Adaptive Traffic Signal Control Using Fuzzy Logic

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Abstract- With increment of purchasing capacity of vehicles by individual, traffic is increasing day by day on the roads and on the intersections. It leads to inconvenience to people as well as increment of pollution. Today, traditional system is not suitable to handle huge traffic. These systems were designed to handle regular pattern of traffic. But today traffic is fluctuating frequently that demands new computing power in the traffic management system. This paper presents the system which can handle the various sizes of vehicles on the road. This model first evaluates the concatenated vehicle size by considering all size vehicles. Calculated vehicle size is then fed into the fuzzy controller with the other input parameters, traffic flow, and traffic density to calculate cycle length. In this basically, three parameters are taken, named as Size of Vehicles, Traffic Density, and Traffic Flow. Fuzzy rules are built by considering the Size of Vehicles, Traffic Density and Traffic Flow, cycle length is calculated using various datasets. The cycle which is calculated using the model of this paper is then compared with the fixed time control cycle length.

Keywords- Fuzzy Logic; Traffic Flow; Traffic Density; Size of Vehicles; Fuzzy Logic Simulator.

I. INTRODUCTION

The conventional traffic system is fixed time control system which has pre-timed set cycle length which cannot be changed whether the traffic changes on the road. This traffic control system is unable to deal the varying traffic data on the road. But traffic on the road is highly increasing, the current system has failed to demonstrate the problem of dynamically varying traffic on the road. In many cities, Automatic traffic signals are often based on a constant green-to-red cycle [1]. This paper presents the adaptive traffic control system which is highly compatible to the varying real time traffic on the road. This system dynamically adjusts the cycle length of traffic light by consider the real time traffic data on the road. Stephen Chiu [2] has given a fuzzy model which also adjusts the cycle length by considering local information but this doesn't use size of vehicles as input parameter. Real time traffic data from sensors, cameras etc. flow to the traffic controller and fuzzy logic system to calculate and to adjust the cycle length. This real time data is integrated and demonstrated with the different input parameters and implemented using fuzzy logic which is based on fuzzy inference rules [3], then fuzzification and defuzzification is done. Several real-time adaptive traffic control systems were developed in the late 70's and early 80's to address this problem. These systems can respond to changing traffic demand by performing incremental optimizations at the local level [4].

II. LITERATURE REVIEW

Mario Collotta et. al [5] proposed a novel approach to dynamically manage the traffic lights cycles and phases in an isolated intersections. It combines the advantage of wireless sensor network advantages. Nitin Maslekar et. al [6] proposed a car to car communication based, an adaptive traffic signal system. It uses a clustering algorithm which estimates the density of vehicles at intersection. It calculates cycle time using density of vehicles. Habib M. Kammoun et. al [7] proposed an adaptive multi-agent system based on the ant colony behavior and the hierarchical fuzzy model. It changes the traffic by integration of an adaptive vehicle route guidance system. Mohamed A. Khamis et. al [8] proposed a multi-agent multi-objective reinforcement learning traffic signal control framework that simulates driver's behavior continuously in space and time dimensions. It is based on multi-objective sequential decision. Patrick mannion et al. [9] described the reinforcement learning for urban traffic management. P. Lopez-Garcia et al. [10] proposed a model which is hybridization of Genetic algorithm and cross entropy to predict the traffic congestion. Vicente Milanes et al. [11] proposed cooperative adaptive cruise control in real time traffic situations system which consists of two controllers. Yiyeng feng et al. [12] presented real-time adaptive signal phase allocation algorithm using connected vehicle data. Weigang wu et al. [13] proposed a novel approach to control traffic at intersection, in this traffic is controlled via coordination among vehicles via vehicle to vehicle or vehicle to infrastructure communication. David Myr et al. [14] proposed a multi- object optimization for real time traffic light control and navigation systems for urban saturated networks. It works in two stages. M amooozadeh et al. [15] proposed a platoon management protocol for CACC vehicles based on wireless communications through VANET which includes three basic platooning maneuvers and a set of micro-commands to accomplish these maneuvers. MC farriera et al. [16] proposed Systems, methods, software, and apparatuses for coordinating traffic. Coordination involves forming an ad-hoc network in a region containing the conflict zone using vehicle to vehicle communications. Jin Yang Li et al. [17] proposed a dynamical traffic light control system, i.e., change the traffic light signals in real time following the speed of vehicles. This system is an instance of V2I(Vehicle to Infrastructure) communication model, realizing data transmission between vehicles and traffic lights. Francesco Marino [18] presented an implementation of a smart predictive monitoring and adaptive control system for the public lighting has been carried out. The vehicular traffic flow acquired using a smart camera has been analyzed and several predictive methods have been studied. Then, a control strategy based on the given traffic forecasts and on the dynamical street class downgrade allowed by the law, has been implemented. Shakeri et al [19] shows the study of urban traffic for the optimization traffic light time duration. Cellular automata based fuzzy algorithm is discussed. Factors affecting the traffic of streets are different times of a day, volume of traffic, shopping centres etc. To overcome limitations with traffic control three level fuzzy system is developed. Anastasios Kouvelas et al. [20] presented the development of an adaptive optimization scheme for perimeter control of heterogeneous transportation networks.

