Prediction and Control of Traffic using Multi Agent Based Model

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***Abstract*—Traffic analysis and delays at road intersections play a vital role in the planning and designing phases while developing a road network as they allow us to select the most optimal solutions as per the traffic and site requirements. This is where traffic simulation models become indispensable tools for collaborative decision-making. In this paper, we have described the agent-based model we designed to simulate the flow of traffic over a road intersection. We have further experimented with the model by predicting the flow of traffic based on positioning of various agents – like signals, pedestrian walkways, bus stops,Parking lot etc. – over the roads, and monitored the performance results for the same. The metrics considered for the results are time taken by a car to cross an intersection and the average speed of cars. The result of the simulation of the system can help in better understanding of the road infrastructure and planning a quality design for efficient traffic control.**

***Index Terms*—Multi-Agent Systems, Agent-Based Modelling, Traffic simulation,congestion, traffic, Signal Optimization, Road Infrastructure, Road Intersections, Applied Artificial Intelligence**

I. Acknowledgement

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II. Introduction

The use of a hierarchical structure to govern large-scale urban traffic networks can be more efficient and adaptable than centralized traffic reduction solutions. Congestion in large cities because it is capable of properly addressing some of the issues. Computational complexity, many control objectives, and limited resilience are all issues that arise while regulating such huge systems. To a variety of uncertainties, and so forth. We suggest a two-level system in this research. For large-scale urban traffic networks, a hierarchical control system is used. Traffic congestion in large-scale urban traffic networks is becoming a growing problem all over the world due to the rapid development of society and the economy. As a result, how to cope with traffic congestion with the present transportation infrastructures remains a major concern for the entire society. Long-term, network-wide traffic signal management is a potential method of reducing traffic congestion. In recent years, there has been an increase in demand for mobility and transportation, resulting in increased traffic and the likelihood of traffic jams during peak hours. As a result, methods and technology to deal with traffic and transportation issues, such as traffic control, effective use of existing road networks, efficient signal handling at junctions, and so on, have become important. We need multidisciplinary methods now more than ever to find a solid answer. As a solution to this challenge, we suggest creating an agent-based system that considers three sorts of Agents: location specific (car position on the road), vehicle specific (vehicle speed, type of vehicle, etc.), and driver specific (perception, driving style, etc.). Special rules will be created for all the different agents, based on which the model will produce traffic flow forecasts. Aside from that, the intersection's circumstances, such as traffic lights, will be considered. For the regulation of urban traffic networks, many control techniques based on various traffic flow models have been devised. However, most of these studies combine centralized control with thorough modelling to achieve a balance between modelling accuracy and computing complexity. As the scope of urban traffic networks with multiple links and signalized crossings grows, hierarchical or distributed control becomes more tractable for implementation in practice than centralized control. As a result, several academics have investigated hierarchical structures for large-scale urban traffic network control.

III. Related Work

We have studied about traffic flow simulation and took reference from many related work to develop our traffic simulated model,Hierarchical Agent-Based Modeling for Improved Traffic Routing[1]: It has been proposed to provide an integrated platform for modelling a wide range of realworld traffic challenges. The challenge of achieving system-optimal traffic flow has been solved. The minimization of total vehicle travel time in a network by affecting traffic allocation over open roads in a network is one feasible criterion for evaluating our approach.In [2] For signalling split, the TUC method employs a feedback control law, in which a static feedback matrix is generated off-line using the LQR methodology and a quadratic programme is solved on-line to determine split feasibility.

Tourism, transport, and land use: a dynamic impact assessment for Kaohsiung's Asia New Bay Area[3]: This paper describes a hybrid method for analyzing relations between public transports, tourism and land use. The agent-based model combines the information from System Dynamics (SD) and Geographical Information Systems (GIS) to analyze these relations. In [4] Discussed When a person encounters obstacle in his path, they make adjustments in their path and movement to avoid it. Based on this fact, we can say that presence of an obstacle changes/affects the movement of an individual. This paper discusses how different types and shapes of obstacles affect the movements of pedestrians. For this study, four different crowd dynamics are taken into consideration: unidirectional, bi-directional, intersecting, and merging. Also, the three shape areas studied: Straight corridor, T-junction, and an Intersection.

