1. INTRODUCTION

1.1 Preamble

V2X architecture is a connected infrastructure technology that is set to become a major business that will impact transportation, infrastructure, and cities all over the world.

Vehicle to everything (V2X), the technology that allows communication between vehicles on the road and any other entity that might affect them—including other vehicles, road infrastructure, pedestrians, traffic lights, and any other connected devices, is one of the essential factors that will determine the success of autonomous cars along with ensuring road safety and reduce of energy/fuel consumption by alleviating traffic congestion.

We are working on developing a V2I architecture simulator to simulate vehicular networks and road traffic and perform their training and testing virtually as opposed to physically, which can be used to further tap into the potential of V2X and boost the development of related emerging technologies such as autonomous vehicles, smart traffic control systems, and much more.

1.2 Motivation

Our project is on developing a V2I architecture that is key to the development of the technologies that are:

- Smart traffic congestion control
- Reduction of energy/fuel consumption in vehicles
- Enhancing safety precaution of autonomous vehicles on the road

1.3 Objectives

- To simulate various types of vehicles and environment.
- To design an algorithm to reduce wait time at traffic signals and carbon emissions for all types of vehicles.
- To analyze different algorithms on various scenarios.
- To apply multiple algorithms to control the congestion of high traffic in a lane.
- To predict the number of vehicles that are going to arrive in each lane for better traffic optimization.

1.4 Literature Survey

[1] Title: Implementation and performance measurement of a V2X communication system for vehicle and pedestrian safety.

Authors: Zishan Liu, Zhenyu Liu, Zhen Meng, Xinyang Yang, Lin Pu, and Lin Zhang

In this research paper Traffic accidents involving cars and weak pedestrians have become one of the most important issues in the transportation system today as vehicles gain

widespread use. Vehicle networking to perceive everything is a research and industry goal to improve transportation safety and prevent accidents. The IEEE 802.11p/1609.x families, also referred to as the specialized short-range communication/wireless access for vehicular environments, have been defined (DSRC) Vehicles having on-board units (OBUs) can connect with roadside units (RSUs), also known as the vehicle-to-Infrastructure, using DSRC (V2I).they showed how to make a heterogeneous vehicular correspondence framework that can uphold IEEE 802.11p, LTE-based V2V, and WiFi-based V2P correspondence. To assess the IEEE 802.11p and LTE-based V2V correspondence execution as far as the PDR and start-to-finish idleness, they applied the correspondence framework. They led various true tests in an uncontrolled way. The examination's three potential settings are our grounds, a metropolitan road, and a rural area. In light of the preliminaries and information examination, they found that LTE-based correspondence beats IEEE 802.11p concerning unwavering quality (PDR), however, that it has a more prominent correspondence idleness.

[2] Title: Design and Numerical Implementation of V2X Control Architecture for Autonomous Driving Vehicles

Authors: Piyush Dhawankar, Prashant Agrawal, Krishna Busawon, Maria Simona

This paper has introduced a different plan and mathematical execution of a V2X control framework engineering for a company of independent vehicles. All the more definitively, they have shown a few parts of detachment based driving with vehicular organization engineering and their consequences for company elements and control. This includes an IDM regulator together working with 802.11p correspondence engineering. They have given a reasonable understanding into the effect of the correspondence geography on the regulator execution to characterize unit vehicles' control systems. They have efficiently explained the impacts of helpful company driving and unit based vehicular correspondence. Reproduction results show the viability of the carried out control engineering in its aversion to a crisis, between vehicular hole, enormous irritation, and the deficiency of correspondence and changing driving climate. Also, the proposed recreation stage demonstrates that it can coordinate any CF or agreement control model with any correspondence framework.

[3] Title: Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication in a heterogeneous wireless network – Performance evaluation

Authors: Kakan Chandra Dey, Anjan Rayamajhi, Mashrur Chowdhury, Parth Bhavsar, James Martin

In this study, the creators exhibited the capability of V2V and V2I in a Het-Net climate with Wi-Fi, DSRC and LTE that ensure the ideal use of accessible correspondence choices and limit the relating backhaul correspondence framework necessities while thinking about associated vehicle application prerequisites. Existing CVT engineering, like CVRIA, proposes that consistent correspondence for V2V and V2I are expected to

use the maximum capacity of CVT applications. For an expansive scope of CVT applications (i.e., wellbeing, versatility, ecological), a practical correspondence choice ought to incorporate V2V and V2I equipped for using a Het-Net ideally without losing network while moving starting with one correspondence network then onto the next. It will require a fruitful handoff starting with one remote organization then onto the next in a Het-Net climate. Nonetheless, these various organizations have not been intended for the consistent message move starting with one organization then onto the next for moving hubs/vehicles.

[4] Title: IMPROVING V2I COMMUNICATION TECHNOLOGY BASED ON INTERFERENCE ANALYSIS FOR WIRELESS NETWORKS

Author: Jamal Raiyn

In this paper ,the impacts of these types of impedance are just somewhat made up for by worldwide models in single recurrence recipients. An AV utilizes V2V, V2I, and V2X interchanges to work on driving security and traffic effectiveness, and to give data and diversion to the driver. Its correspondence conventions are fit for driving with practically no human investment. Be that as it may, right now there are just hypothetical thoughts regarding how AVs with correspondence capacities can further develop traffic effectiveness, and wellbeing, and forestall issues like car crashes, clog, and CO2 discharges among others. One of the best difficulties of agreeable correspondence frameworks in vehicles is satisfying the QoS necessities for negligible postponement. Expanded defers in helpful correspondence are the primary driver of gridlock. The keeping insignificant separation between two vehicles guarantees a productive helpful correspondence and decreases the packet's misfortune proportion.

