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Adaptive traffic management system using traffic API

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ABSTRACT

Traffic congestion is rising in cities around the world. Contributing factors include expanding urban population, aging infrastructure, inefficient and uncoordinated traffic signal timings. According to researchers, Signal Timer issues (like out of sync timers) are in the top causing factors of traffic congestion along with a disproportionate number of vehicles and road-work/accidents. The purpose of this article is to illustrate one of the possible solutions to increase the efficiency of existing traffic signals by optimizing signal timings with the help of real time traffic data using a traffic API. The proposed solution is bolstered by a mathematical equation which follows the principle of equity.

Keywords: *Traffic Density, Traffic Flow, Traffic API, Traffic Congestion, Equity, Optimization*

1. INTRODUCTION

The world is rapidly expanding with the new technological advancements which is leading to an influx of jobs especially in the urban sectors. Naturally, the need for transport and vehicles is increasing, creating traffic jams and congestions. Such congestions worsen during peak office hours. [2]

The effects of traffic congestion might seem short termed but they severely affect social harmony and the overall development of a community. [3] According to a survey conducted in 2020, in US cities with more than 1 million people, an average commuter spends around 71 hours stuck in traffic congestions every year. [21]

While the current traffic control systems are functional, they do not take into consideration the variable traffic on each of the roads. Most have a fixed green and red-light timer which is not efficient in case of dynamically changing traffic.

With a continuous increase in traffic congestion by 1-3% every year since 2008 [21], it is important to adapt to smarter traffic management systems for congestion control.

This article will aim at providing one possible solution to increase the efficiency of existing traffic signals by optimizing signal timings with the help of real time traffic data using traffic API.

2. TERMINOLOGIES

(a) Traffic density: Traffic density is the number of vehicles on a road in a per unit area.[5]

(b) Traffic-Flow: Traffic-flow is defined as the total number of vehicles passing a given point in some fixed amount of time.[6][10]

(c) Signal Cycle Length: It is the time required for all signals at a junction to switch to green exactly once, before returning to the first signal.

(d) API: API stands for Application Programming Interface which is a piece of software code that allows two applications to communicate with each other. The proposed solution will be utilizing a Traffic API.

(e) Traffic API: A traffic API is used to fetch traffic details in real time. The details include vehicular flow, average speed, travel time, etc. Microsoft Azure Maps, TomTom, Here Maps are few of the companies that provide a Traffic API. [4]

(f) Equity: Equity is to provide support proportional to the severity of one's problems. This principle is going to be a strong foundation for the proposed solution.

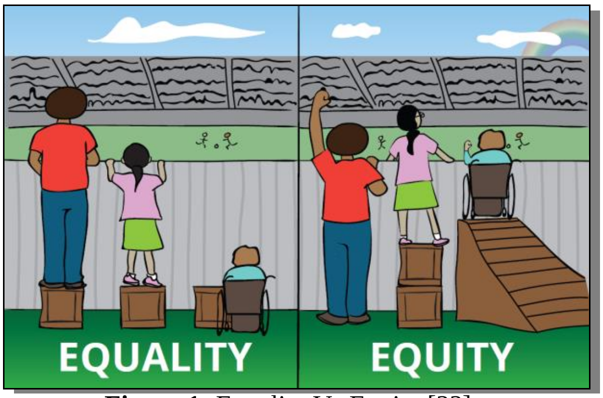

Figure 1: Equality Vs Equity [22]

3. LITERATURE REVIEW

There have been many attempts to tackle the problem of traffic congestion at traffic signals which require knowledge of civil engineering and road mechanics.[7] Specifically, there have been two main approaches to handle traffic signal timers with the help of real time data -

3.1 Using Cameras

In this approach, cameras are set up facing the incoming roads of a signal junction. The setup camera uses image processing and determines the traffic density of each of the roads.[9] Based on this data, it changes the signal timer duration of each of the roads.[8]

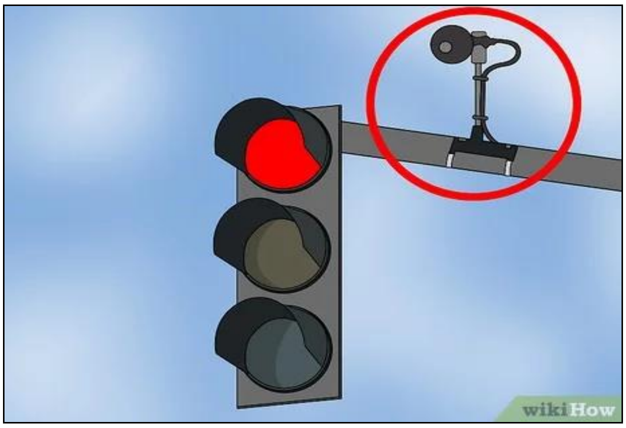

Figure 2: Traffic Management System using Cameras [16]

However, this solution has a few drawbacks. Firstly, weather conditions affect the ability of the camera to calculate the traffic density accurately. Furthermore, setup and maintenance of cameras at every junction is expensive and needs a manual team for the same. Also, in case of curvy roads, there might be a need to set up multiple cameras since the field of view of a single camera cannot capture the entire traffic.