Optimal design of low computational burden model predictive control based on SSDA towards autonomous vehicle under vision dynamics[5]: In the development of self-driving intelligent vehicles, the main issue that we encounter is predicting the steering angle of the vehicle. The Model Predictive Control (MPC) strategy is devoted to provide control of steering to the AVs. However, developing a simple model of MPC with few parameters that can accurately predict the angle is a difficult problem to resolve. In [7]: This paper discusses the Adaptive Signal Control System (ASCS) strategies applied in realtime to reduce the wait time at signaled intersections and reduce the congestion at those points.

Expressway Exit Station Short-Term Traffic Flow Prediction with Split Traffic Flows According Originating Entry Stations[23]: Short-term traffic flow prediction is a vital step in anticipating traffic congestion and is an important component of Intelligent Transportation Systems (ITS). Data-driven algorithms with a range of attributes have been widely used to improve traffic flow prediction due to the availability of large amounts of traffic data.In [24] Paper discusses Modern Intelligent Transportation Systems research and practise include short-term forecasting of traffic factors such as flow and occupancy.In [25] Paper discusses ,Short-term traffic flow prediction is critical in the development and implementation of intelligent transportation systems. In the extraction of traffic features, the neural network approach can leverage massive data for training and has more advantages than other prediction models. However, extracting the spatiotemporal aspects of traffic flow in a simple and sufficient approach to increase prediction accuracy remains an issue.

IV. Approach

Our approach for the traffic flow agent-based model is to first select a satellite image of a city, and we created road networks and intersections based on the satellite image. In addition to this, we added traffic flow logic for vehicles and then added traffic lights setup. Moreover, we optimized traffic light phases (Red, Yellow, and Green Setup). Moreover, we added a parking lot and bus route. We added a pedestrian library for simulating the pedestrian crossing. Furthermore, integrated this traffic flow agent with a pedestrian library and simulation of a pedestrian crossing. Finally, we got the output as predicted and control of traffic jams. In this Model we assume ,All drivers follow rules properly and follow traffic signals.

Additionally, we have added traffic lights at every intersection and their operational logic to control the collision of vehicles on road intersections. The model is programmed with the vehicle's orientation and movement based on signals. Earlier cars are passing by, if the passengers are crossing the pedestrian path so to overcome this issue, we have added a one more stop line so that if any of the passengers are crossing a pathway then traffic lights will be Red and when all passengers have crossed the pathway then only the traffic light turn to Green and then cars will pass on. The signal is affected by the positioning of pedestrian walkways and the movement that occurs over them. For example, the signal will not turn green if there are people crossing the road.

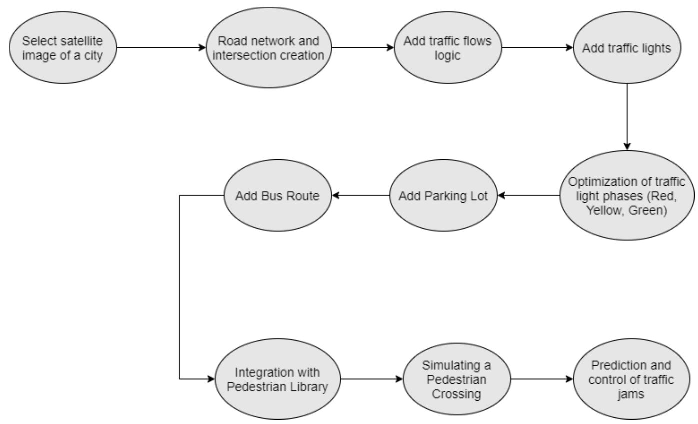

Fig. 1. Steps to Create ,Control and Predict Road Traffic

V. Experimental Setup

We used Any Logic University version as a software tool for the development of an agent-based model for traffic flow project.Here are the detailed subsections representing steps we have used to create our Road traffic model.

