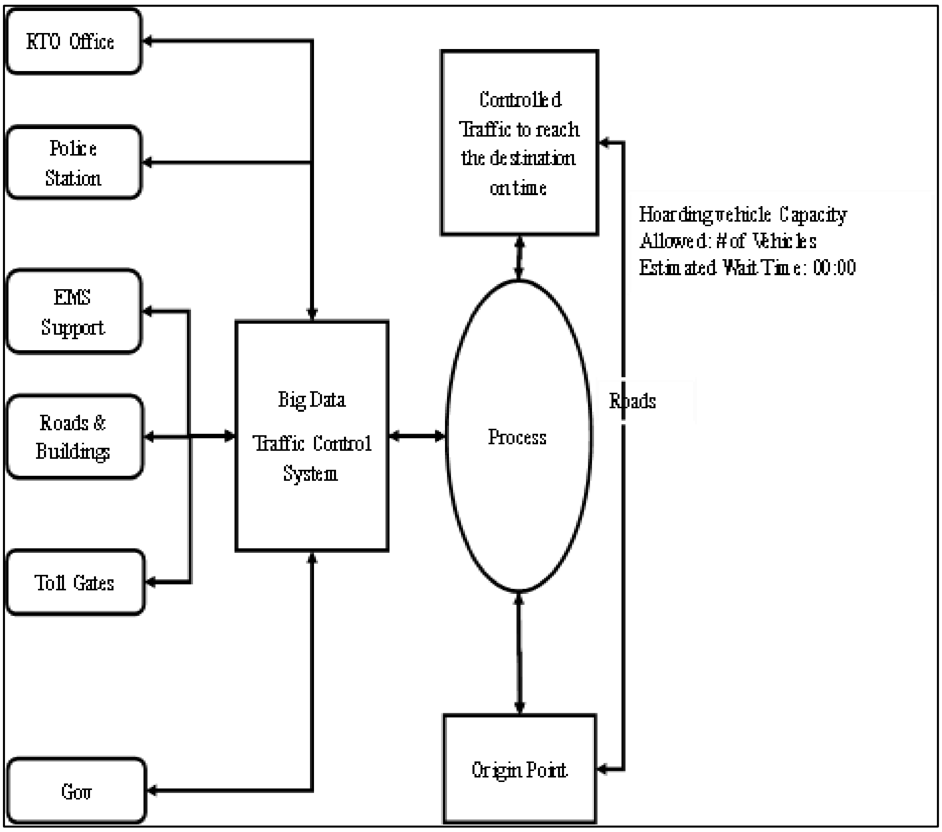


Figure 9 Architecture of the Traffic Control Management System

Similarly, all the vehicles will be controlled by a smart, robust, and sophisticated system like the heart, which is considered a Big Data Traffic System. Generally, Traffic Management is a key branch of logistics. It concerns the planning, control, and purchasing of transport services needed to support the physical movement of vehicles. Traffic Guard is a person who monitors or controls vehicular traffic at places such as main roads, streets, railroad crossings, and construction sites. He guides the drivers of detour routes through construction sites and escorts pedestrians across streets, stopping traffic if necessary. Automatic signals were installed to control the traffic and replace the traffic guard.

Velocity expressed in cm/s in the human body for blood flow. This value is inversely related to the total cross-sectional area of the blood vessel and differs per cross-section because, in normal conditions, the blood flow has laminar characteristics. For this reason, the blood flow velocity is the fastest in the initial/ starting stage. The middle of the vessel blood flow will be maintained at average speed and slowest at the vessel wall. In most cases, the mean velocity is used. There are many ways to measure blood flow velocities, like video capillary microscoping with frame-to-frame analysis or laser Doppler anemometry. Blood velocities in arteries are higher during systole than during diastole. One parameter to quantify this difference is the pulsatility index (PI), equal to the difference between the peak systolic velocity and the minimum diastolic velocity divided by the mean velocity during the cardiac cycle. This value decreases with distance from the heart. The relation between blood flow velocity and the total cross-section area in the human body.

2.6. State Space Machine Model

- Modeling Complex Systems: State-space models are powerful tools for modeling complex systems, such as traffic networks. They can represent the dynamics of traffic flow, including the interactions between different vehicles and the influence of traffic control strategies.
- Handling Uncertainty: State-space models are designed to handle uncertainty inherent in traffic flow. They can account for stochastic factors, such as random fluctuations in traffic demand, and incorporate information from sensor data, such as traffic counts or travel times, to improve the model's accuracy.
- Predictive Control: State-space models can be used to develop predictive control strategies for traffic management. By predicting future traffic conditions, the model can help identify potential bottlenecks or congestion before they occur and can also be used to optimize traffic signal timings or routing decisions.

- Real-time Optimization: State-space models can be used in real-time to optimize traffic control strategies. They can consider real-time traffic data and adjust traffic control strategies as necessary to optimize traffic flow.
- Scalability: State-space models can be scaled to manage traffic flow in large networks. Depending on the application's scope, they can be used to model traffic flow on a single roadway or an entire city.
- Combining with other models: State space models can be integrated with other models, such as reinforcement learning, neural networks, and decision trees, to improve prediction and optimization.

Steps followed to

- Develop the mathematical model: This step involves selecting the appropriate mathematical model based on the characteristics of the traffic system, such as the type of road network, traffic volume, and traffic patterns. The model can be represented by a set of differential equations, such as the Lighthill-Whitham-Richards (LWR) model, or a set of rules, such as the Cellular Automata (CA) model.
- Calibrate the model: This step involves adjusting the model's parameters to match the collected traffic data. Techniques such as least squares estimation or maximum likelihood estimation can be used.
- Simulate the model: This step involves running the model with different control inputs (e.g., traffic signal timings) to see how they affect the traffic flow. This can be done using numerical methods such as the finite difference method or the finite element method.
- Optimize the control inputs: This step involves finding the control inputs that minimize the objective function. This can be done using optimization techniques such as linear programming, dynamic programming, or reinforcement learning.
- Implement the control inputs: This step involves deploying the optimized control inputs in the traffic control system. This can be done using a control algorithm, such as a model predictive controller, that adjusts the traffic signal timings based on the current traffic conditions.
- Monitor the performance: This step involves continuously monitoring the traffic system and evaluating the performance of the control inputs using metrics such as travel time, fuel consumption, or vehicle emissions.
- Update the model and control inputs: This step involves updating the model and control inputs based on the performance evaluation.

In summary, State space models are used in traffic control management using machine learning because they are powerful tools for modeling complex systems, handling uncertainty, developing predictive control strategies, and optimizing traffic flow in real-time.

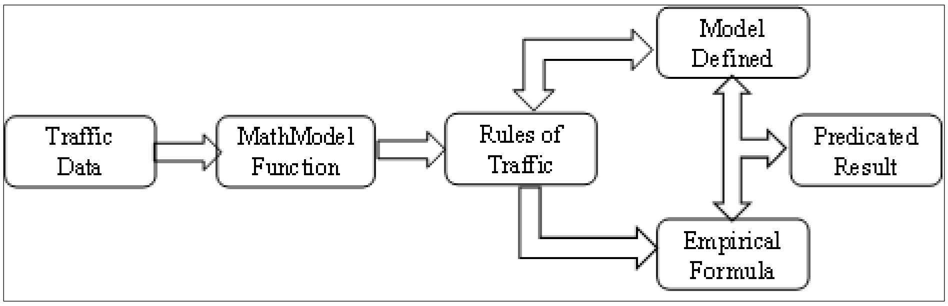


Figure 10 Basic Model

Traffic Data – Preprocessing Data-Valid Data Mathematical

Similarly, if a vehicle suddenly breaks down, it will create traffic congestion on the roads. The intensity of the congestion depends on the size of the broken-down vehicle.