[5] Title: An empirical study of vehicle to infrastructure communications - An intense learning of smart infrastructure for safety and mobility

Author: Dhaya Kanthavel, S. K. B. Sangeetha, K. P. Keerthanas

In this paper the contact among vehicles and frameworks, remote information dividing between vehicles. V2I correspondence is normally remote and bidirectional through equipment, programming and firmware: remote stockpiles can be given frameworks like path signs, street signs and lights, and vice versa. Rich, ideal data can be utilized through the assortment and trade of such a lot of information to give a wide range of guard, versatility, and natural advantages. The streets are destined to be the site of a revolt. They have concentrated on the full escalated comprehension of V2I top to bottom about how V2I has been instrumental in correspondence and has put forth a tremendous expected attempt in this section. This section basically features applications for remote innovation fueled by V2I.

1.5 Problem Definition

The development of a vehicle-infrastructure simulator to test and analyze various traffic management methods, decrease average wait times, and cut carbon emissions

2.PROPOSED SYSTEM

2.1 Description of Proposed System

A vehicle-infrastructure network simulator is a computer program or system that simulates the interactions and movements of vehicles in a transportation network. It typically includes a virtual representation of roads, intersections, traffic signals, and other infrastructure elements, as well as the vehicles themselves. The simulator allows users to set different scenarios, such as varying traffic volumes and road conditions, and observe how the network responds. This can be used to evaluate the effectiveness of different traffic management strategies and identify potential bottlenecks or congestion points. The simulator may also include tools for analyzing data and generating reports on various aspects of the network performance.

2.2 Description of Target Users

The target users for a vehicle-infrastructure network simulator would be transportation planners, traffic engineers, and researchers who are involved in designing and analyzing transportation networks. These individuals may use the simulator to test and evaluate different strategies for managing traffic flow, optimize the allocation of resources, and assess the impact of potential changes to the network. The simulator could also be useful for educators who are teaching transportation planning and engineering concepts, as well as for students who are studying these fields.

2.3 Advantages/Applications of Proposed System

The proposed vehicle-infrastructure network simulator offers several advantages and applications for transportation planning and engineering. Some of these include

1. Testing and evaluating different traffic management strategies: The simulator allows users to set different scenarios and observe how the network responds, allowing them to identify potential bottlenecks and congestion points, and evaluate the effectiveness of different strategies for managing traffic flow.

2. Optimizing the allocation of resources: By simulating different scenarios and analyzing the data generated by the simulator, transportation planners and engineers can identify areas of the network that may require additional resources, such as additional lanes or traffic signals, and make informed decisions about where to allocate these resources.

3. Assessing the impact of potential changes to the network: The simulator can be used to evaluate the potential impact of changes to the network, such as the construction of new roads or the introduction of new traffic control systems, and identify any potential negative impacts before these changes are implemented.

4. Teaching and learning: The simulator can be a valuable tool for educators who are teaching transportation planning and engineering concepts, as it provides a hands-on way for students to apply their knowledge and explore different scenarios. It can also be used by students who are studying these fields to gain practical experience and better understand the complexities of transportation networks.

5. Research and development: The simulator can be used by researchers to conduct studies on various aspects of transportation networks, such as traffic flow patterns and the impact of different traffic management strategies. It can also be used to develop and test new algorithms and algorithms that can be used to optimize the performance of transportation networks.

2.4 Scope

The detailed scope of the proposed vehicle-infrastructure network simulator includes the following features and capabilities:

- A virtual representation of roads, intersections, traffic signals, and other infrastructure elements in a transportation network
- The ability to set different traffic volumes and road conditions to simulate different scenarios
- Tools for analyzing the data generated by the simulator, such as traffic flow patterns and congestion levels
- The ability to evaluate the effectiveness of different traffic management strategies and identify potential bottlenecks and congestion points
- Reporting and visualization tools for presenting the results of simulation runs and analysis

The simulator is not intended to be used for simulating other aspects of transportation systems, such as the scheduling of public transit services or the management of freight traffic. It is also not designed to be used as a tool for directly controlling or managing traffic in real time. Instead, it is intended to be used by transportation planners, traffic engineers, and researchers who are involved in the design and analysis of transportation networks, to evaluate and optimize the performance of these networks.

3. SOFTWARE REQUIREMENT SPECIFICATION

3.1 Overview of SRS

Software Requirement Specification(SRS) is the beginning stage of the product-creating activity. As the framework developed more mind-boggling it became clear that the objective of the whole framework can't be easily comprehended. Consequently, the requirement for the necessity stage emerged. The product project is started by the client. The SRS is the method for interpreting the thoughts of the personalities of clients (the info)into a proper report (the result of the necessity stage.)

3.2 Requirement Specifications

3.2.1 Functional Requirements

- The application should simulate V2I architectures
- The vehicles must appear to move in a particular section path
- The vehicles should stop according to the traffic lights
- The vehicles must not collide with each other
- The application should simulate all the conditions of the path of the vehicles