A. *Traffic Flow Logic*

We created Cars, buses, bus stops, bus route, car source, car dispose, car move, pedestrian, road network descriptor agents in our simulator. We have created logic associated with the movements of Vehicles and set the probability of cars moving on each road. For traffic flow logic we have created car source, car move to and car dispose blocks to represent the flow of cars moving on roads. for example, car source 1 block represents car originating from Road 4 and car can go straight, right, and left from this Road 4, car move to 1, car move to 2 and car move to 3 blocks representing car will go straight, right, and left respectively from road 4. We have adjusted the probabilities of each car choosing these 3 options. Car dispose block depicts car will end there. We have set the different speeds of cars originating from each road. To control the collision between cars at Intersection, we have added a yield sign. We have added traffic lights on intersections. We have added 2 yellow lights of 5 seconds.

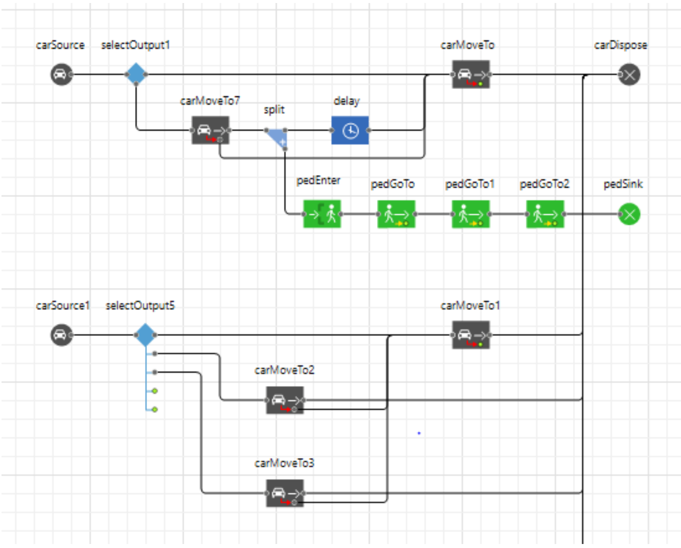

Fig. 2. Traffic Flow Logic

B. Meantime of cars

We have created a custom car type Agent to note the time of each car entered the model. we have added a parameter start time to this Agent to record the arrival time of each car into the model. Now we have created an initially empty population of agents that are from the car type that we have just created. We clicked on each "car Source" and under the advance section, assign the added cars to the custom population that we have created in the last step. Next, we added a "Histogram Data". We point to the histogram in the main and add the difference between the current time and the time this car arrived at the model. We record the duration of time this car will spend in the model. We added a histogram and assign the "timeInModel" histogram to it. We have also added logic to calculate the meantime. Then we run the model for a reasonable time, we will be able to see the mean duration time that the cars spent in this model.

C. Set Up and Optimization of Traffic lights

Before Optimization of Traffic lights, we see the average time in the model is around 55 seconds with the current setup of traffic lights. We want to parametrize the duration of each phase; therefore, we created five parameters with a default value of 30 seconds. Now we go back to each traffic light and change the duration of each phase with the parameters. to create a new optimization experiment, we right-click on the model, new experiment, and select the optimization experiment, all the parameters in the main area now in this optimization experiment. Our objective is to minimize the mean value of the time all cars spend in the model. Now we have changed the type of all five parameters to discrete. Their values could be between 10 to 35 seconds