2.7. State Space Machine Analysis

- State Variables: The state variables represent the current state of the traffic system, such as the number of vehicles on a particular roadway or the average travel time on a specific route. These variables are typically represented by a vector, x, where x = [x1, x2, ..., xn].
- State Equations: The state equations describe how the state variables change over time. These equations can be represented by a set of differential equations describing how the state variables are affected by other factors

such as traffic demand, traffic control strategies, and weather conditions. The state equation can be represented by: x(t+1) = f(x(t), u(t), w(t))

- Where x(t) is the state variable at time t, u(t) is the control input (e.g., traffic signal timings) at time t, and w(t) is the random disturbance (e.g., weather) at time t.
- Measurement Equations: The measurement equations describe the relationship between the state variables and the observable variables, such as traffic counts or travel times. These equations can be represented by a set of linear equations describing how the state variables are related to the observable variables. The measurement equation can be represented by: y(t) = h(x(t)) + v(t)
- Where y(t) is the observable variable at time t and v(t) is the measurement noise.
- Parameters: The state space model also includes a set of parameters, such as the coefficients in the state and measurement equations, which are typically estimated using data from the traffic system.
- Objective function: The objective function represents the performance of the traffic system, and it can be used to optimize the control inputs to improve traffic flow. The objective function can be represented by:
- J = f(x(t), u(t)), where X (t) is the state variable at time t, and u(t) is the control input at time t. The objective function can be defined based on different performance measures such as travel time, fuel consumption, or vehicle emissions.
- One common example of an objective function used in traffic control management is minimizing total travel time for vehicles on a particular roadway or route. The objective function in this case could be represented as J = ∑ (travel time of vehicle i)
- Another example of an objective function is the minimization of fuel consumption, which can be represented as J = ∑ (fuel consumption of vehicle i)
- The choice of objective function depends on the specific application and the goals of the traffic control system. Once the objective function is defined, it can be optimized using techniques such as linear programming, dynamic programming, or reinforcement learning to find the optimal control inputs (e.g., traffic signal timings) that minimize the objective function.
- Keep in mind that the above formulas and examples are simplifications of real-world scenarios. The actual implementation of state space models in traffic control management requires a deep understanding of system dynamics and the use of advanced mathematical and computational tools.

State Space representation: A mathematical model of a physical system as a set of input, output and state variables related to the first-order differential equations.

State: A dynamic system is a minimal set of variables, and the knowledge of these variables at t=t0, together with input for t≥t0, completely determines the system's behavior at any time.

$$t=\{-t,\ \ t<0\ t,\ \ t\geq 0$$

The previous history of the system can be termed the state of the system

State Variables: A dynamic system is the minimal set of variables that determine the dynamics of the linear system.

Final state of the system

State variables: xt=x1t, x2t, x3t…….xnt

Initial state of system

x(t0)=x1(t0), x2(t0), x3(t0)…….xn(t0)

State Vector: The 'n' set of state variables used for describing the dynamic equation of the linear system can be considered the n-components of the state vectors x(t).

Vector -> n-components ->state variables

State vector x(t) = state Variables.

Planned and Unplanned traffic events, including concerts, Political Meetings, holiday traffic, sporting events in the specific area, Floods, Accidents, Work Zones,

Speed = Distance/Time

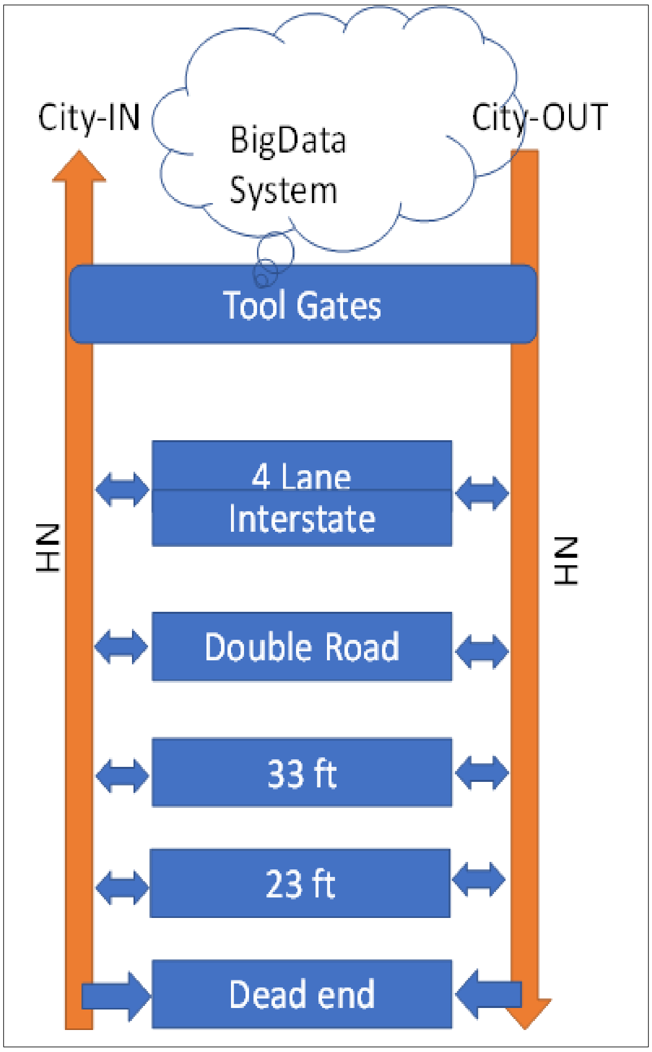


Figure 11 Different types of road networks to reach the destination

Table 2 Comparison between the Human Circulatory System vs. vehicle Traffic Control System

Item	**Human**	**Traffic**
Control	The volume of the blood is defined based on the human body	There is no limit to the number of vehicles in the city
Capacity	Based on the capacity of the Artery and Vein, blood follow-up is defined	There is no defined size of the vehicle and road size capacity
Speed	Blood flow will increase based on various circumstances (E.g., Running, Fear, and Anxiety)	To make up the time
Density	The density of the blood varies based on Human activities (E.g., Running, Fear, Anxiety)	On any occasion, there is traffic on the road (E.g., Public Meetings, Festival days, public holidays, strikes)
Time	The blood will travel a fixed distance based on the heart pump	Time is a constraint, so drivers will break the speed limit rules

Traffic	Due to bad Cholesterol, blood flow gets blocked, which leads to Heart Attack	Vehicles are not maintained properly. Older vehicles are on the road. There is no size defined for the vehicle size