III. MODEL OF ADAPTIVE TRAFIC SIGNAL CONTROL

Fig. 1 represents the proposed model, Adaptive Traffic Signal Control model [21], which is designed to work on 2-way traffic lane, it means one lane in each direction, one traveling in one direction and other traveling in opposite direction. This model is prepared to work in the metropolitan areas where very large sizes of vehicles like heavy loaded trucks are not allowed.
Here the distance considered is 200 meters in length to calculate the traffic density. In this, the right turn is prohibited which make the vehicle to go straight in opposite direction and can take the left turn. Startup Lost time for 2 seconds is also considered in this model. In this model different sizes of vehicles are taken, the optical sensor are placed within 200m distance which will visualize and measure the size of vehicles and distinguishably different sizes of vehicles are counted. The evaluation of vehicles size is done to calculate concatenated vehicle size and output evaluated vehicles size is received by the fuzzy logic simulator as input and output cycle length is calculated with the use of other input.

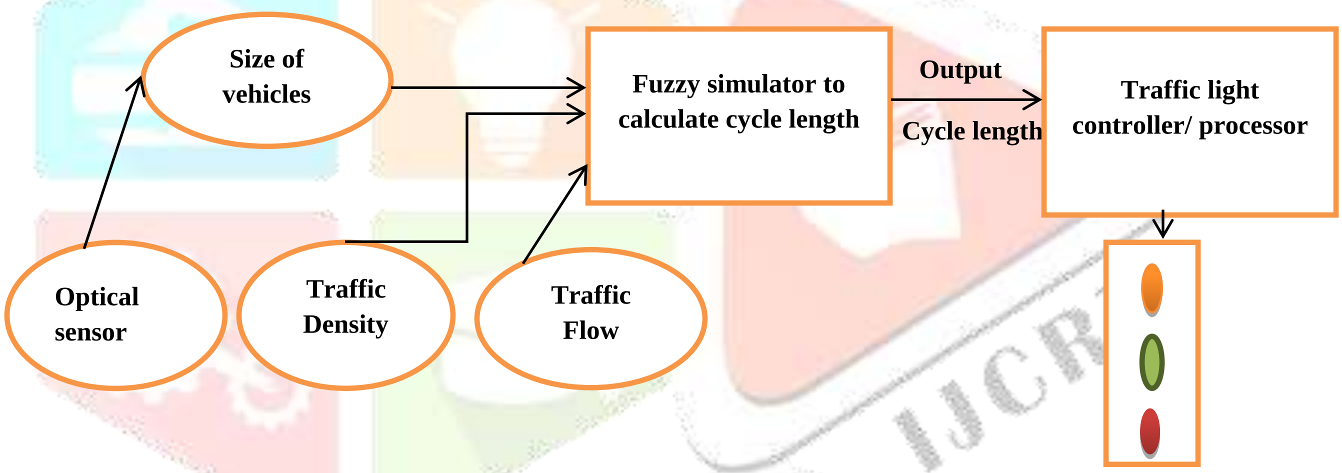

Fig.1 Adaptive Traffic Signal Control Model[21]

A. Adaptive traffic signal control

In adaptive signal control, the time of the cycle is not fixed, It will vary as the inputs are gathered and changed. In this technique either the cycle length can be decreased or it can be increased. The minimum cycle length will be of 20 seconds and the maximum will be of 120s.