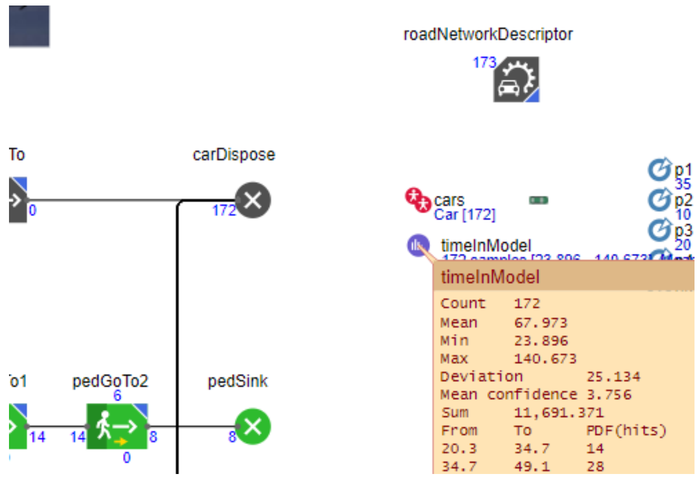

Fig. 3. Mean Time Of Cars

with steps of 5. Now we created a default UI and then run the

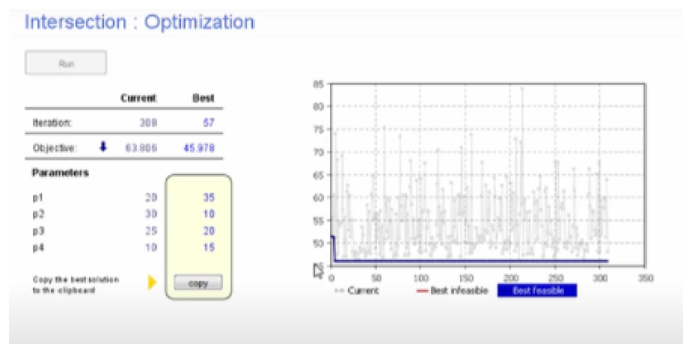

Fig. 4. Optimization of Traffic Lights

optimization experiment. AnyLogic automatically detects the number of available cores and runs several iterations in parallel on different processor cores. The chart visually illustrates the optimization process. The X-axis represents simulations, and the Y-axis represents the Current Objective, Best Feasible Objective and Best Infeasible Objective found for each simulation. now we copy the best feasible values and paste them to the original simulation experiment. We can see that the mean value is decreased to 46 seconds after optimizing the traffic lights.

D. Ser Up Parking lot

We also added a parking lot to the model."Parking lot" is a space markup element in the road traffic library. We change the number of parking spaces to 10. Now we need to add a "selectOutput", a "carMoveTo", and a "delay" block to this part of the flowchart. Some of the cars that are starting at the left segment of the upper road will go to this parking lot. Their duration of stay in the parking lot is coming from a triangular distribution. The delay also has a maximum capacity. we see 50 percent of cars will try to park in the parking lot. We received the "Car failed to reserve a parking space in parking lot" error, To resolve this error we have used the "outWayNotFound" port to tell the cars that cannot park(due to space constraints) to go straight.

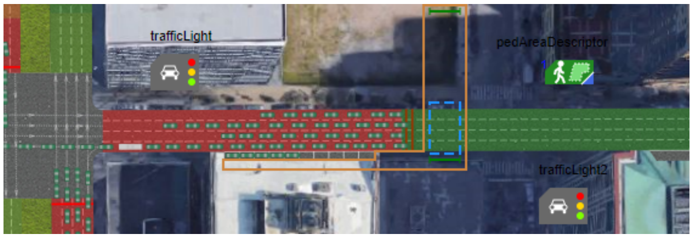

Fig. 5. Set Up Parking Lot

E. Create a Bus Route

We have added 3 bus stops to the network. Next, we build a custom agent type for buses. We added a parameter and name it "stopCounter".This parameter is of type integer and counts the number of bus stops each bus has passed by. We have set the Length of the buses to 8 meters and their initial and preferred speed is 40 kilometers per hour. We build a custom object for bus routes "BusRoute", Now, we build the flowchart that each bus will pass through whenever they enter this custom object. Whenever a bus is injected into the model, it goes to the "busRoute" custom object, We created a "carMoveTo", a "delay", and a "selectOutput" block. Buses will be injected into the model at a rate of 1 per minute. We set the bus to start at the lane with an index of zero which is the furthest right lane. After going through all the bus stops each bus will go to the right segment of the upper road and eventually leave the model. Now we created a custom object