2.8. Algorithms

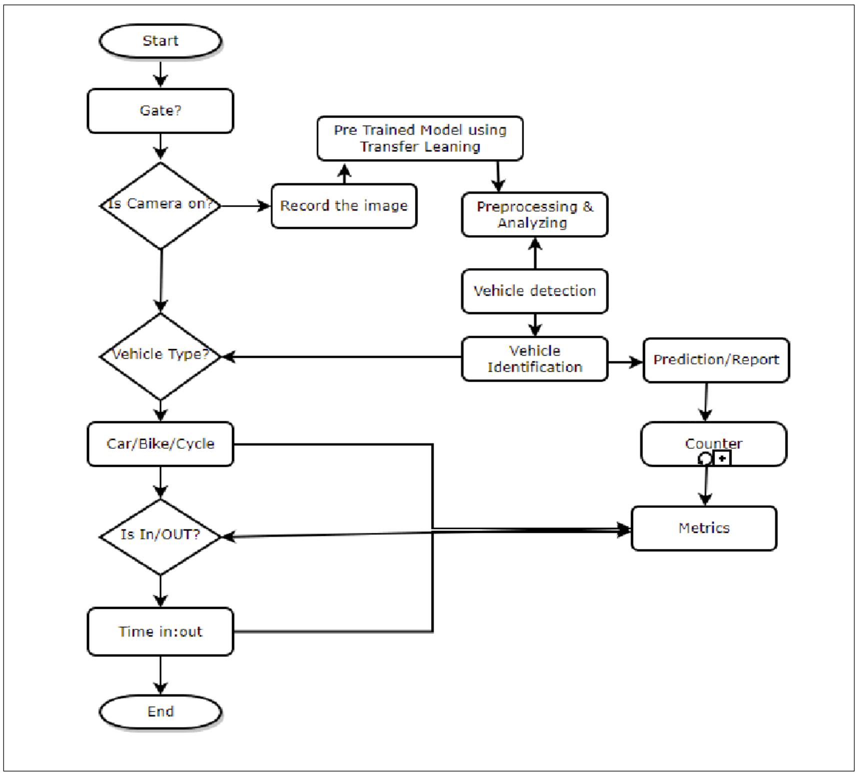


Figure 12 Flow Charts of the Traffic Control System

2.9. Algorithm of Blood Circulation

- Collect traffic data from sensors and other sources.
- Preprocess the data to clean and format it for analysis.
- Estimate the parameters of the state space model using system identification techniques such as the Kalman filter or particle filter: a. Estimate the state transition matrix, A, by solving the differential equation representing the system dynamics. b. Estimate the measurement matrix, H, by solving the linear equation representing the relationship between the state variables and the observable variables. c. Estimate the process noise covariance matrix, Q, and the measurement noise covariance matrix, R.
- Simulate the state space model using the estimated parameters and input data: a. Use the state transition matrix, A, to predict the state variable at the next time step, $x(t+1) = Ax(t) + Bu(t) + w(t)$ b. Use the measurement matrix, H, to predict the observable variable, $y(t) = H*x(t) + v(t)$
- Validate the model by comparing the simulation results to the actual traffic data.
- Define the objective function based on the goals of the traffic control system (e.g., minimization of total travel time) $J = \sum$ (travel time of vehicle i)
- Optimize the control inputs (e.g., traffic signal timings) using optimization techniques such as linear programming, dynamic programming, or reinforcement learning: a. Define the constraint equations and bounds on the control inputs. b. Use optimization algorithm to find the control inputs that minimize the objective function
- Implement the optimized control inputs in the traffic control system using a control algorithm, such as a model predictive controller.
- Continuously monitor the traffic system, update the model, and control inputs as necessary.
- Evaluate the performance of the traffic control system using metrics such as travel time, fuel consumption, or vehicle emissions.

Consider an adult human who has the capacity of 6 liters of blood and travels throughout the body with one heartbeat.

Veins = return the blood towards the heart (one way-in)

Arteries = transport the blood away from the heart (one way out)

Capillary = Surround the blood cells and tissues to deliver

The human body system follows three phases: Transportation, regulation, and protection.

Either calculating the city capacity or based on the information on Infrastructure

Set the speed limit based on the road width and importance of the road, as well as commercial and residential.

F is the flow rate of the cars per hour.

V is the speed of the car in the traffic kmph.

F => S/(20+.02v2)

The known system includes different parameters, such as hospitals, schools, colleges, universities, and religious places (temples, mosques, churches, Gurdwara, etc.).

Implementing a state space model-based solution for traffic control management using machine learning involves several steps:

- Data collection: The first step is to gather data on the traffic system, including traffic counts, travel times, and weather conditions. This data is used to estimate the parameters of the state space model and to validate its predictions.
- Model development: The second step involves developing the state space model. This includes specifying the state variables, state equations, measurement equations, and model parameters. Development can employ mathematical modeling techniques like differential equations or system identification methods such as the Kalman filter or particle filter.
- Model validation: The third step is to validate the model using the collected data. This entails comparing the model's predictions with actual traffic data to evaluate its accuracy and reliability.
- Optimization: The fourth step is to optimize the control inputs (e.g., traffic signal timings) to enhance traffic flow. This can be achieved by addressing the optimization problem defined by the objective function using techniques such as linear programming, dynamic programming, or reinforcement learning.
- Deployment: The final step is implementing the optimized control inputs in the traffic control system. These inputs can be executed in real-time through a control algorithm, such as a model predictive controller, adjusting traffic signal timings based on current conditions.

2.10. Input parameters

- Traffic flow rates
- Road network capacity
- Traffic signal timings
- Vehicle speeds
- Vehicle counts
- Queue lengths
- Travel time

- Linear Programming (LP): LP is a mathematical method that can optimize a linear objective function subject to constraints represented by linear equations or inequalities. LP can be used to optimize traffic flow by minimizing the total travel time or maximizing the total vehicle throughput.
- Quadratic Programming (QP): QP is a mathematical method for optimizing a quadratic objective function subject to constraints represented by linear equations or inequalities. It can also optimize traffic flow by minimizing fuel consumption or maximizing the average vehicle speed.

- Dynamic Programming (DP): DP is a mathematical method for solving complex optimization problems by breaking them down into smaller, simpler subproblems. For example, DP can be used to optimize traffic flow by determining the optimal signal timing for traffic lights.
- Stochastic optimization techniques, such as Genetic Algorithms (GA) and Simulated Annealing (SA), can be used to optimize traffic flow by finding the best combination of traffic signal timings.
- Model Predictive Control (MPC) is a control strategy that uses a mathematical model of the system to predict future behavior and then optimizes control actions to achieve a desired objective. It can be used in traffic control management to optimize traffic flow by adjusting traffic signal timings in real time based on traffic conditions.
- Reinforcement Learning (RL) is a machine learning technique for optimizing traffic control systems by learning from past experiences. It can also optimize traffic flow by adjusting traffic signal timings based on historical data.
- Linear Programming (LP) is a widely used, relatively simple, computationally efficient technique. It is best suited for problems where the objective function and constraints are linear and the number of variables is small. However, LP is not well suited for problems with non-linear objective functions or constraints.
- Quadratic Programming (QP) is similar to LP but can handle quadratic objective functions and constraints. This makes it well suited for problems where the objective function or constraints are non-linear, but it can be computationally more expensive than LP.
- Dynamic Programming (DP) is a powerful technique for solving complex optimization problems. It is particularly useful for problems with sequential decision-making and can be applied to problems with uncertain or stochastic elements. However, it can be computationally intensive, especially for large problems.
- Genetic Algorithm (GA) and Simulated Annealing (SA) are stochastic optimization techniques for solving problems with nonlinear objective functions and multiple local optima. Both techniques can handle a large number of variables, but they can be computationally expensive. SA is generally more efficient than GA in solving problems with continuous variables.
- Model Predictive Control (MPC) is a control strategy for optimizing the control inputs of dynamic systems in real-time. It is particularly useful for problems with constraints and can handle uncertain or stochastic elements. However, it can be computationally intensive, especially for problems with large state and control spaces.
- Reinforcement Learning (RL) is a machine learning technique for optimizing control systems by learning from past experiences. It can be applied to problems with sequential decision-making and can handle uncertain or stochastic elements. However, it can be computationally intensive and requires much data to train the model.