B. Research Terminologies

Terminologies which are indulged and attributed in this work are as follows [21]:-

1- Traffic flow:- It is the number vehicles calculated at a particular point over a particular period of time. If the number of vehicles calculated at a point be (N) over a particular point of time (t). Traffic flow (Q) will be calculated as:-

$$Q=N/t$$

2- Traffic density:- It is the number of vehicles calculated within the distance or over the stretch of the road. If N is the number of vehicles over a particular distance of road (d). Traffic density (K) is calculated as:-

$$K=N/d$$

3- Size of the vehicles:- It is the size of the particular vehicles which is calculated in terms of meter.

4- Cycle length:- It is the amount of time from when a movement first is given the right of way until that movement receives it again.

IV. TRAFFIC CONTROL FUZZY RULES

A set of 27 fuzzy rules are considered to change the cycle length of green light timing parameter. The rules for adjusting cycle length are decoupled so that distinguishably the size of vehicles and output cycle length could be calculated. The increment and decrement of the cycle length can be adjusted easily.

A. Size of vehicles adjustment

Size of vehicles is adjusted because, in this model, three types of vehicles are considered, small, medium and large, effectively taken the sum of the size of different vehicles on the road to adjust. In this there is a possibility of having different sizes of vehicles, which create difficulties to calculate actual size, so with the algorithm, we can compute the concatenated size to feed.

Algorithm to calculate vehicle sizes

Below algorithm is used to calculate the concatenated vehicle size which is then feed to the simulator to calculate the cycle length.

1. Start
2. Declare variable Size of vehicles, Input vehicle size.
3. Read values Input vehicle size.
4. While 3<= Input vehicle size <=10 && Size of vehicles <= 192.
5. Add Size of vehicles and Input vehicles size and Assign to the result size of vehicles.
6. Size of vehicles ← Size of vehicles + Input vehicles size.
7. Display Size of vehicles.
8. Stop.

Algorithm to choose density on lane of phases

Below algorithm is used to choose the density on different lanes of different phases. 2 phases are there in a cycle, each having different lanes.

1. Start.
2. Declare variables Traffic density, Traffic $density_1$, Traffic $density_2$.
3. Read values Traffic $density_1$, Traffic $density_2$.
4. Find Max Traffic $density_1$, Traffic $density_2$ and assign to Traffic density.
5. Display Traffic density.
6. Stop.

B. Cycle length adjustment

25-IF(TrafficFlow is SMALL) and (TrafficDensity is LARGE) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is MEDIUM)
26-IF(TrafficFlow is MEDIUM) and (TrafficDensity is LARGE) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is LARGE)
27-IF(TrafficFlow is LARGE) and (TrafficDensity is LARGE) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is LARGE)

V. SIMULATION

This model is simulated using fuzzy inference system or fuzzy logic simulator. In this three input variables are considered which are traffic low, traffic density and size of vehicles. The Various input parameters values are coupled and fed into the simulator which then calculates the cycle length, in this rules are taken from the given references but some rules (2,3,5,20,25) are refined to calculate the cycle length [21].