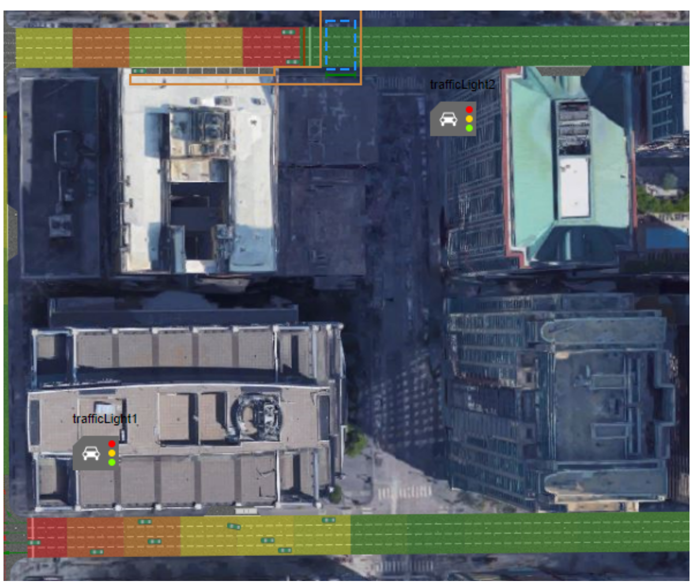

Fig. 6. Set Up Bus Route

to be capable of selecting the bus stops. To do so, we added a parameter to "BusRoute".The parameter is an array of bus stops. We change its label to Bus Stops and its control type to a one-dimensional array. Now we go back and click on the "busRoute" object, and put bus stops in the array. we choose the bus stops in the correct order. The agents that are passing through this custom object are of type Bus and they are moving to bus stops. Each bus will pick its next stop from the "busStops" array, starting from index zero. Then the bus increments its "stopCounter" to know the index of the next bus stop. This "selectOutput" should work similarly to a while loop. As long as the bus has not passed by all the bus stops, it will be sent back to the "carMoveTo" block. For this, we have added the condition that if the bus's "stopCounter" is equal to the total number of bus stops in the "busStops" array, then the bus has passed by all the stops and it should exit the "busRoute" object. Finally, we adjust the values of triangular distribution in the delay. Delay has a maximum capacity.

F. Predict Traffic Jams

We added a "Road Network Descriptor". We used it to get access to all the vehicles located in one road network. We set the "road section length" to 20 meters and speed to 5 km/hour to depict Traffic. These sections are used in density maps and average speed reporting.

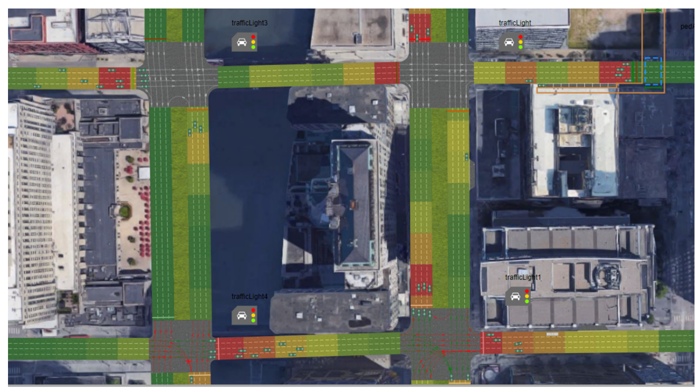

Fig. 7. Prediction of Traffic Jams

G. Set Up Pedestrian Path

First, we draw a wall around the pedestrian movement area. The "wall" space markup is on top of the "Pedestrian library" pallet then, We draw two target lines and a "rectangular area" to define the pedestrian movement. We need a "pedAreaDescriptor". This block allows defining rules on pedestrians being inside the rectangular area. We add a stop line here. We added a Traffic Light block and assign it to this stop line. The traffic light will specify the traffic behavior at this stop line. To modify the flowchart and add the pedestrians. We start with a "split" block that lets us create several pedestrians for each incoming car. We need a "pedEnter" after the split to assign locations to pedestrians and inject them into the model. We added three "pedGoTo" blocks here and a "pedSink" at the end. Before setting the attributes of these blocks, we need to add a custom pedestrian type. We kept the default animation, and add two parameters to record the pedestrians' initial location. Now on the split block, the "new agent" type should be the custom Pedestrian. A number of copies of the passengers of the cars are coming from a discrete uniform distribution."On exit copy" field, we assign the location of cars to the pedestrians. agent" is the pedestrian and "original" is the car.We get the X and Y of the car and assign it to the pedestrian. For the Y-axis of the pedestrian, We added a 5 pixel offset. Pedestrians that are injected by "pedEnter" should appear at a point. X and Y values of that point is equal to the values of x and y parameters inside each pedestrian. Now I'm setting the movement of pedestrians by these three "pedGoTo" blocks. First, they go to the bottom target line, then the rectangular area, and finally the target line on top. We can see that the cars are parking and passengers