Linear Programming (LP) formula: The LP problem can be formulated as follows:

minimize $c^T x$ subject to: $A x \le b$ and $x \ge 0$

Where: c = coefficients of the linear objective function x = decision variables A = constraint coefficients matrix b = right-hand side of the constraints

Quadratic Programming (QP) formula: The QP problem can be formulated as follows:

minimize $1/2\, x^T H x + c^T x$ subject to: $A x \le b$ and $x \ge 0$

Where: H = quadratic coefficient matrix c = linear coefficient vector x = decision variables A = constraint coefficients matrix b = right-hand side of the constraints

Dynamic Programming (DP) formula: The DP problem can be formulated as follows:

$V(s) = \max[a(s, s') + V(s')]$

Where: $V(s)$ = value of state s $a(s, s')$ = action taken to move from state s to state s'

Genetic Algorithm (GA) formula: The GA problem can be formulated as follows:

fitness(chromosome) = evaluate(chromosome)

Where: chromosome = an individual candidate solution fitness = the value that indicates how good the chromosome is evaluated = function that calculates the fitness of the chromosome

Simulated Annealing (SA) formula: The SA problem can be formulated as follows:

$P(E_i,E_j,T) = e^{-((E_i - E_j)/T)}$

Where: E_i = energy of the current state E_j = energy of the next state T = temperature (controls the probability of accepting a worse solution)

Model Predictive Control (MPC) formula: The MPC problem can be formulated as follows:

minimize $J(u,x) = x(N|k)^T Q x(N|k) + \sum_{i=0}^{N-1} \left(x(i|k)^T Q\, x(i|k) + u(i|k)^T R\, u(i|k)\right)$ subject to: $x(i+1|k) = A\, x(i|k) + B\, u(i|k)$ and $x_{min} \le x(i|k) \le x_{max}$ and $u_{min} \le u(i|k) \le u_{max}$

Where: J = the cost function, x = the state variables, u = the control inputs Q, R = weighting matrices for the state and control inputs respectively x_{min}, x_{max} = lower and upper bounds for the state variables u_{min}, u_{max} = lower and upper bounds for the control inputs

It is important to note that the formulas provided are just examples and may not be exact depending on the specific implementation and problem.

- Linear Programming (LP) can optimize traffic flow by minimizing the total travel time or maximizing the total vehicle throughput. The LP problem can be formulated as follows:
    - minimize $c^T x$ subject to: $A x \le b$ and $x \ge 0$

  Where: c = coefficients of the linear objective function (e.g., total travel time) x = decision variables (e.g., traffic signal timings) A = constraint coefficients matrix (e.g., traffic flow rates) b = right-hand side of the constraints (e.g., the capacity of the road network)

- Quadratic Programming (QP) can optimize traffic flow by minimizing fuel consumption or maximizing the average vehicle speed. The QP problem can be formulated as follows:
    - minimize $1/2\, x^T H x + c^T x$ subject to: $A x \le b$ and $x \ge 0$

  Where: H = quadratic coefficient matrix (e.g., fuel consumption rates) c = linear coefficient vector (e.g., average vehicle speed) x = decision variables (e.g., traffic signal timings) A = constraint coefficients matrix (e.g., traffic flow rates) b = right-hand side of the constraints (e.g., the capacity of the road network)

- Dynamic Programming (DP) can be used to optimize traffic flow by determining the optimal signal timing for traffic lights. The DP problem can be formulated as follows:
    - Dynamic Programming (DP) can be used to optimize traffic flow by determining the optimal signal timing for traffic lights. The DP problem can be formulated as follows:
      $V(s) = \max[a(s, s') + V(s')]$

      Where: $V(s)$ = value of state s (e.g., total travel time) $a(s, s')$ = action taken at state s to reach state s' (e.g., signal timing) s' = next state (e.g., traffic flow rate)

      DP uses a recursive approach to finding the optimal solution. It breaks down the problem into smaller sub-problems and uses the solutions of these sub-problems to find the optimal solution for the original problem.

    - Genetic Algorithm (GA) is a method that is inspired by the process of natural selection. It can be used to optimize traffic flow by finding the optimal signal timings for traffic lights. The GA problem can be formulated as follows:
    - $F(x) = f(x) + penalty(x)$
    - Where: $F(x)$ = fitness function (e.g. total travel time) $f(x)$ = objective function (e.g. average vehicle speed) $penalty(x)$ = penalty function (e.g. constraints violation) x = signal timings (chromosome)

GA uses a population-based approach to find the optimal solution. It begins with a random population of solutions and then uses selection, crossover, and mutation operators to generate new solutions. The best solutions are selected to generate new solutions in the next generation.

- Simulated Annealing (SA) is a method inspired by the annealing process in metallurgy. It can be used to optimize traffic flow by finding the optimal signal timings for traffic lights. The SA problem can be formulated as follows:
- F(x) = f(x) + penalty(x)
- Where: F(x) = fitness function (e.g. total travel time) f(x) = objective function (e.g. average vehicle speed) penalty(x) = penalty function (e.g. constraints violation) x = signal timings
- SA uses a probabilistic approach to find the optimal solution. It starts

MPC uses a receding horizon approach to find the optimal solution. It predicts the system's future behavior using a mathematical model and optimizes the control inputs based on the predictions. It then implements the control inputs for a certain time period, known as the prediction horizon, and repeats the process by updating the predictions and the control inputs.

- Reinforcement Learning (RL) is a method that learns from experience to optimize decision-making. It can be used to optimize traffic flow by determining the optimal signal timings for traffic lights. The RL problem can be formulated as follows:
  - Q(s,a) = max[r + gamma * max(Q(s',a'))]

  Where: Q(s,a) = Q-value of state-action pair (e.g., total expected travel time) s = state of the system (e.g., traffic flow rate) a = action taken (e.g., signal timing) r = reward (e.g,. average vehicle speed) gamma = discount factor (e.g., 0 < gamma <= 1) s' = next state a' = next action

Reinforcement Learning (RL) is a machine learning technique that allows an agent to learn how to behave in an environment by interacting with it and receiving feedback in the form of rewards or penalties. It can be used to optimize traffic flow by determining the optimal signal timings for traffic lights. The RL problem can be formulated as follows:

$$Q(s,a) = r + max(Q(s',a'))$$

Where: Q(s,a) = Q-value of state-action pair (e.g. total expected travel time) s = state of the system (e.g. trsaffic flow rate) a = action taken (e.g. signal timing) r = reward (e.g. average vehicle speed) s' = next state a' = next action

The agent interacts with the environment by selecting an action based on the current state and then receiving a reward or penalty based on the state transition. The agent updates its Q-value function based on the observed reward and uses it to select the next action. The Q-value function can be learned using Q-learning, SARSA, or other RL algorithms.