3.2 Using Sensors

Similar to the previous solution, in this method, sensors (like piezoelectric or ultrasonic) are installed near the signal junctions such that they can accurately capture traffic readings on every road and using these readings, the signal timer duration is determined.

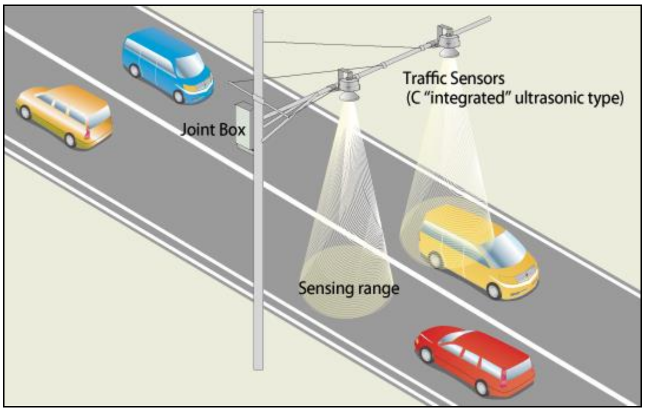

Figure 3: Traffic Management System using Sensors [17]

However, this solution too has multiple shortcomings. To begin with, sensors are made up of electrical hardware parts which often lead to maintenance issues. Moreover, this solution is not weather friendly as weather conditions can affect the accuracy of the sensors. Finally, with rapid urbanization, there is a constant development of roads. The relocation of sensors with such changes is not economically feasible.

4. PROPOSED SOLUTION

4.1 Architecture

The proposed system architecture consists of four main phases-

a. Real-Time Traffic
b. Traffic API
c. Calculation of Timer Duration
d. Updating Signal Timings

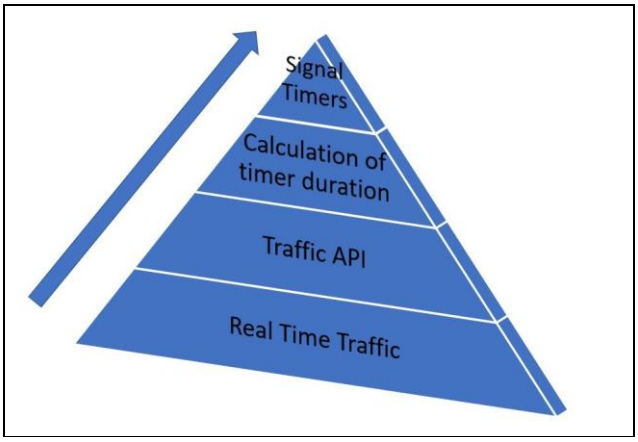

Figure 4: Architecture

To minimize traffic congestion, the system is developed for a road intersection. Capturing of the traffic information in real time will be done using a Traffic API. Traffic API takes longitudinal and latitudinal coordinates as inputs and returns traffic information in real-time.[18][19][20] The readings from the API will be used to find the traffic densities on the roads at the intersection. Further, according to these densities, the optimal signal timer duration for each of the roads will be calculated. Finally, the calculated optimal timings will be fed to the traffic signal which will dynamically change the green and red-light timings so as to efficiently manage the traffic.

4.2 Algorithm

To find the optimal signal timer duration, a proportionality logic is applied.

$$(\text{Green Light Time})_x \; \alpha \; (\text{Traffic Density})_x$$

where subscript 'x' represents one of the roads on the signal junction.

The above equation illustrates that the Green Light Time for a particular road is going to be proportional to the amount of traffic density on that road. Further, there is also a fixed signal cycle length defined. The cycle length will be split into the number of roads at the junction according to the proportionality equation mentioned above.