3.2.2 Use case diagrams

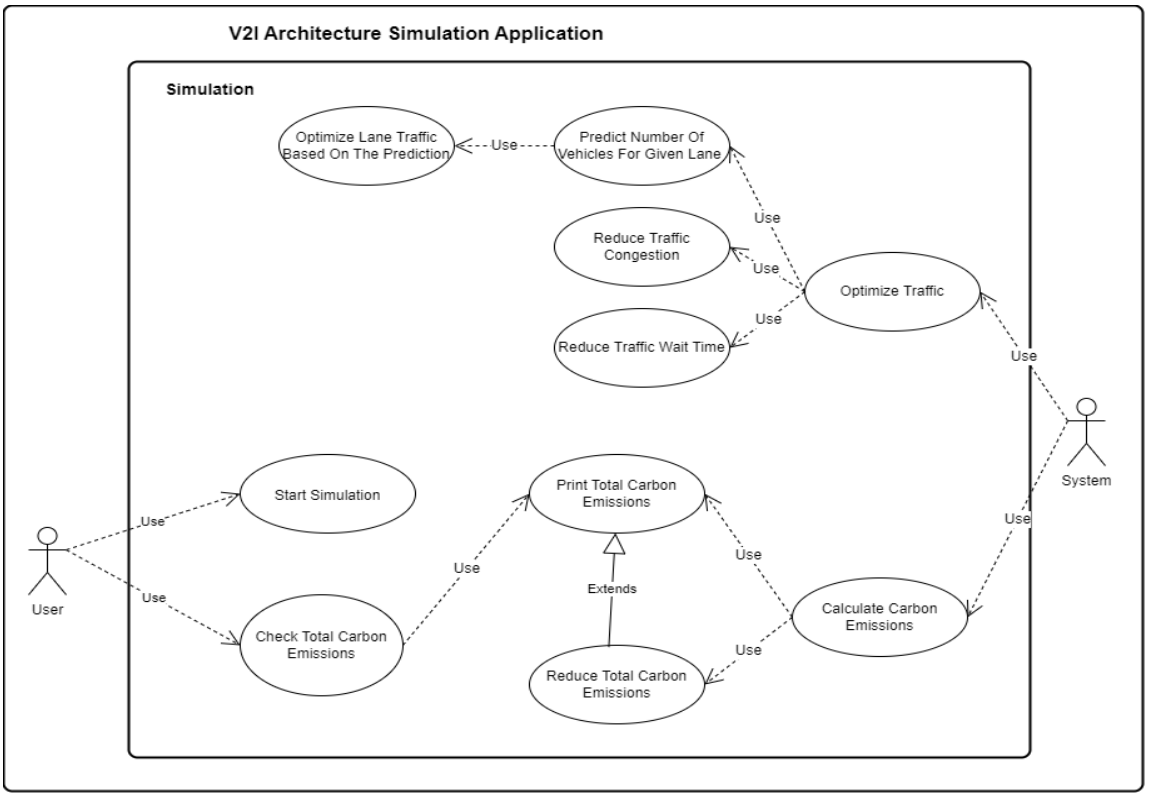

Figure 1. Use Case Diagram for V2I Architecture Simulator

Here in the given figure 1, the two main actors are the user and the system. The user shall be able to:

- Start the simulation
- Check the total carbon emissions

System provides services that include:

- Optimize traffic
    - Predict the number of vehicles in the lane
    - Reduce traffic congestion
    - analyze traffic wait time
- Calculating carbon emissions
    - Print total carbon emissions
    - analyze total carbon emissions

3.2.3 Use Case Description & Scenarios (Pressman template)

Use Case ID	1
Use Case	Start Simulation
Primary Actor	USER
Description	User begins the simulation of the layout
Goal In Context	To start the simulation
Preconditions	N/A
Trigger	User clicks on ‘Start Simulation’
Scenario	User clicks on ‘Start Simulation’
Exceptions	N/A

Use Case ID	2
Use Case	Check Total Carbon Emissions
Primary Actor	USER
Description	User is able to check the total carbon

	emissions generated by the layout
Goal In Context	To get the total carbon emissions of the road layout
Preconditions	N/A
Trigger	N/A
Scenario	User views the total carbon emissions generated by the layout during its simulation
Exceptions	N/A

Use Case ID	3
Use Case	Optimize traffic
Primary Actor	SYSTEM
Description	System performs traffic optimization by: ● Predicting the number of vehicles in the lane ● Reducing the traffic congestion ● Reducing the traffic wait time
Goal In Context	To perform traffic optimization
Preconditions	N/A
Trigger	N/A
Scenario	N/A
Exceptions	N/A

Use Case ID	4
Use Case	Calculate Carbon Emissions
Primary Actor	SYSTEM
Description	System calculates the total carbon

	emissions generated by the given layout based given emission rates, initial emissions and the number and types of vehicles in the layout
Goal In Context	To calculate the total carbon emissions of the layout
Preconditions	N/A
Trigger	N/A
Scenario	N/A
Exceptions	N/A

3.2.4 Nonfunctional Requirements

- The application should be user-friendly
- The application should be light and trustworthy
- The application should not be resource exhaustive
- The application can be used any number of times by the user
- The algorithm of application should produce the desired or better result

3.3 Software And Hardware Requirements Specification

Software Requirements

The development and deployment of this project requires following minimum requirements for the software :

- Programming language : Python 3.8 with gui
- IDE: Jupyter Notebook
- Operating System : macos/windows/linux
- Module/library : pygame

Hardware Requirements

The turn of events and organization of the application requires the accompanying general and specific minimum necessities for equipment:

- Processor (arm, 32 bit or 64 bit)
- RAM: 4GB

4. SYSTEM DESIGN

4.1 Architecture of the System (explanation)

The architecture of the system in this code is centered around a simulation of traffic at a 4-way intersection using Pygame. The code includes variables and data structures to store information about the traffic at the intersection, such as the number of vehicles in each lane and the time that each traffic signal is set to stay green. It also includes variables to store information about the traffic signals, the vehicles at the intersection, and the coordinates for various elements of the simulation (e.g. the stop lines, traffic signals, and vehicle count displays). The code also includes several dictionaries and lists to store and organize this data. Finally, the code includes a TrafficSignal class and a Vehicle class to represent the traffic signals and vehicles in the simulation, respectively, and a simulation group to store the sprites for the simulation. The simulation is run using a loop that updates the state of the traffic and the simulation at each iteration.