RL can also be used in a model-based approach where the agent learns a model of the environment and uses it to plan its actions. In this case, the agent can use techniques like Dyna-Q or model-based RL algorithms like PILCO or Guided Policy Search.

In both cases, the agent learns to optimize its actions over time to maximize the cumulative reward,

Reinforcement Learning (RL) is a method that learns from experience to optimize decision-making. It can be used to optimize traffic flow by determining the optimal signal timings for traffic lights. The RL problem can be formulated as follows:

$$Q(s,a) = max[r + gamma * max(Q(s',a'))]$$

Where: Q(s,a) = Q-value of state-action pair (e.g. total expected travel time) s = state of the system (e.g. traffic flow rate) a = action taken (e.g. signal timing) r = reward (e.g. average vehicle speed) gamma = discount factor (e.g. 0 < gamma <= 1) s' = next state a' = next action

RL uses a trial-and-error approach to find the optimal solution. The agent (e.g., traffic controller) interacts with the environment (e.g., traffic system) by taking actions and receiving rewards. The agent learns from the rewards and improves its decision-making over time. Q-learning is a popular RL algorithm that can be used for traffic control management.

In Q-learning, the Q-value of a state-action pair is updated using the following formula:

*Q(s,a) = Q(s,a) + alpha * [r + gamma * max(Q(s',a')) - Q(s,a)]*

Where: alpha = learning rate (e.g. 0 < alpha <= 1)

In Reinforcement Learning (RL) for traffic control management, the goal is to learn an optimal policy for controlling traffic signals that maximizes some performance metric, such as average vehicle speed or minimum travel time. The RL agent interacts with the traffic system by taking actions, such as changing the signal timings, and receives rewards based on the system's performance.

One popular approach to RL in traffic control is using Q-learning, which is a model-free, off-policy algorithm. The Q-learning algorithm uses a Q-table to store the expected future rewards of taking a particular action in a given state. This table is updated during the learning process as the agent interacts with the environment. The Q-table is initialized with arbitrary values, and then the agent explores the environment by selecting actions based on the current state of the system and the Q-table. The agent receives rewards based on the performance of the system and uses these rewards to update the Q-table using the following update rule:

*Q(s,a) = Q(s,a) + alpha * (r + gamma * max(Q(s',a')) - Q(s,a))*

Where: s is the current state of the traffic system, a is the action taken by the agent, r is the reward received for taking action a in state s s' is the next stage of the traffic system, alpha is the learning rate, which determines how much the agent updates its Q-values based on new information gamma is the discount factor, which determines the importance of future rewards about immediate rewards

The agent continues this process of exploration and learning until it reaches a satisfactory level of performance or a stopping criterion is met. The optimal policy is then determined as the action with the highest Q-value for each state.

As the traffic system is dynamic and uncertain, the agent may need to adapt to changing conditions and use techniques like function approximation, experience replay, and target network to improve performance.

2.11. Experimentation Procedure

- Travel Time: This is the time it takes for a vehicle to travel from one point to another on a specific road. It can be calculated using the formula: Travel Time = Distance / Average Speed.
- Level of Service (LOS): This is a measure of traffic congestion and delay, typically rated on a scale from A (free-flow) to F (failure). The LOS is determined by various factors such as vehicle speed, travel time, and density of vehicles on the road. Different methods are used to calculate LOS, such as the Highway Capacity Manual (HCM) method, the Synchro method, and the TRANSYT method.
- Volume-to-Capacity Ratio (V/C): This is the ratio of the number of vehicles on a road to the capacity of the road. It is used to evaluate the level of congestion on a road. It is calculated using the formula: V/C = Volume / Capacity.
- Speed: This is the average speed of vehicles on a road, measured in miles per hour or kilometers per hour. Speed can be measured using various methods such as loop detectors, radar, or GPS.
- Delay: This is the extra time it takes for a vehicle to travel from one point to another due to traffic congestion. It can be calculated using the formula: Delay = Travel Time - Free-flow Travel Time.
- Fuel consumption: This is the amount of fuel consumed by the vehicle during the travel. It can be calculated using the formula: Fuel Consumption = Distance / Fuel Efficiency.
- Air pollution: This is the amount of pollutants the vehicle emits during travel. It can be calculated using different models, such as the MOVES (Motor Vehicle Emission Simulator) model, the COPERT model, or the HBEFA (Handbook Emission Factors for Road Transport) model.
- Safety performance: This is the number of accidents and incidents that occur in the road network. It can be calculated using various methods, such as the crash rate, the crash frequency, and the crash severity.
- It's important to note that the accuracy of these metrics depends on the quality and availability of data and the methods used to collect and analyze the data. Also, these mathematical models are just one way to evaluate the performance of a traffic control system; they are not the only approach, and different models may have different assumptions and limitations.

These metrics can be used to evaluate the performance of a traffic control system and identify areas for improvement, such as optimizing traffic signal timings, adding capacity to a congested road, or re-routing traffic to reduce congestion.

The analytical Framework has been implemented as follows:

- Collect the traffic data.
- Preprocessing the data
- Analyzing the data and visualization of the data
- Implement the bio-inspired algorithm.
- Control the traffic in the city.
- Recommendation of the speed limit based on Vehicle congestion

The speed limit can be predicted based on the distance of the road and the number of vehicles on the road.

Always define the speed limit classification with Min and Max

20-30 –Building Zone (School zone)

30-40-Double Road

20-40-Traffic Zone

Note: Any vehicle that can drive with a minimum speed limit can ride, and the vehicle that can drive with the maximum speed limit.

Vehicles that do not support these conditions can be prosecuted.

with 100

i.e., 6 liters of blood = 100 vehicles

Heart = Toll gates

Brain = Big Data with AI, which consists of Rules and Decision-based systems.

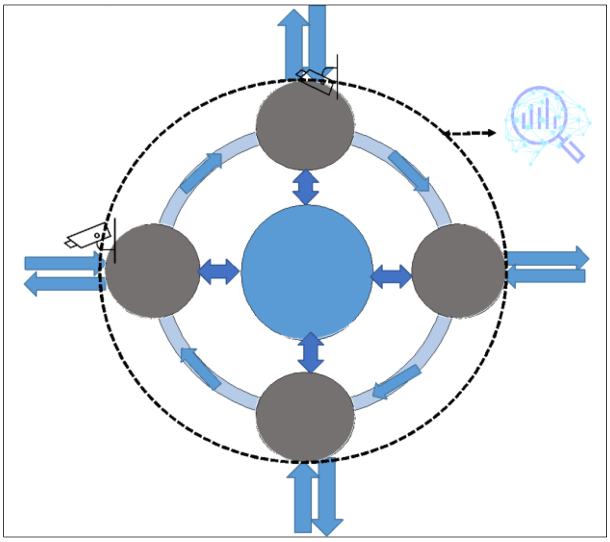


Figure 13 Health Check-up needed either regular or in an emergency

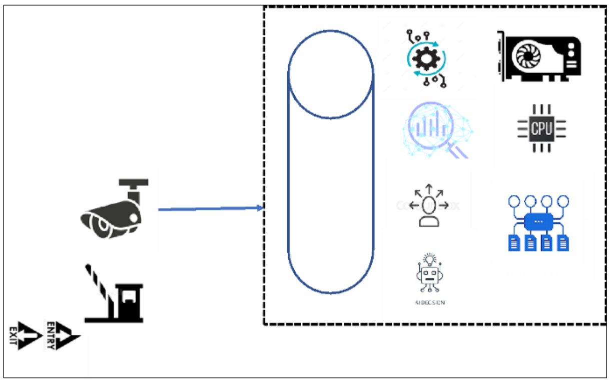


Figure 14 Health Check-up Analogy for Traffic Monitoring in Emergency and Regular Scenarios