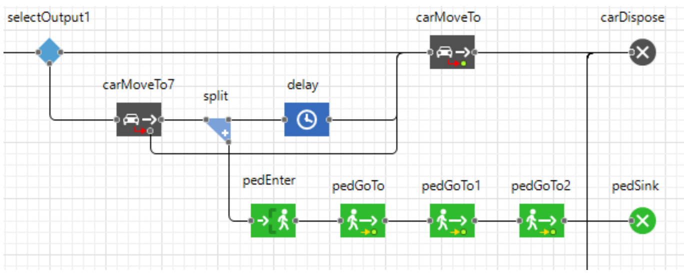

Fig. 8. Set Up Pedestrian Path

getting out of the cars. Then they move toward the target line. but the problem is passengers don't pay attention to the traffic light and cross the road whenever they reach the target line even when the light is green for the cars. we fixed this by going to the traffic lights and "on phase change" field I only open the "pedAreaDescriptor" during the red light."currentPhaseIndex" equals 2 means when the traffic light is in the red phase. Whenever the phase index is not equal to 2 the expression will be false and therefore "pedAreaDescriptor" will be closed which will prevent pedestrians from crossing the road. As you can see the pedestrians only start crossing the road when the traffic light is red. However, if pedestrians are in the middle of the road and the traffic light turns green, cars will ignore the pedestrians and pass through them. To fix this, we added a second stop line and put it after the stop line assigned to the traffic light. Now we go to the "on entering" field of "pedAreaDiscriptor" and set the signal of the stop line to red. This means that whenever a pedestrian moves into the rectangular area, the stop line will be red stopping cars from passing. We also need to change the light to green whenever the rectangular area is empty. I do this by adding this code in the "On Exit" field. Now, the traffic light is green but cars are not moving because some pedestrians area in the rectangular area and therefore the second stop line is red.

Discussion/Results

We added car population . Difference between current time and the time this car arrived at the model. Basically will record the duration of time this car will spend into model. The time in model is showed with histogram graph and this graph will shown mean as well. If we can run the model for a reasonable time it will be able to see the mean duration time that the car spend in this model.

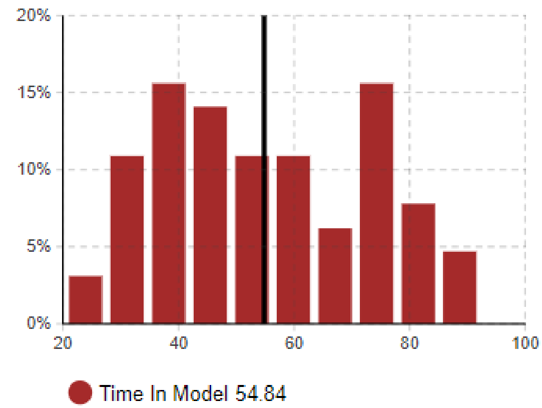

Fig. 9. Time Duration of Car In Model

We also created a custom Car type agent and add the parameter to calculate the Average speed of a car in our model.The Average Speed of a car is showed with histogram graph.