4.2 Class Diagram (brief explanation)

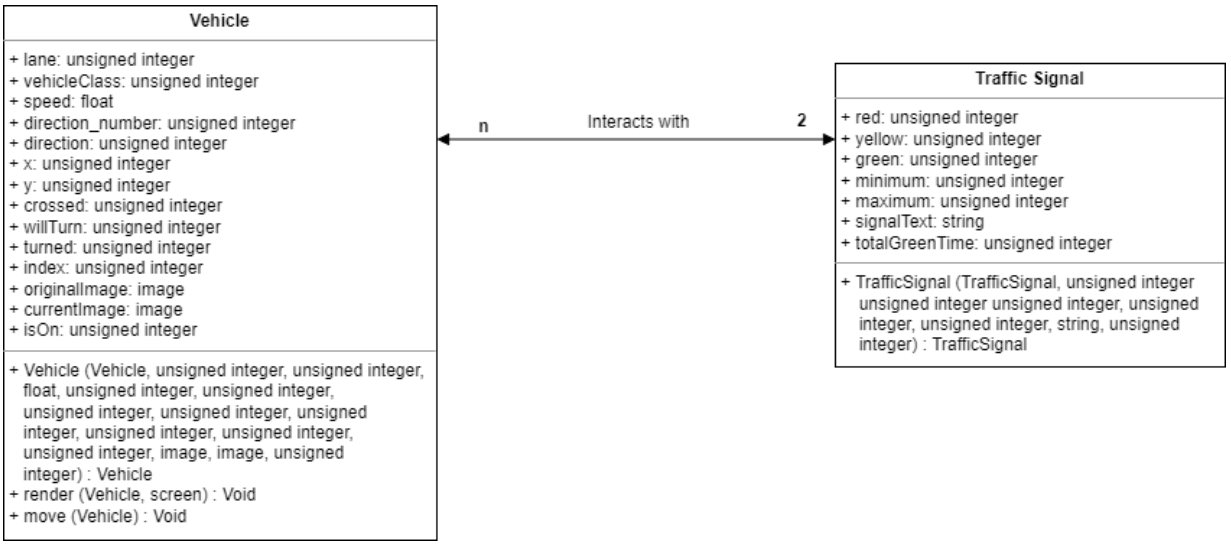

Figure 2. Class Diagram for V2I Architecture Simulator

There are primarily only two classes that interact with each other: TrafficSignal, representing the road traffic signals, and Vehicle, representing the road vehicles. In our simulator, every vehicle interacts with two traffic signals, one in its lane and another in the lane that the vehicle may take a turn into. On the other hand, every traffic signal interacts with multiple vehicles on its own as well as its adjacent lanes.

4.3 Data Structures Used

- Lists: Lists are used to store a collection of items in a specific order. For example, the signals list stores information about the traffic signals at the intersection, and the vehicleCountTexts list stores the current vehicle counts at the traffic signals as strings.

- Dictionaries: Dictionaries are used to store key-value pairs. For example, the speeds dictionary stores the average speeds of different types of vehicles, and the carbonValue dictionary stores the carbon emissions of different types of vehicles per second.

- Tuples: Tuples are used to store a collection of items that cannot be modified. For example, the signal coordinates, signalTimerCoods, and vehicle Count Coordinates variables store the coordinates for the images of the traffic signals, their timers, and the vehicle count displays, respectively, as tuples.

- Strings: Strings are used to store text data. For example, the vehicleCountTexts list stores the current vehicle counts at the traffic signals as strings.

5. IMPLEMENTATION

5.1 Proposed Methodology

we are currently using two different algorithms for the implementation of the V2I architecture of the proposed system which are as follows:

1.**Static Time** for each signal:

In this the time for each signal of the system remains fixed and the time gap between any two of the signals in the system also always remains constant .

Generally this algorithm is a famous concept of having a fixed participation or distribution of all components in the system and widely used around the globe in implementation of various different models.

The formula in this concept of fixed time for each signal is

Avg waiting time = Total waiting time of all vehicles / Count of vehicles

2. **Proportional Division** of one time -unit upon change in the traffic volume of the system

In this algorithm let in one time frame suppose there are 60 seconds then it is divided proportionally among all 4 traffic signals on the basis of the traffic volume (i.e total no of different types of vehicles occupying the volume or space in that particular lane or road).

Time gap between any two traffic signals may vary at any point of time in the system, in this method we also record the traffic volume in each road , at the start of the time frame.

We record the traffic volume and proportionally divide one unit of time among all 4 lanes and the time for each signal remains fixed till the next time frame.

This algorithm allocates the time based on demand and there is no case of starvation as after each time frame a new value gets allocated ,this is very beneficial in real world scenario , as in real world we way see high congestion in one road of an intersection and another completely empty.

let us suppose

one_time_frame=60 (in seconds)

greentime_road1=one_time_frame*(vehicle_count_road1/total_vehicle_count)

greentime_road2=one_time_frame*(vehicle_count_road2/total_vehicle_count)

greentime_road3=one_time_frame*(vehicle_count_road3/total_vehicle_count)

greentime_road4=one_time_frame*(vehicle_count_road4/total_vehicle_count)

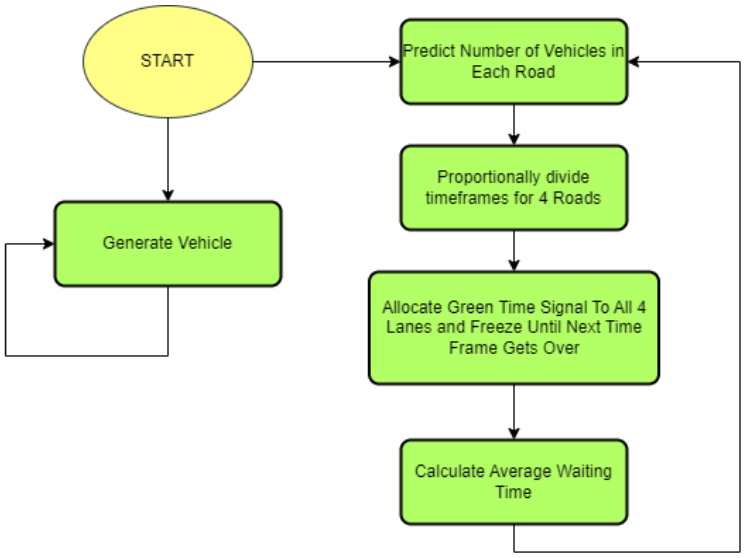

Figure 3. Flowchart Diagram for V2I Architecture Simulator

5.2 Description of Modules

The code imports several Python modules at the beginning. The random module provides functions for generating random numbers and selecting random items from a list. The math module provides mathematical functions such as square root, trigonometric functions, and exponential functions. The time module provides functions for working with time, such as measuring the time elapsed and sleeping for a certain period of time. The threading module provides support for creating and managing threads, which are separate flows of execution that can run concurrently within a program. The pygame module is a set of Python modules designed for writing video games, and it provides functions for creating and manipulating graphical elements, handling user input, and playing sounds and music. The sys module provides functions and variables related to the Python interpreter, such as the command-line arguments and the current version of Python. The os module provides functions for interacting with the operating system, such as accessing and manipulating files and directories.