Environment Details:

Web Camera:

RAM: 24 GB

GPU: Nvidia GTX-3070, GTX-970, GTX-750 TI

CPU: Xeon Processor

Storage: SSD 1 TB

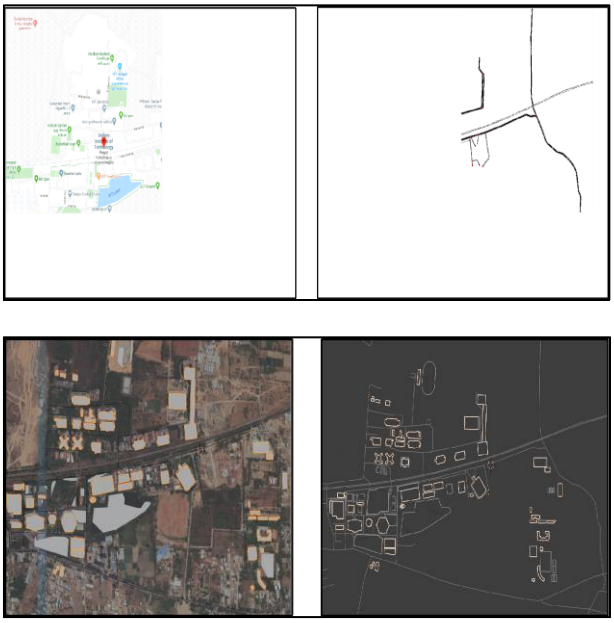
Operating System: Linus Mint

Decision

Pretrained Models:

Each Camera records the data and generates the results promptly, which is scheduled.

Consider the VIT university campus for simulation and experimentation results using the Belnder GIS application.



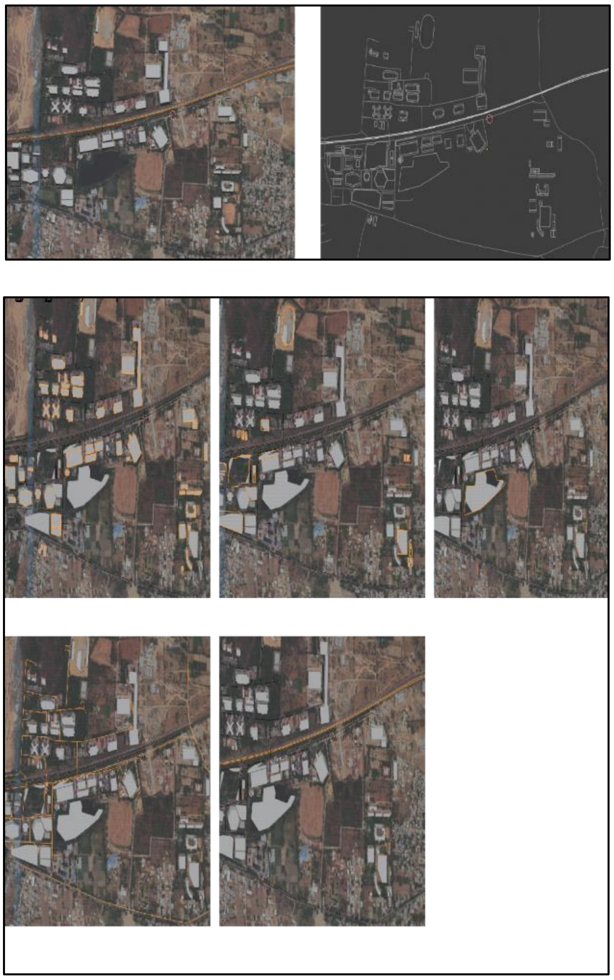


Figure 15 Simulation Setup using Blender GIS for VIT University Campus Traffic Analysis

2.12. Simulation

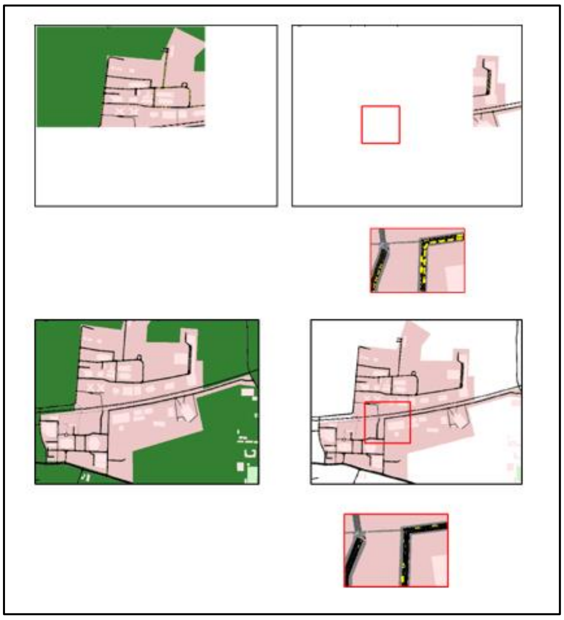


Figure 16 Visual Representation of Vehicle Movement and Traffic density in Simulation environment

Calculate the road risk factor based on the parameters below.

Number of vehicles and Time

Identify the peak and off-peak times.

- Peak:
  - In the morning: 7 AM to 9 AM on weekdays
  - In the evening: 4 PM to 6 AM on weekdays
- Off-Peak:
  - Daytime: 9 AM to 3 PM
  - Late evening: 6 PM to 7 AM

Note: The speed limit on the road will vary for different Vehicle types

Public Transports: Bus

pubt1, pub2…..pubtn => $\sum_{n=0}^{m} pubn$ --------------1

Private Transports: Private Bus, Lorries, Tractors

pvt1, pvt2…..pvtn=> $\sum_{n=0}^{m} pvtn$ ---------------2

Rental/Taxi:

rt1, rt2…rtn=> $\sum_{n=0}^{m} rtn$

Auto:

a1, a2 …an=> $\sum_{n=0}^{m} an$

Own vehicles:

o1, o2, …on => $\sum_{n=0}^{m} on$

The total volume of Vehicle Capacity in University: Tvc

How to calculate the total capacity of Vehicles Parking Spaces University

Number of Car Parking Lots => $\sum_{n=0}^{m} pln$

Number of Street parking signs => $\sum_{n=0}^{m} spsn$

Number of Roads/Streets => $\sum_{n=0}^{m} rstn$

Total Number of Parking Spaces in University limit => $\sum_{n=0}^{m} stn$

$$\sum_{n=0}^{m} stn = \sum_{n=0}^{m} pln + \sum_{n=0}^{m} spsn + \sum_{n=0}^{m} rstn$$

$$\sum_{n=0}^{m} stn$$

- Type of vehicle: Heavy, Mid-Sized, Low, Light Motors Bus, Lorry, Tractor, Car, Minivan, Tempo, Auto, Motor Bikes, Bicycles
- Wheels: number of wheels for the vehicle
- Speed of the vehicle
- Road: Length and Width
  Road Length: rl