1-*IF(TrafficFlow is SMALL) and (TrafficDensity is SMALL) and (SizeOfVehicles is SMALL) THEN(CycleLength is SMALL)*
2-*IF(TrafficFlow is SMALL) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is SMALL) THEN(CycleLength is SMALL)*
3-*IF(TrafficFlow is SMALL) and (TrafficDensity is LARGE) and (SizeOfVehicles is SMALL) THEN(CycleLength is MEDIUM)*
4-IF(TrafficFlow is SMALL) and (TrafficDensity is SMALL) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is SMALL)
5-IF(TrafficFlow is SMALL) and (TrafficDensity is SMALL) and (SizeOfVehicles is LARGE) THEN(CycleLength is MEDIUM)
6-IF(TrafficFlow is SMALL) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is LARGE) THEN(CycleLength is LARGE)
7-IF(TrafficFlow is MEDIUM) and (TrafficDensity is SMALL) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is MEDIUM)
8-IF(TrafficFlow is MEDIUM) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is SMALL) THEN(CycleLength is MEDIUM)
9-IF(TrafficFlow is MEDIUM) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is LARGE) THEN(CycleLength is LARGE)
10-IF(TrafficFlow is MEDIUM) and (TrafficDensity is SMALL) and (SizeOfVehicles is LARGE) THEN(CycleLength is MEDIUM)
11-IF(TrafficFlow is MEDIUM) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is MEDIUM)
12-IF(TrafficFlow is MEDIUM) and (TrafficDensity is LARGE) and (SizeOfVehicles is SMALL) THEN(Cycle_length is LARGE)
13-IF(TrafficFlow is LARGE) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is LARGE) THEN(CycleLength is LARGE)
14-IF(TrafficFlow is LARGE) and (TrafficDensity is SMALL) and (SizeOfVehicles is LARGE) THEN(CycleLength is MEDIUM)
15-IF(TrafficFlow is LARGE) and (TrafficDensity is LARGE) and (SizeOfVehicles is SMALL) THEN(CycleLength is LARGE)
16-IF(TrafficFlow is LARGE) and (TrafficDensity is SMALL) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is MEDIUM)
17-IF(TrafficFlow is LARGE) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is SMALL) THEN(CycleLength is MEDIUM)
18-IF(TrafficFlow is SMALL) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is MEDIUM)
19-IF(TrafficFlow is MEDIUM) and (TrafficDensity is SMALL) and (SizeOfVehicles is SMALL) THEN(CycleLength is SMALL)
20-IF(TrafficFlow is LARGE) and (TrafficDensity is SMALL) and (SizeOfVehicles is SMALL) THEN(CycleLength is SMALL)
21-IF(TrafficFlow is LARGE) and (TrafficDensity is MEDIUM) and (SizeOfVehicles is MEDIUM) THEN(CycleLength is MEDIUM)
22-IF(TrafficFlow is LARGE) and (TrafficDensity is LARGE) and (SizeOfVehicles is LARGE) THEN(CycleLength is LARGE)
23-IF(TrafficFlow is SMALL) and (TrafficDensity is LARGE) and (SizeOfVehicles is LARGE) THEN(CycleLength is MEDIUM)
24-IF(TrafficFlow is MEDIUM) and (TrafficDensity is LARGE) and (SizeOfVehicles is LARGE) THEN(CycleLength is LARGE)

membership functions CENTROID is used to calculate the input and output values.

A. Simulation of cycle length

In this model to calculate the cycle length the three input parameters, traffic flow, traffic density, size of vehicles are simulated to calculate the output cycle length. Input and output variables, small, medium, large are considered.

1. Input Variables

Fig.2 shows the simulation of size of vehicles in which it is shown that range of size of vehicles is 3-10 meters. Fig.3 shows the simulation of traffic flow which shows the range 1-1890 vehicles. Fig.4 shows the simulation of traffic density having range 1-66 vehicles