6. TESTING

6.1 Acceptance Testing

Table 1: Acceptance test plan

Test id	Input Description	Expected output	Actual output
1	A vehicle should stop at a red light	stop	stop
2	A vehicle should not be able to pass through a vehicle	stop before a car	stop before a car

6.2 Unit Testing

Table 2: Unit test plan for module signalLogic()

Test id	Input Description	Expected output	Actual output
1	All traffic signals are green	Traffic signals should stay green for their designated green time	Traffic signals stay's green for their designated green time
2	One traffic signal is yellow	Traffic signal should turn red after yellow time elapses	Traffic signal turn red after yellow time elapses
3	One traffic signal is red	Traffic signal should stay red for its designated red time	Traffic signal stay red for its designated red time
4	All traffic signals are red	Next traffic signal should turn green after red time elapses	Next traffic signal turn green after red time elapses
5	Minimum green time is reached	Traffic signal should stay green until maximum green time is reached	Traffic signal stay green until maximum green time is reached

7. RESULTS & DISCUSSIONS

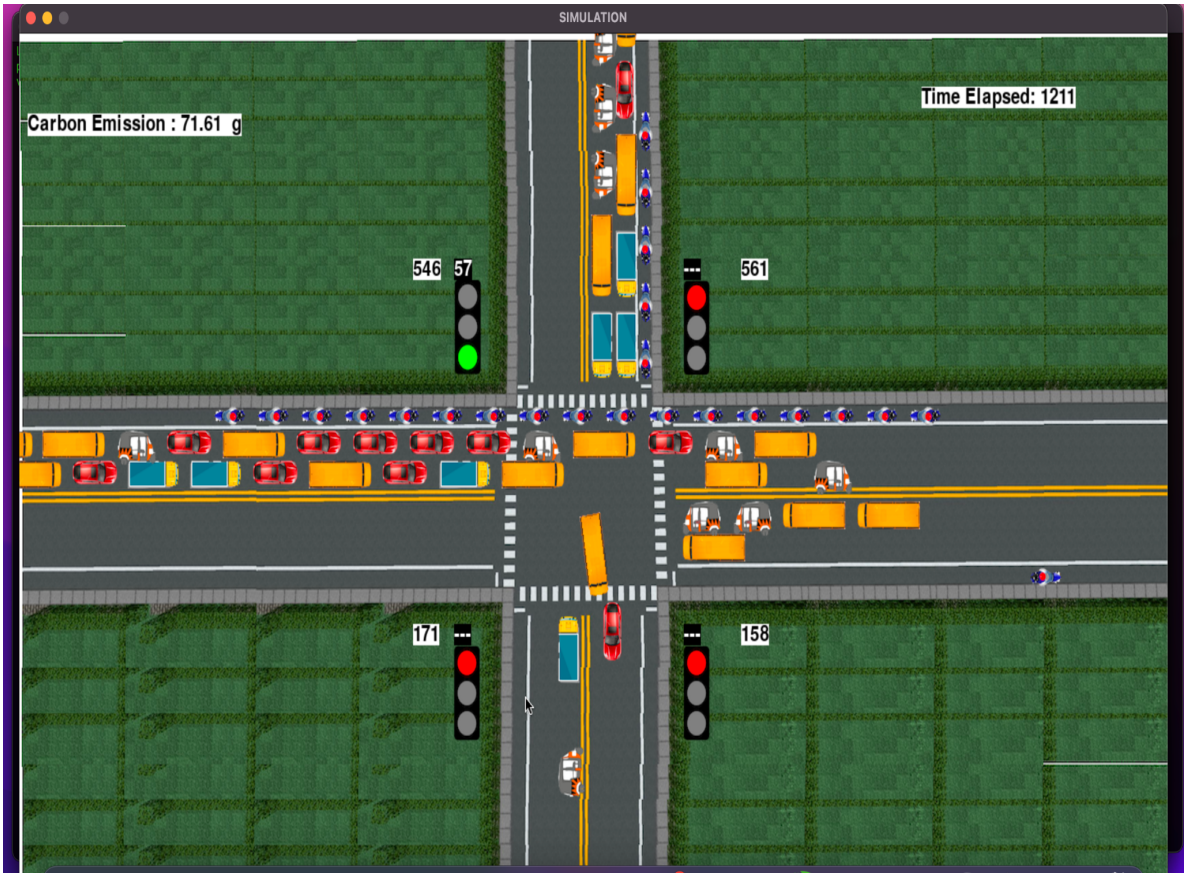

figure 4 - simulation of vehicles

In our vehicle-infrastructure network simulator, we implemented virtual representations of roads, intersections, and traffic signals, as well as the vehicles themselves. We set different scenarios, varying the traffic volumes and road conditions, and observed the movements of the vehicles and the resulting traffic flow patterns.

One of the key results we observed was the impact of different traffic management strategies on the network performance. For example, we found that implementing traffic signals at intersections can significantly reduce congestion and improve traffic flow, compared to allowing vehicles to move freely without any control. We also observed that increasing the number of lanes on roads can help to reduce congestion, but only up to a certain point, after which the additional lanes may not have a significant impact on the network performance.