Consider a 4-way crossroad with 10, 6, 8, 6 as density indices on the four roads respectively and a signal cycle length of 2 mins. Applying the above equation:

$(\text{Green Light Time})_{road\text{-}1} = (10/(10+6+8+6)) * 120$ seconds = 40 seconds

$(\text{Green Light Time})_{road\text{-}2} = (6/(10+6+8+6)) * 120$ seconds = 24 seconds

$(\text{Green Light Time})_{road\text{-}3} = (8/(10+6+8+6)) * 120$ seconds = 32 seconds

$(\text{Green Light Time})_{road\text{-}4} = (6/(10+6+8+6)) * 120$ seconds = 24 seconds

It can be observed that the sum of all the green light times turns out to be 120 seconds = 2 mins (signal cycle length). A fixed time out of each of the green light times will be set aside for the orange light.

4.3 Advantages

The above system has multiple advantages over the previously built systems:

(a) Real Time System: With the usage of Traffic APIs, traffic will be captured in real time. With such real time captures, signal timers can be changed dynamically throughout the day. This will efficiently manage the traffic at intersections.

(b) Low Setup and Maintenance Costs: As usage of APIs do not need any hardware setup, the setup cost will be low. The system will be weather friendly and can be operated from the signal control centre.

(c) Follows the principle of Equity: Consider a 4-way cross road in the traditional setup with fixed duration of signal timers. In such a case, each road would be getting the same amount of green light time, regardless of the difference in amount of traffic at each of the roads. This would mean that there might be some green light time wasted on one of the roads where there are very few or no vehicles waiting to cross the junction.

However, in the proposed system, if one of the roads has a greater traffic density, then, the signal wait time will be proportionally lower. This means that there will not be any green light time wasted, instead that time will be utilized by some other road on the same intersection.

5. IMPLEMENTATION

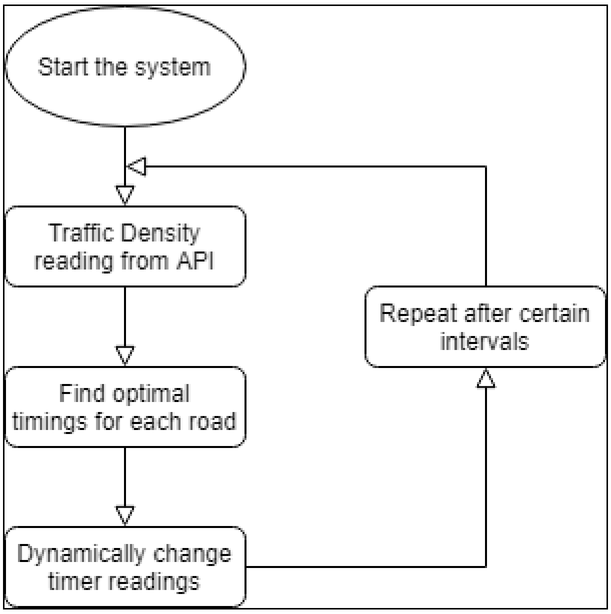

Figure 5: Implementation Flow Diagram

Before the system is started, we need to provide the Traffic API with coordinates of all roads at the signal junction. Once begun, the system will start fetching the traffic data in real-time in the form of a JSON file with all the required traffic information. The format of the JSON file can be seen in figure 6.

{"flowSegmentData":{"frc":"FRC4","currentSpeed":25,"freeFlowSpeed":25,"currentTravelTime":51,"freeFlowTravelTime":51,"confidence":0.9700000286102295,"roadClosure":false,"coordinates":{"coordinate":[{"latitude":18.553240822816775,"longitude":73.80963784964047},{"latitude":18.55302086958285,"longitude":73.80963650853596},{"latitude":18.552641274769407,"longitude":73.8096298030134 2},{"latitude":18.552276538744294,"longitude":73.80961773307286},{"latitude":18.552229575944562,"longitude":73.80961639196835},{"latitude":18.552155833992686,"longitude":73.80961370975933},{"latitude":18.552027103353833,"longitude":73.80960968644581},{"latitude":18.551827252817827,"longitude":73.8096083453413},{"latitude":18.551737379597956,"longitude":73.8096083453413},{"latitude":18.551274742345257,"longitude":73.80960163981877},{"latitude":18.550901898081957,"longitude":73.8096083453413},{"latitude":18.550209924942745,"longitude":73.80960566313229},{"latitude":18.550130778548297,"longitude":73.8096070042368},{"latitude":18.550089218730104,"longitude":73.8096070042368},{"latitude":18.55004757943746,"longitude":73.80960432202778},{"latitude":18.550000695488944,"longitude":73.80960432202778}]},"@version":"traffic-service 3.2.005"}}

Figure 6: JSON File Output

The next step is to use the algorithms mentioned in section 4.2 to find the density indices and the optimal green time for each of the roads at the signal junction.

```
Traffic Density Index - (Signal 1): 8
Traffic Density Index - (Signal 2): 10
Traffic Density Index - (Signal 3): 5
Traffic Density Index - (Signal 4): 7
```