Road width: wd

- Vehicle: Length and Width and Height
  Vehicle Length: vl

  Vehicle width: vw

  Vehicle height: vh

- Speed limit
  Speed limit: S

Conditions: Number of vehicles = n

Assume n =15 miles radius, i.e., Human Body

6 liters of blood (b)= Total max number of vehicles inside the University (tvmax)

tvintUvcap => $\sum_{n=0}^{m} pubn + \sum_{n=0}^{m} pvtn + \sum_{n=0}^{m} rtn + \sum_{n=0}^{m} an + \sum_{n=0}^{m} on$

tvmax = total number of vehicles inside the University (tvintUvcap)+ total number of in-transit vehicles (tvin-transit) - total number of out-transit vehicles(tvout-transit)

tvmax = 100

tvintUvcap = 60

tvin-transit = 20 to 40

Dataset:

- Number of Cars-25 to 250
- Number of trucks-5 to 25
- Number of Bikes-50 to 250
- Number of Bicycles-100 to 300
- Number of Pedestrians- 200 to 1500

tvin-transit = Total vehicles into the city

tvout-transit = Total vehicles out

tvmax = tvintUvcap + (tvin-transit - tvout-transit)

Scenerio:1 Tvmax < Volume of vehicles (Vv)

Tvmax < (tvintUvcap + (tvin-transit -tvout-transit))

Vehicles are Allowed

Scenerio:2 tvmax = Volume of vehicles (Vv)

tvmax = (tvintUvcap+(tvin-transit -tvout-transit))

- Control in-transit vehicles aligned with out-transit vehicles.
- Stop the in-transit vehicles until the moment of the out-transit vehicles.

Scenerio:3 Tvmax > Volume of vehicles (Vv)

Tvmax > (tvintcitycap+(tvin-transit-tvout-transit))

Stop the in-transit vehicles until the moment of the out-transit vehicles.

The total number of vehicles reached the maximum, then implementing the slab rates.

First 150 Vehicles – X amount

Second 100 Vehicles – Y amount

Third 50 vehicles – Z amount

$$\text{i.e., } X > Y >> Z$$

$$M = V+X+Y+Z$$

$$N! = M$$

$$(N-M) < 50$$

What is the percentage of vehicles in the University at any point in time?

- Define the controlling Factors of the traffic.
- Several sightseeing locations around the University.
- Number of incoming vehicles is not equal to Number of outgoing vehicles.

$$X - Y < Z$$

Z should be less than 0 to 15%, which is set as a threshold value

Controlling Factors:

- Admissions
- College Fest
- Festivals
- Holidays
- Floods, Earth Quake, Fire Accidents
- Road Accidents
- Work Zones

For I = 0

If (X-Y) < 60% (if the x-y = 80%), then it should be the traffic of the inflow to control the traffic)

Then I++

Else

Break

Fitness function:

- There should not be any accident.
- No traffic congestion
- Capacity of the university: Max: number of vehicles at any given point in the campus

2.13. Testing Optimization Experiments

An optimization simulation experiment was created to explore optimization possibilities for the times associated with traffic lights/Signals. It has been chosen that each traffic light phase can take between 10 and 50 seconds to obtain a minimum average crossing time. This optimization simulation experiment was adapted to both cases of intersection traffic light configuration. In both cases, the optimization experiment will be run for 60 epochs.

3. Traffic Control Test Results

3.1. Test Case:1 Gate Crossing (year and duration of the time)

Before

Table 3 The mean time of the daily number of cars crossing gates

	G1-IN	G2-IN	G3-IN	G1-OUT	G2-OUT	G3-OUT
Bikes	420	398	329	101	183	179
Cars	810	878	490	844	627	688
Bus	400	690	627	432	670	565

3.2. Proposed Data

Table 4 The mean time of the daily number of cars crossing gates after implementing the proposed system

	G1-IN	G2-IN	G3-IN	G1-OUT	G2-OUT	G3-OUT
Bikes	182	131	205	237	229	141
Cars	397	241	299	581	450	527
Bus	292	392	478	397	365	391

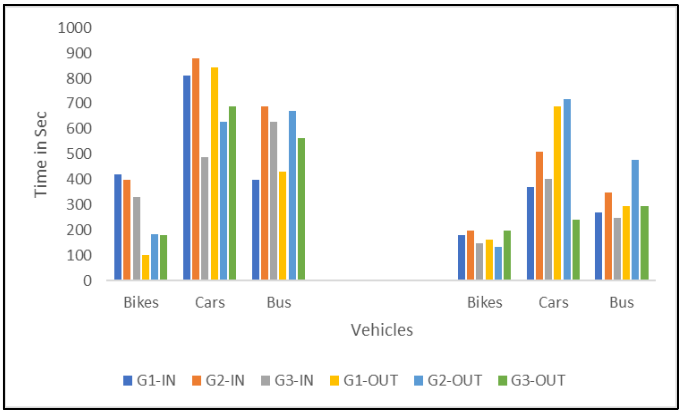


Figure 17 Explanation of Test Case 1

3.3. Test case:2

Calculate the Speed limit within the university on various roads

Table 5 Speed Limits within the University on Various Roads

Speed Limit in Kms	Speed Limit in Kms	Speed Limit in Kms	Speed Limit in Kms
Cars	45	35	25
Bikes	Bikes	Bikes	Bikes
Cars	Cars	Cars	Cars
Bus	Bus	Bus	Bus

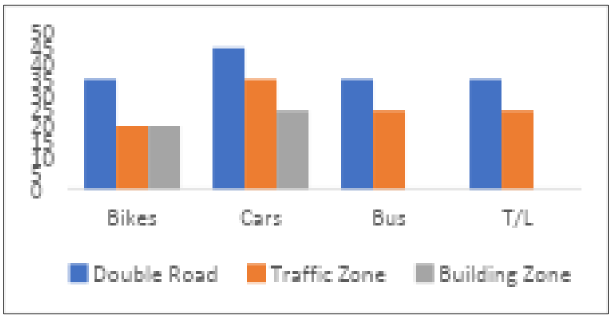


Figure 18 Explanation of Test Case 2

3.4. Test case: 3

A POI annotation indicates the presence of a giveaway in a nearby location. (e.g., landmark, location)

Table 6 Travel Time Before and After Traffic Control at Key POIs

	Before (Time in min)			**After (Time in min)**		
POI	Bikes	Cars	Bus	Bikes	Cars	Bus
Main Building	10	2	3	10	2	10
Library	15	4	5	15	4	15
Boys Hostel	25	10	15	25	10	25
Biomedical Center	25	10	15	25	10	25
Technology Tower	17	13	17	17	13	17
Girls Hostel	19	13	19	19	13	19
SJT	20	17	20	20	17	20

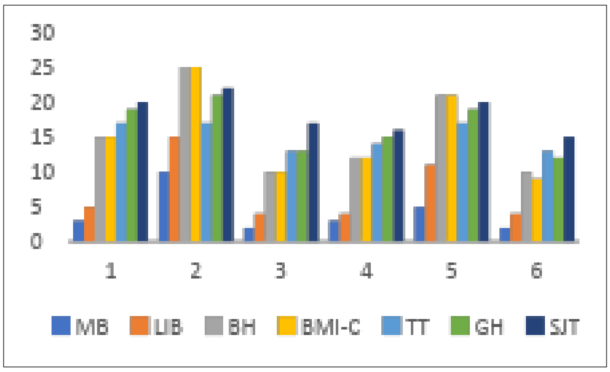


Figure 19 Explanation of Test Case 3

3.5. Test Case: 4

Traffic Calming: A point of Intersection (POI) annotation which indicates the presence of traffic calming in a nearby location (e.g., police stations, VIT Security Staff)