We also calculated the carbon emissions generated by the vehicles in our simulations, and found that implementing traffic signals and reducing traffic volumes can significantly reduce emissions. This demonstrates the potential benefits of adopting traffic management strategies that are designed to optimize the performance of transportation networks and reduce the environmental impact of vehicle use.

In addition to the results of our simulations, we also developed visualization tools that allow users to see the movements of the vehicles and the traffic flow patterns in real-time. These tools provide a useful way for users to understand the dynamics of the network and identify potential bottlenecks or congestion points.

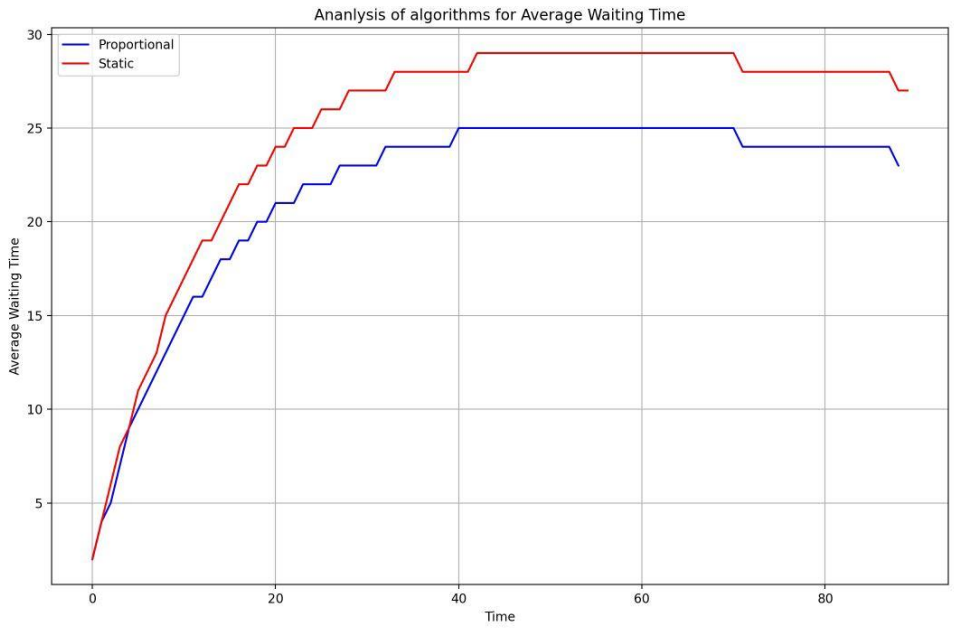

Fig. 5 Analysis of Algorithms for Average Waiting Time

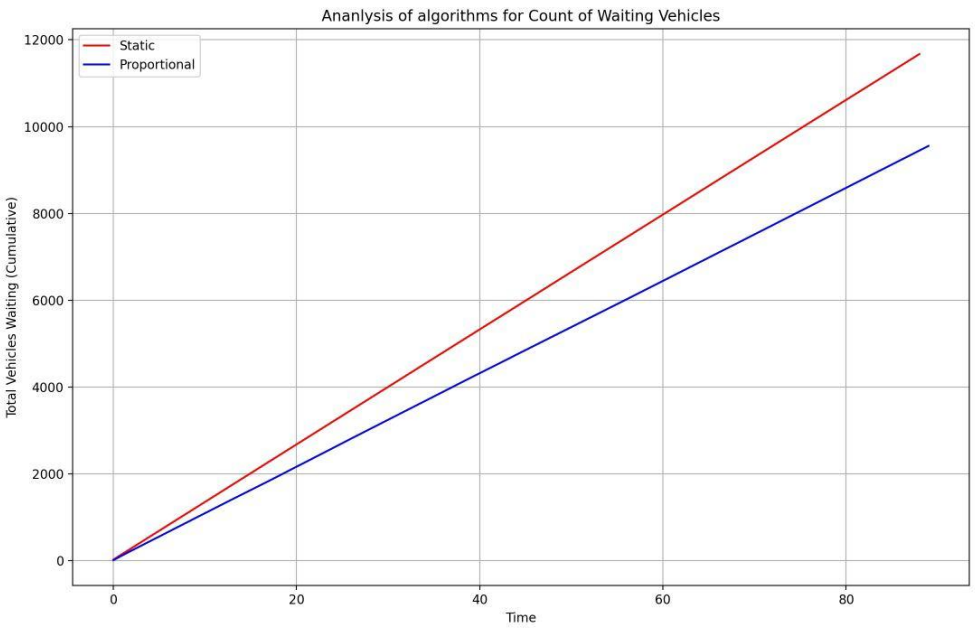

Fig. 6 Analysis of Algorithms for Count of Waiting Vehicles

In Fig. 5 we are analyzing the average waiting time of all the vehicles in the system with different algorithms: proportional and static .
Avg waiting time of all vehicles was least in the proportional algorithm and highest in the static algorithm . proportional algorithm reduced avg waiting time by 14 % .
In figure 6 we are having the data analysis of above three algorithms of total count of the average waiting vehicle. It showed up the results as the highest count of no of vehicles waiting in the static algorithm .