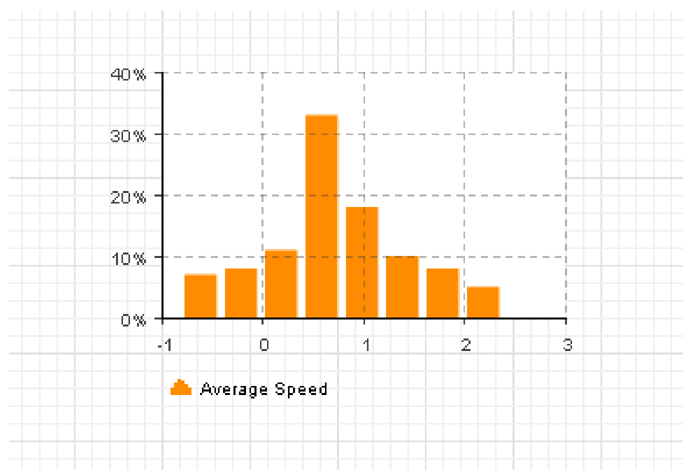

Fig. 10. Average Speed of Car In Model

We made custom object capable to selecting the bus stops and for this, add a parameter called bus route, this parameter is an array of bus stops with control type of one-dimensional array. Road network descriptor is used to get access of all the vehicles located in road network and enable density maps that makes road with colour depending upon average speed of vehicles and road section length such as green speed level, red speed level.Red Depicts Traffic Jams ,yellow depicts slowly moving traffic and Green depicts fast moving Vehicles

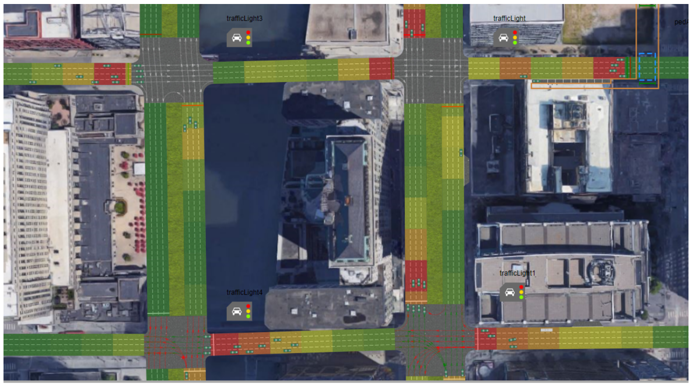

Fig. 11. Predict Traffic Jams

CONCLUSION

In recent years, there has been an increase in demand for mobility and transportation, resulting in increased traffic and the possibility of traffic jams during peak hours. As a result, methods, and technology to deal with traffic and transportation issues, such as traffic control, optimal use of existing road networks, efficient signal handling at intersections, and so on, have become important. We need interdisciplinary approaches now more than ever to find a solid solution. The need of an efficient road network and optimal placement traffic signals that can control the flow of traffic better. Traffic congestion can be alleviated if we have a well-functioning road network. The correct placement of traffic lights can lower the risk of accidents by an order of magnitude. We can build optimal techniques for developing new routes by forecasting traffic flow.

As a solution to this challenge, developing an Agent-based model that can simulate the traffic flow based on change/addition in the existing road network. We propose creating an agent-based system that considers three sorts of Agents: location specific (car location on the road), vehicle specific (vehicle speed, type of vehicle, etc.), and driver specific (perception, driving style, etc.). Special rules will be created for all of the different agents, based on which the model will produce traffic flow forecasts. Aside from that, the intersection's conditions, such as traffic lights, will be considered. We have added traffic lights and logic to control the collision of vehicles on intersection. The direction of vehicles and their movement based on the signals is programmed in the model. The placement of pedestrian walkways and movement over them effects the signal, i.e. if there are pedestrians crossing the road, the signal will not turn green.

One limitation we've seen in several studies is the lack of real-time data with which we can examine situations and make predictions. This is a problem because weather and road conditions aren't always consistent, and getting real-time data is difficult. Furthermore, we were unable to discover a model that could account for all the factors identified and mentioned in the studies we reviewed. Using all of the information acquired from the models, we will aim to simulate traffic flow forecast and propose strategies for better management in this project.

FUTURE WORK

The study of traffic congestion is a potential field of study. As a result, future study could go in a variety of areas. In the forecasting of road traffic congestion, a variety of forecasting models have already been used. However, with the newly created forecasting algorithms, there is additional room to improve the accuracy of congestion predictions. In addition, in this digital age, using more available traffic data in conjunction with newly created forecasting models can improve prediction accuracy.

Another future option could be to concentrate on traffic congestion levels. Several studies have classified traffic congestion into several states. Knowing the level of congestion, on the other hand, is critical for effective traffic management. As a result, future study should concentrate on this. Furthermore, most research concentrated on only one traffic parameter to anticipate congestion to predict congestion. This may be a great future path to focus on more than one parameter and combine the data during congestion forecasting to improve the accuracy of the forecasts[22].