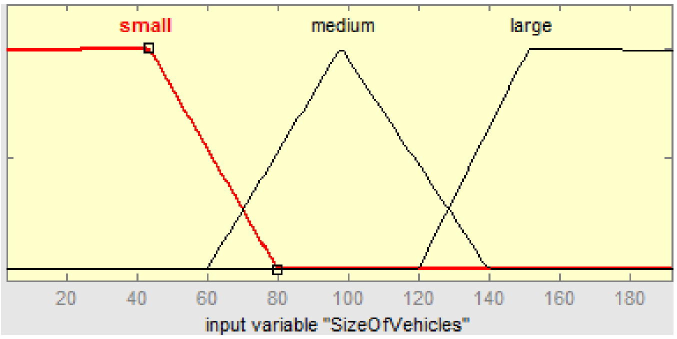

Fig.2 Simulation of size of vehicle

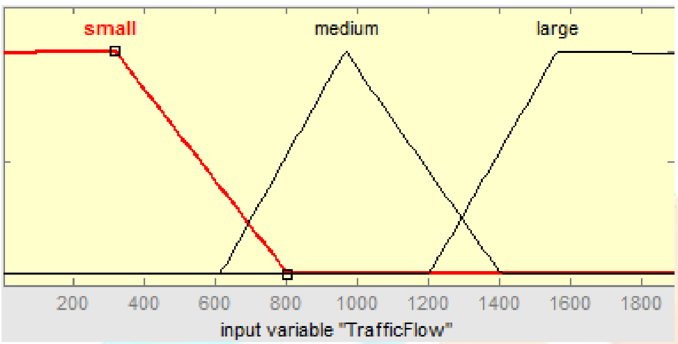

Fig.3 Simulation of traffic flow

VI. EXPERIMENTAL RESULTS

In the experimental study, various inputs are fed to the simulator or data set is put for calculations. Below figures show the graphical representation of input data set and output cycle length compared to the fixed cycle length which is calculated using historic data. Fig.6, 7, 8 represents how the cycle length fluctuates with the input parameters. In each figures red line shows the fixed cycle length and the blue line represents the adaptive cycle length. Here, cycle length which is fixed doesn't show any fluctuation alike adaptive cycle length which changes as the input parameters changes.

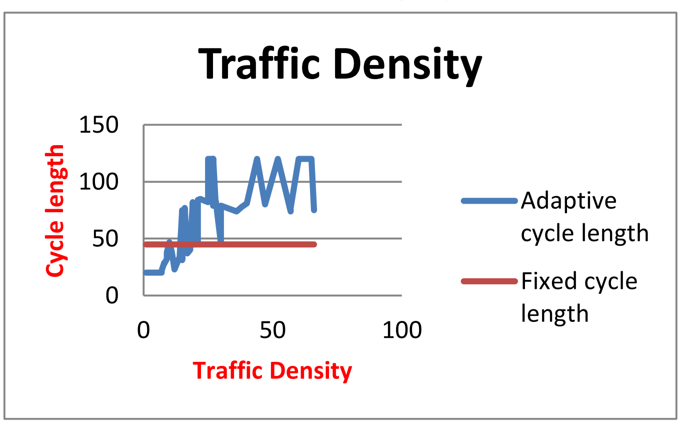

Fig.6 Graph between traffic density and cycle length

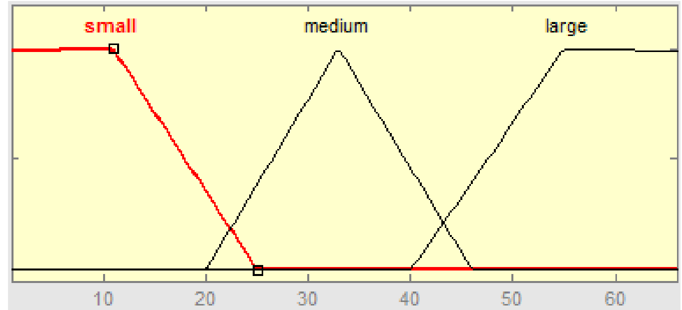

Fig.4 Simulation of traffic density

2. Output Variables

Fig.5 shows the output cycle length which is calculated and lies in the range 20-120 seconds.