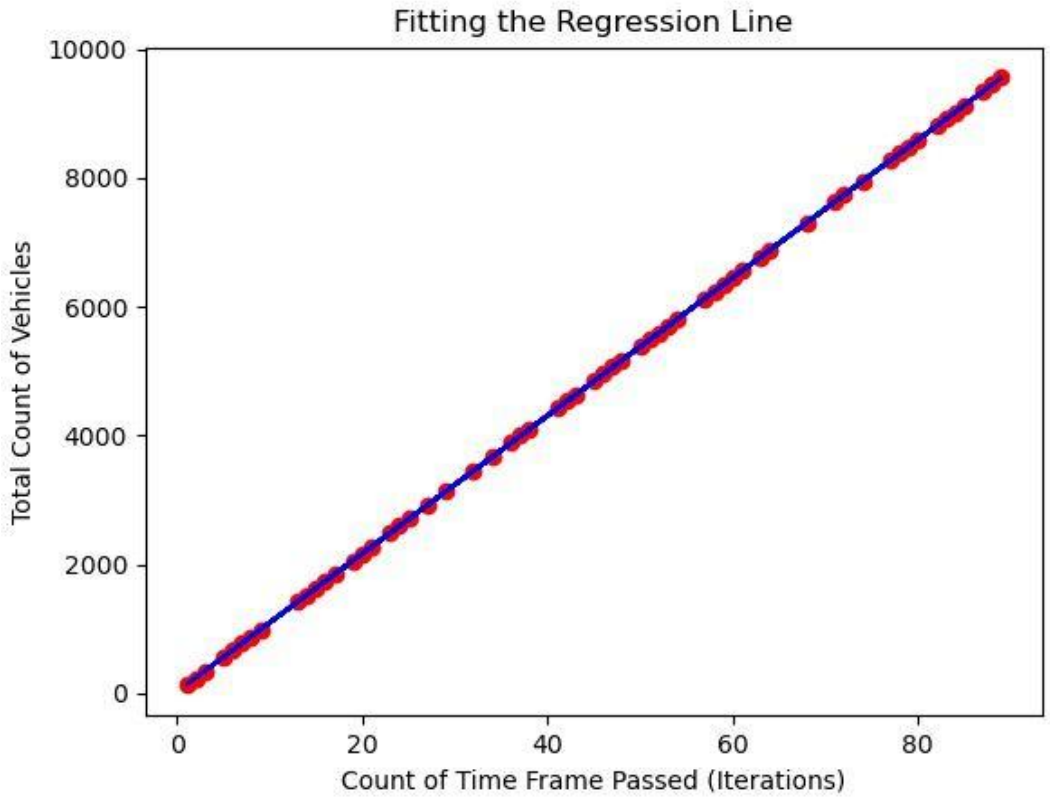

figure -7 :prediction of count of vehicles will wait

Since our generated data of vehicles waiting on the road was linear in nature so we have used a linear regression model to predict the number of vehicles which would be waiting in the next time frame.In the figure above we can see that our prediction line (in blue) has been fit perfectly into our data (in red).And we achieved a very high accuracy of 99.7% in predicting the number of vehicles that would be coming and waiting in the next time frame.

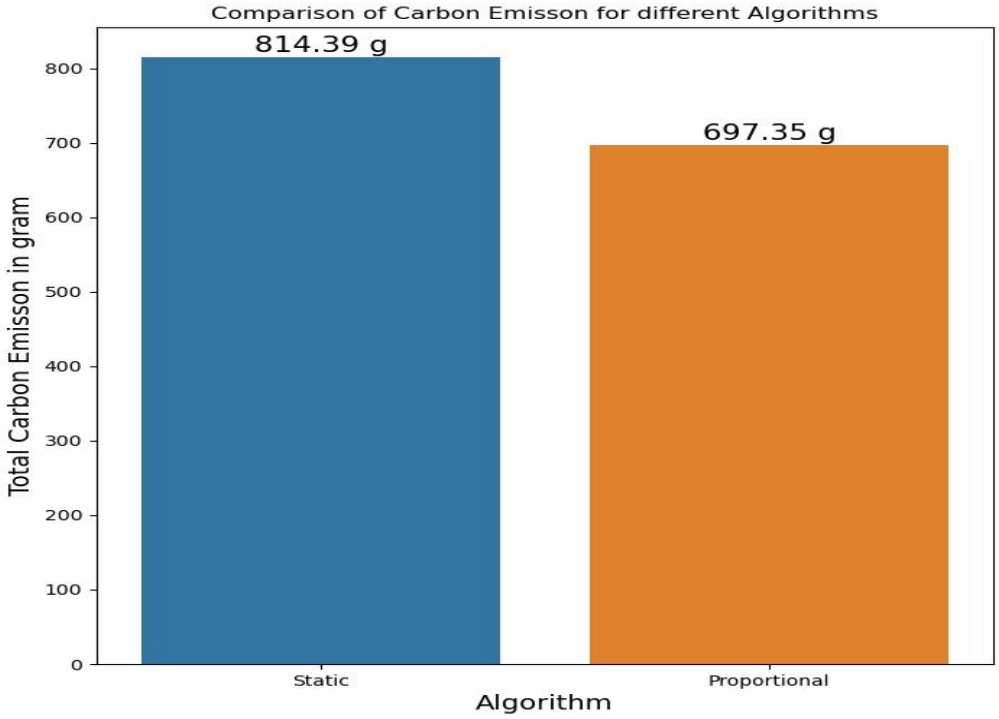

figure-8 comparison of carbon emission

In the figure 8 we compared the carbon emissions for the two algorithms and the highest was in the static algorithm was around 814.39 g and least for proportional 697.35 g .Hence proportional division of time frame in each road was best suitable algorithm which followed up in optimized way for all the functionalities as it reduced significantly carbon emission by 15% .

Overall, our vehicle-infrastructure network simulator demonstrated the value of using simulation tools to evaluate and optimize the performance of transportation networks. The ability to set different scenarios and analyze the resulting data provides valuable insights into the impact of different traffic management strategies and the potential benefits of reducing vehicle emissions. The visualization tools also provide a useful way for users to understand the dynamics of the network and identify potential improvements.

```
Accuracy score of prediction of vehicles on Right Road :  99.97336933197799
Accuracy score of prediction of vehicles on down Road :  99.99675232760953
Accuracy score of prediction of vehicles on left Road :  99.94306828076682
Accuracy score of prediction of vehicles on Up Road :  99.91552349209786
```

figure-9: accuracy of the model

8. CONCLUSION AND FUTURE SCOPE

Conclusion:

In conclusion, the vehicle-infrastructure network simulator is a valuable tool for evaluating and optimizing the performance of transportation networks. It allows users to set different scenarios and observe the movements of vehicles and the resulting traffic flow patterns. The ability to calculate carbon emissions generated by vehicles also demonstrates the potential environmental benefits of adopting strategies that are designed to optimize network performance and reduce emissions. The visualization tools provide a useful way for users to understand the dynamics of the network and identify potential bottlenecks or congestion points. Overall, the vehicle-infrastructure network simulator is a valuable tool for transportation planners, traffic engineers, and researchers who are involved in designing and analyzing transportation networks.