Table 7 Traffic Calming Measures Near Key Locations

Protection Team		Main Gate	Thiruvalluvar statue
Police Station	Distance in Kms	3.3	3.1
	Time in Min	9	11
VIT Security Staff	Distance in Kms	0.1	0.3
	Time in Min	2	4

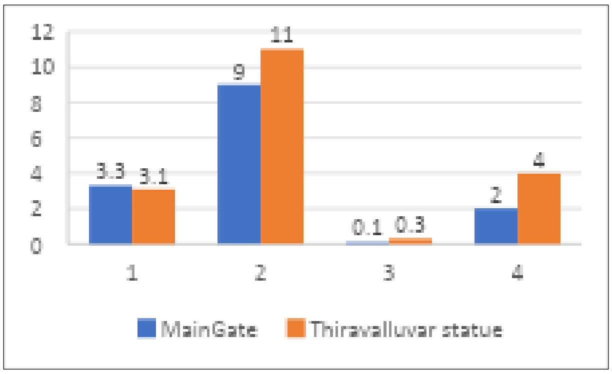


Figure 20 Explanation of Test Case 4

3.6. Test Case: 5

Traffic increases at our gate due to public holidays

Table 8 Traffic Volume at University Gates During Public Holidays

Out-Gate-1	Bikes	Cars	Taxis
Main Building	5	12	6
Library	7	17	18
Boys Hostel	25	37	42
Biomedical Center	15	25	27
Technology Tower	17	26	27
Girls Hostel	25	35	32
SJT	20	22	27

3.7. Test case: 6 Max number of vehicles inside the campus

Total number of vehicles at any time = Total vehicles inside the campus + total number of vehicles in gates.

Max capacity of campus = Number of vehicles on campus + Total capacity of the campus: VIT team (number of day scholars + Number of Prof + Number of Non-Teaching staff) + Outside team (Working staff in hotels/constructions, Guests)

Comparison between the different models based on the below metrics:

- Number of true positive predictions (TP): This is the number of instances correctly classified as positive by the model or algorithm.

- Number of true negative predictions (TN): This is the number of instances that the model or algorithm correctly classified as negative.
- Number of false positive predictions (FP): This is the number of instances where the model or algorithm incorrectly classified as positive.
- Number of false negative predictions (FN): This is the number of instances where the model or algorithm incorrectly classified as negative.
- Number of data points: This is the total number of instances in the dataset used for evaluation.
- Predicted traffic volume: This is the traffic volume the model or algorithm predicts.
- Actual traffic volume: This is the actual traffic volume, as measured by sensors or other means.
- Convergence rate: This is the rate at which the algorithm's solution gets close to the optimal solution.
- Diversity: This is the variety of solutions generated by the algorithm.
- Scalability: This is the ability of the algorithm to handle large amounts of data.

3.7.1. Accuracy

Accuracy measures the percentage of correctly classified traffic patterns. It is calculated as the number of true positive and true negative predictions divided by the total number of predictions.

Formula: (True Positives + True Negatives) / (True Positives + True Negatives + False Positives + False Negatives)

3.7.2. Precision

Precision measures the proportion of true positive predictions among all positive predictions. It is calculated as the number of true positive predictions divided by the number of true positive predictions plus the number of false positive predictions.

Formula: True Positives / (True Positives + False Positives)

3.7.3. Recall

Recall measures the proportion of true positive predictions among all actual positive instances. It is calculated as the number of true positive predictions divided by the number of true positive predictions plus the number of false negative predictions.

Formula: True Positives / (True Positives + False Negatives)

3.7.4. F1 Score

The F1 Score is the harmonic mean of precision and recall, a commonly used metric for evaluating the performance of binary classification models.

*Formula: 2 * (Precision * Recall) / (Precision + Recall)*

3.7.5. AUC-ROC Curve

The AUC-ROC curve is a graphical representation of a binary classification model's performance at different classification thresholds. It plots the true positive rate (TPR) against the false positive rate (FPR) at different thresholds and is useful for evaluating a model's overall performance, particularly when the class distribution is imbalanced.

AUC (Area Under the Curve) is a single number summary of the curve, where a higher AUC indicates a better model.

Formula: TPR = True Positives / (True Positives + False Negatives) , FPR = False Positives / (False Positives + True Negatives)

3.7.6. Mean Squared Error (MSE) or Mean Absolute Error (MAE)

MSE and MAE are the metrics commonly used to evaluate the performance of regression models. MSE is the average square of the difference between the predicted and actual traffic volume. MAE is the average difference between the predicted and actual traffic volume.

*Formula for MSE: (1/n) * Σ(predicted - actual)^2*

*Formula for MAE: (1/n) * Σ|predicted - actual|*

where n is the number of data points.

It's important to note that these metrics don't tell the whole story and that it's important to look at all the metrics together to get a more comprehensive view of the model's performance. Limitation:

- Accuracy: This measures the percentage of correctly classified traffic patterns.
- Precision: This measures the proportion of true positive predictions among all positive predictions.
- Recall: This measures the proportion of true positive predictions among all actual positive instances.
- F1 Score: This is the harmonic mean of precision and recall and is a commonly used metric for evaluating the performance of binary classification models.
- AUC-ROC Curve: This plots the true positive rate against the false positive rate at different classification thresholds and is a useful metric for evaluating a model's overall performance, particularly when the class distribution is imbalanced.
- Mean Squared Error (MSE) or Mean Absolute Error (MAE): This measures the difference between predicted and actual traffic volume and is commonly used to evaluate the performance of regression models.
- Convergence rate: This measures the rate at which the algorithm's solution gets close to the optimal solution.
- Diversity: This measures the variety of solutions generated by the algorithm.
- Scalability: This measures the ability of the algorithm to handle large amounts of data.

Anxiety, Happiness, Worry, Sorrow, and Fear can change the heartbeat and cause a heart attack. Similarly, it can lead to traffic congestion and accidents on the road network.

3.8. Future scope of work

- Predict the speed limit using the Time series
- Predict the traffic limit near the POI
- How to reduce the traffic without increasing the infrastructure
- Detecting traffic jams and taking action to release them.
- Automatic tracking of the Evidence in accidents and Traffic law violations.

4. Conclusion

Traffic is controlled by setting standards. The speed limit should be calculated to control a vehicle's speed based on the road capacity. As in the human body, the heart pumps oxygenated blood through the left atrium and the left ventricle to the entire body with a certain pressure. The heart will also pump the blood flow velocity, which is the fastest in the middle of the vessel and slowest at the vessel wall. However, deoxygenated blood will return to the Heart through the right channel.

In case of an accident or damage to a vehicle, the roadways and police authorities take immediate precautions. Inside the city or business hub/center, where there is huge traffic due to the population, vehicles should be controlled through one-way traffic to avoid any accidents by following certain speed limits.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. All authors have contributed significantly to the work and have approved the final version of the manuscript. No financial, personal, or professional relationships have influenced the content or interpretation of the findings presented in this study.

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