Figure 7: Calculation of traffic density indices

Finally, the calculated signal timer values need to be updated in real-time. One important thing to note is that the fetching of traffic data from the traffic API is going to be after fixed intervals to ensure that the traffic is managed in real time.

```
Signal Cycle Length = 2 mins = 120 sec
Signal 1 running for - 32 seconds
Signal 2 running for - 40 seconds
Signal 3 running for - 20 seconds
Signal 4 running for - 28 seconds
```

Figure 8: Actual signal running time

6. SIMULATION

We have built a simulation using PTV Vissim Simulator 2020 to check the effectiveness of our solution. In the simulation we have tried to replicate the traffic conditions of a traffic junction with a signal cycle length of two minutes.

At time=0 the simulation shows the following status (figure 9) of vehicles on the road.

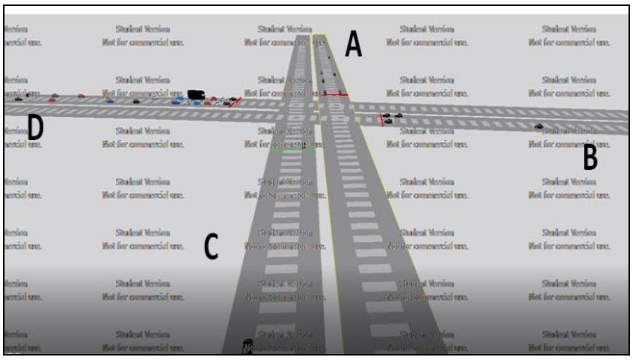

Figure 9: Simulation at time=0

As the simulation has just begun (time=0), we can see that all the four roads have less traffic at the signal junction.

Traditional System

Let us take a look at the traditional approach, where signal timings are divided into fixed intervals. After one complete cycle (time=2 mins), we can observe, in figure 10 that roads A, C and D have a lot of traffic, whereas road B has very less traffic in comparison (uneven distribution of traffic on the four roads). It is important to note that the green light of road B is switched on, but the number of vehicles passing is very less. This green light time could have been optimally utilized by road A, C, or D to free up the traffic congestion.

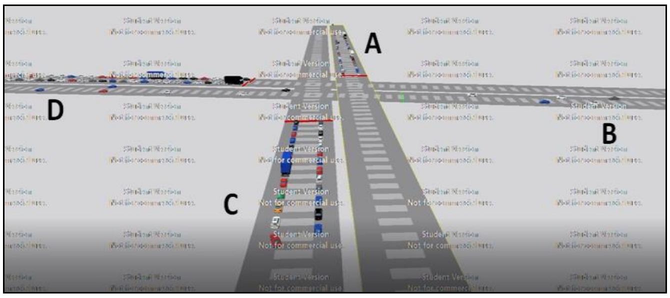

Figure 10: Simulation after one complete cycle (Traditional System)

Proposed System

After applying the proposed solution on the same simulation, the traffic distribution after one complete cycle can be seen in figure 11. The major difference here is that the amount of traffic is distributed evenly throughout the roads. Road B is currently having a green light, and this green time is not wasted because of the traffic present on road B. In the previous case, this time was wasted as traffic was absent on road B.

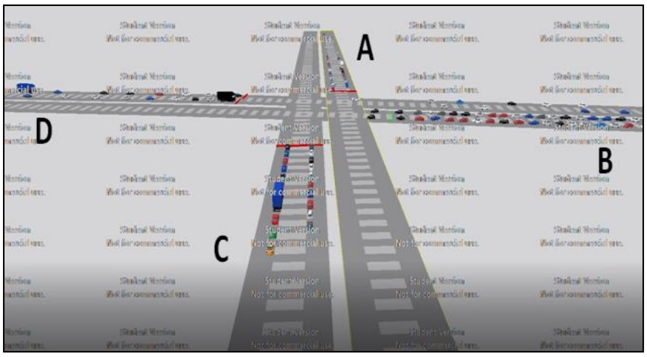

Figure 11: Simulation after one complete cycle (Proposed System)

7. CONCLUSION

An efficient traffic management system using traffic API has been implemented, simulated and presented in this article. The advantages of the system as well as how they are better than the previous solutions is discussed. Proposed system will decrease the average wait times at a signal which will lead to a drastic reduction in carbon emissions. The ease of implementation suggests that this system can be adopted by traffic management systems all over the world.

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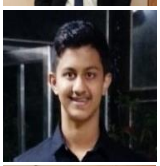

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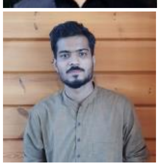

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