Future scope:

The future scope of the vehicle-infrastructure network simulator could include additional features and capabilities, such as:

The ability to simulate other aspects of transportation systems, such as the scheduling of public transit services or the management of freight traffic. This would provide a more comprehensive view of the performance of transportation networks and allow users to evaluate the impact of different strategies on a broader range of factors.

Tools for directly controlling and managing traffic in real-time. This could allow users to experiment with different traffic management strategies and see the immediate effects on the network performance, providing valuable insights into the effectiveness of different approaches.

The integration of data from real-world transportation networks, such as traffic flow data from sensors or traffic cameras. This could provide users with a more accurate representation of the network and allow them to test and evaluate strategies based on real-world conditions.

The inclusion of other factors, such as the impact of weather conditions or the availability of public transit options, on the performance of transportation networks. This would provide a more comprehensive view of the factors that can impact network performance and allow users to evaluate the impact of different strategies in a wider range of scenarios.

Overall, the future scope of the vehicle-infrastructure network simulator could include a wide range of additional features and capabilities that would enhance its value as a tool for transportation planners, traffic engineers, and researchers.

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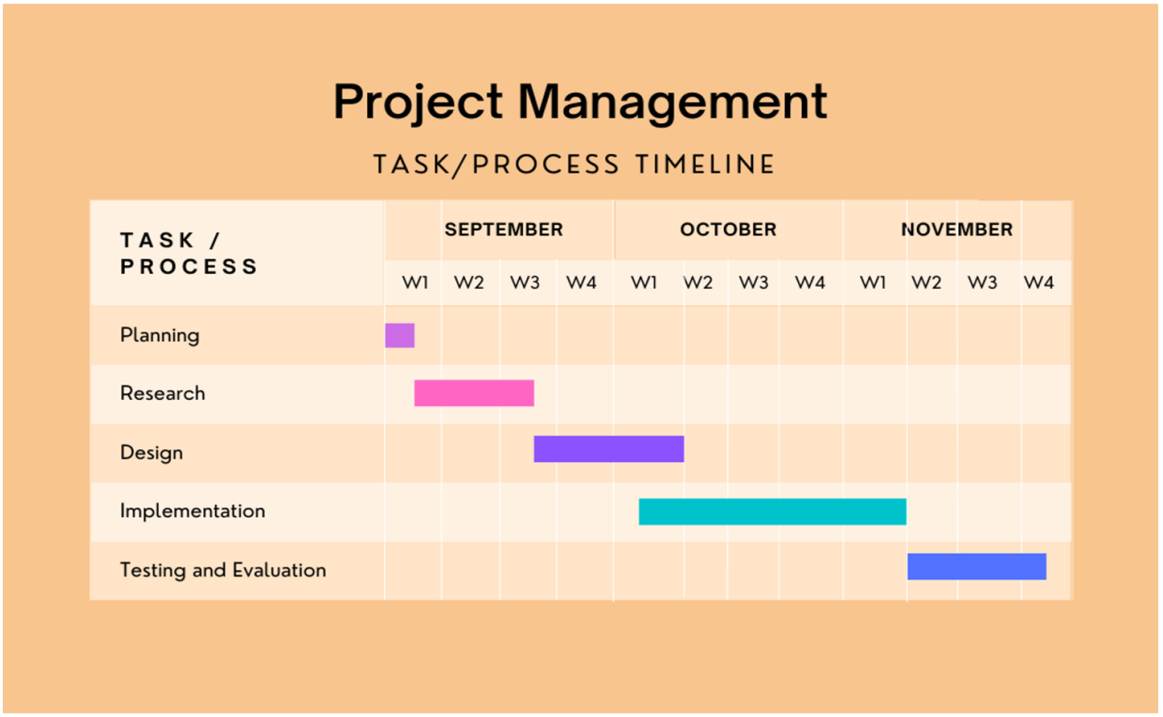
10. APPENDIX

- **Gantt Chart**



- **Glossary**

- V2X (Vehicle to Everything) architecture: A connected infrastructure technology that enables communication between vehicles on the road and other entities that may affect them, such as other vehicles, road infrastructure, pedestrians, traffic lights, and connected devices.

- Autonomous vehicles: Vehicles that are capable of operating without human input or supervision, using sensors, cameras, and algorithms to navigate and make decisions.

- Smart traffic control systems: Systems that use sensors, cameras, and algorithms to gather data about traffic flow and adjust traffic signals and other infrastructure to optimize traffic flow and reduce congestion.

- Traffic congestion: The state of a road or network of roads being heavily used to the point that vehicles are slowed down or stopped.

- Carbon emissions: Gasses that are emitted as a result of burning fossil fuels, such as carbon dioxide, which contribute to climate change.

- Algorithm: A set of instructions or steps followed to solve a problem or perform a task.

- Traffic optimization: The process of improving the efficiency and flow of traffic on a road or network of roads.

- **Description of Tools & Technology used**
- Simulation software: This could include specialized tools specifically designed for simulating vehicular networks and traffic, as well as more general-purpose simulation platforms that can be customized to meet the specific needs of the project.We used pygame module in python to create simulation for the project.

- Programming languages: Depending on the complexity and scope of the simulation,we choose python to create and implement the various algorithms and control systems being tested.

- Data analytics and visualization tools: To analyze and interpret the results of the simulation,we used python libraries like pandas ,matplotlib,etc to create charts, graphs, and other visual representations of the data generated.