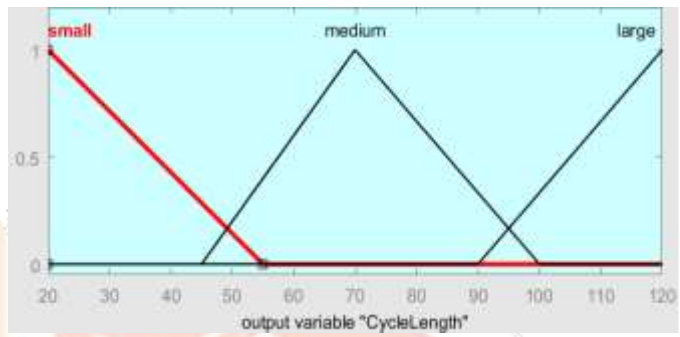

Fig.5 Output cycle length

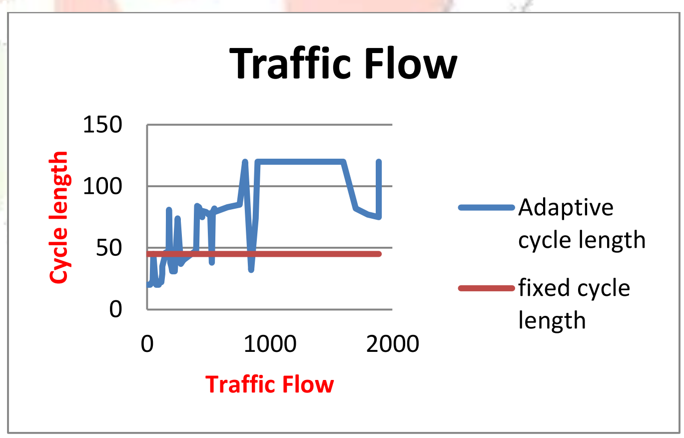

Fig.7 Graph between traffic flow and cycle length

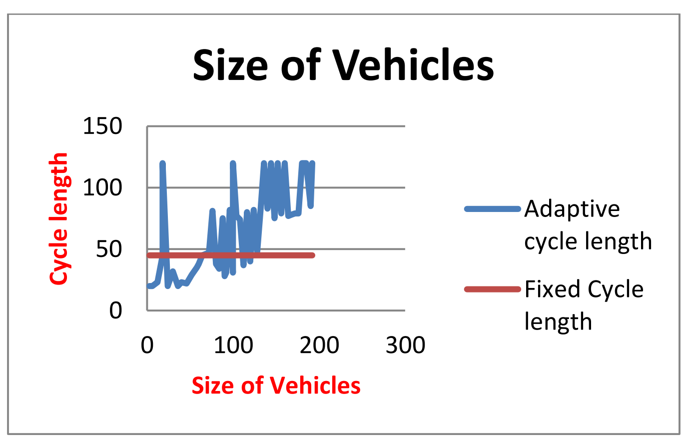

Fig.8 Graph between size of vehicles and cycle length

VII. COMPARATIVE ANALYSIS

This proposed model calculated cycle length is compared with fixed time control cycle length given in table.2. In this comparison percentage of improvement and reduction in cycle length is also calculated as a point of comparison with the fixed cycle length. .

TABLE.2 COMPARISON OF PROPOSED MODEL CYCLE LENGTH WITH WEBSTER'S FIXED CYCLE LENGTH

S. No.	PARAMETERS			CYCLE LENGTH (SECONDS)		% OF IMPROVEMENT OR REDUCTION
	TRAFFIC FLOW	TRAFFIC DENSITY	SIZE OF VEHICLES	AdTSC3	WEBSTER'S	
1	1	1	3	20	45	+125%
2	25	4	6	20	45	+125%
3	100	12	40	23	45	+95.6%
4	200	14	84	34	45	-32%
5	180	40	76	81	45	-44.4%
6	550	25	96	82	45	-45%
7	1000	27	152	120	45	-62.5%
8	1100	62	180	120	45	-62.5%
9	1500	60	18	120	45	-62.5%
10	1700	19	124	82	45	-45%
12	1890	66	192	120	45	-62.5%

VIII. CONCLUDING REMARKS

It is concluded that cycle length can't have the fixed interval. It fluctuates as the values of traffic flow, traffic density and size of vehicles vary. It is also concluded that adaptive traffic control signal is better control system than fixed time traffic control. In this, the distributed architecture is considered, where cycle length at intersections is changed using the values of input parameters. This model changes the cycle length by considering the size of vehicles, whether size is small, large, medium size vehicles or having different sizes. All vehicles sizes would contribute to calculating cycle length by evaluating the size.

IX. FUTURE SCOPE

This model is based on the three parameters. Furthermore, researchers can include more than three parameters for future work and analysis. This model works on the 2-way lane road, more way lane network can be included for further research. Heavy vehicles and very small sizes vehicles can also be included because this model is tested for the metropolitan area, where heavy vehicles are not allowed.

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