Furthermore, the model is simulated assuming all the drivers follow the driving rules so we can take driving habits for more accurate results. We can optimize delay times at intersection by developing better traffic signals policies for example, coordinating the times between adjacent signals.

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Appendix

We have created agents like signals, pedestrian walkways, bus stops,Parking lot etc. – over the roads

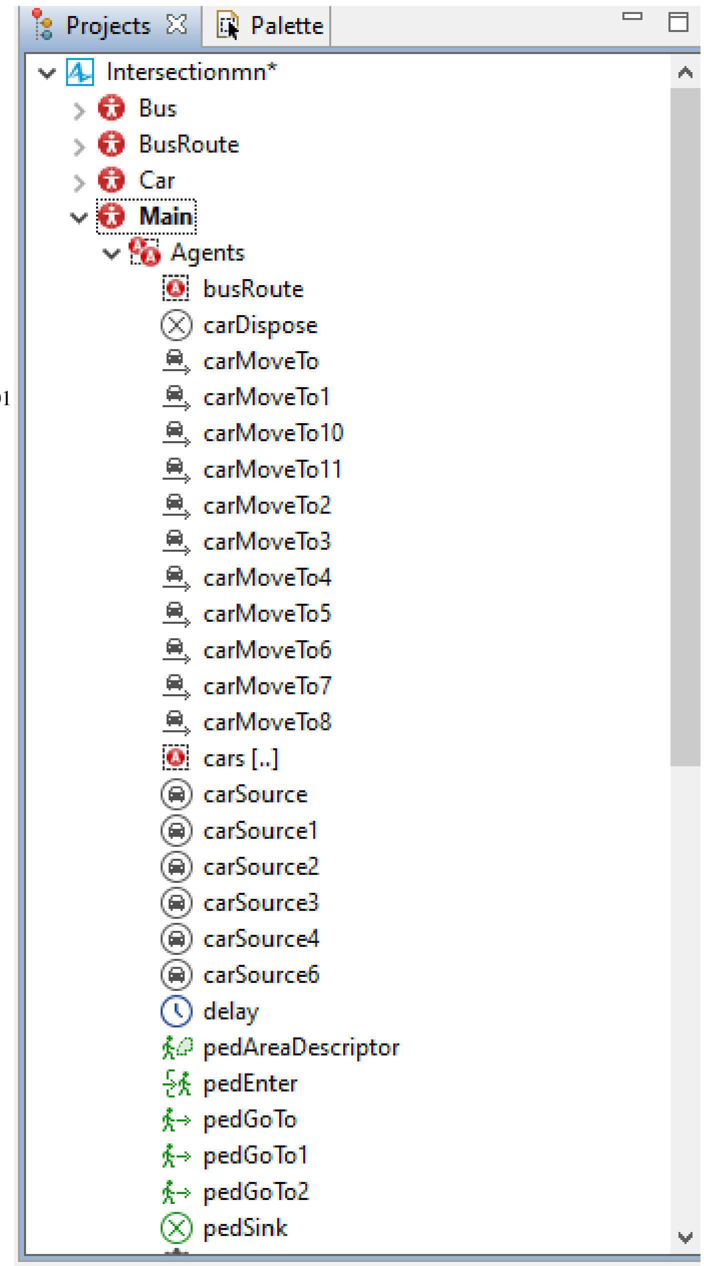

Fig. 12. Multiple Agents Created

We have created 5 Parameters to Optimize Traffic Lights so to control the traffic flow.

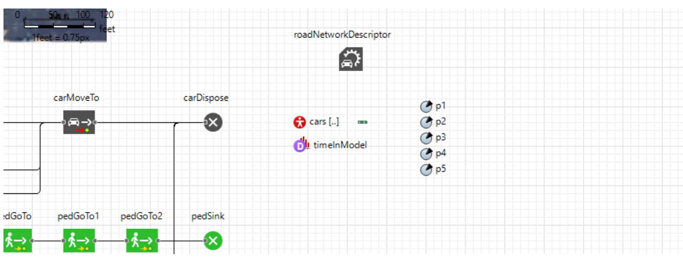

Fig. 13. Multiple Parameters Created