XAVIER UNIVERSITY – ATENEO DE CAGAYAN
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Agent-Based Modelling and Simulation of Street Traffic Caused by Phantom Intersection

In partial fulfillment of
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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The modern plague known as traffic congestion has been driving us crazy for decades. At some point during the week, many of us are stuck in our cars, going nowhere. In addition to the in-the-car misery, the grind of gridlock raises environmental concerns, and there’s also the problem of lost productivity. Despite all of the technological advances that make our lives easier, we’ve yet to come up with a definitive answer to the traffic congestion conundrum, and it doesn’t seem like the problem is going to get better anytime soon [1]. Many of us are quick to blame traffic congestion on other drivers. If just those few drivers ahead of us would pay closer attention, then we could breeze by and arrive at our destination with (relative) ease. But as drivers, we’re all part of the problem. Of course, there are many factors that are out of our hands [2]: There's not enough supply (roads) to meet demand (traffic flow, given the number of cars); there's road work, out-of-sync traffic lights and even the presence of pedestrians [3] — though putting any blame on pedestrians isn’t the answer. There are lots of factors we need to take into account, including that everyone behind the wheel if a vehicle is a factor. Is it that we're all terrible drivers who have no respect for others on the road? [4-5] In some cases, yes. But, a lot of it has to do with other issues — like not having the necessary reaction time needed to keep traffic flowing steadily or an inability to control the distance between cars.

The main idea behind a highway is that it's supposed to keep traffic at a steady flow because no one has to stop at intersections. We already know that more intersections and more lights create more traffic, so in theory, we should all be able to hit the freeways with little interference from traffic congestion. Unfortunately, that's not how it works. For one, there are other types of intersections as people enter or exit the highway. The number of intersections is definitely less than on a main road, but the intersections are there nonetheless. But, even if there were no intersections, we still wouldn't even be able to avoid traffic. This is where the idea of the phantom intersection comes into play. To explain phantom intersections, let's consider what would happen if a chicken were to cross a one-lane highway. In this case, drivers have been traveling smoothly along the highway with no intersections to impede the flow of traffic, and then a chicken decides to cross the road. The driver who sees the chicken must momentarily slow down to avoid hitting the chicken, which ultimately causes every other driver to have to slow down as well. It may not happen immediately, but at some point, a driver is going to have to come to a complete stop. Given the fact that humans don't have the greatest reaction time, every driver is going to be breaking and slowing down at different speeds, which means there's no longer steady traffic flow. Even though the chicken crossed the road a long time ago, it created a phantom intersection because everyone had to slow down as if an intersection were present. It'd be nice to think that phantom intersections are only created by chickens crossing over a one-lane highway, but multilane highways with no chickens are just as vulnerable (if not more so) to phantom intersections. When drivers are crossing highway lanes too quickly, that causes the drivers behind to have to react and then slow down to avoid a collision. Drivers move through multiple lanes all the time (in every direction), which means all of us are constantly slowing down and speeding up, which creates unsteady traffic flow. The best way to remedy the traffic caused by phantom intersections is for every driver to stay equidistant between the car in front of them and the car behind them. But, that's pretty much impossible to do.

Modelling heterogeneous traffic flow for Asian countries is one of the emerging research areas in the past few years. The two main challenges in modelling are: capturing the effect of varying size of vehicles, and the lack in behavior (a phenomenon of congested traffic where vehicles try to percolate through the available gaps in the road section ahead) of vehicles [6]. Existing conventional continuum type traffic flow models are well suited for developed countries with homogeneous traffic and perfect lane discipline. In fact, even in the so called homogeneous traffic, the vehicles' sizes may vary. Frequent lateral/lane changing movements in heterogeneous traffic forces modelling approaches to consider the entire road width as a whole instead of multiple lanes [7]. The capacity filling behavior makes the road capacity in entire road width as a whole instead of multiple lanes. The capacity filling behavior makes the road capacity in Asian countries much higher when compared to the other developed countries since the same section length of the road can be occupied by different types of vehicles at the same time. Thus, the conventional measure of traffic concentration, the density which is measured as vehicles per unit length, is not a good choice for heterogeneous traffic. Recently, [8] and [9] introduced the concept of area occupancy for measuring heterogeneous traffic concentration.

Road traffic has many advantages for both national and individual levels. Traffic facilitates the movement of goods and people, provides access to markets, education, care, leisure and so on. Traffic is ubiquitous [6-7] and it's a large scale phenomenon which meets these criteria: (i) traffic is composed by heterogeneous entities, (ii) the number of entities composing the traffic is very high and interactions between these entities are non-linear, (iii) traffic is geographically and fundamentally a distributed phenomenon, (iv) there are several levels of detail of traffic observation [9,13]. Traffic is therefore a complex system because interactions between the entities are non-linear and the collective behavior of these entities is non-trivial. However, in the recent decades, with the exponential increase of the number of users (vehicles, pedestrians, etc.), this transportation mode, although very practical for a user, was quickly faced of several financial, safety, energy and social issues. One solution to try to answer these issues is modeling and simulation of traffic. Modeling and simulation of road traffic helps to provide answers to the problems of improving the traffic conditions of goods and people. To model and simulate traffic, several approaches have been proposed and can be classified into microscopic, mesoscopic and macroscopic levels [10]. However, to simulate large-scale traffic, it can be interesting to integrate different representations in the same model which leads to hybrid approach. Most of the existing hybrid models define a priori the different abstraction levels [11].

There are a number of various road traffic modeling approaches that are presently used by many researchers in the present:

a) Static models [7-8]

- A static model is a simplified representation of journey on a study area and a given time period that does not take into account the fluctuations of demand ohows f journey over the considered period nor the interactions between the different time and distance steps. Static models are fairly widespread and can be used to evaluate major modifications of transport system or public policies. The most widely static model used in the literature is the four-step model (the other models are derived from the latter by often adding intermediate steps).

The four-step model is based on the division of the agglomeration into an area. The main steps of this model are trip generation, trip distribution on the network, the mode choice of transport and finally the assignment of demand on the network.

b) Dynamic Models [8]

- A dynamic model is based on the principle of the variability of transport demand in the study period. Therefore, dynamic models are used to describe the physical flow of road traffic. Several modeling approaches were proposed:

    i. Microscopic models: It's the most accurate and closest to real behaviors of the entities of the system because it represents the individuals, interactions between the individuals, which create the dynamics of the system. There are several approaches. Firstly, the driver behavior based approach called nanoscopic model or behaviour8 model that emphasizes the real behaviors of the drivers and mathematics approach that describes behavior by equation. Another approach is cellular automaton that presents an interest because its speed and its dynamic behavior, but verification of cellular automaton reveals unconvincing results in urban network and highway at the macroscopic level. Finally, an activity-based approach named TRANSIMS (TRansportation ANalysis SIMulation System) that is an integrated system of travel forecasting based on four primary modules: population synthesizer, activity generator, route planner and microsimulator. Microscopic models lead to emerging phenomena such as congestion, but require a high computational cost.

ii. Mesoscopic models [8]: Mesoscopic traffic models can be considered as intermediate between macroscopic. models and microscopic models. Two approaches to design are presented in the literature: one in which individual vehicles are not taken into account because the vehicles are grouped in packets or platoons that move along the links, and the one in which the dynamics of the flows is determined by the simplified dynamics of individual vehicles. Mesoscopic exhibits coarse behavior.

iii. Macroscopic models [9]: They represent traffic as a flux in analogy with the kinetics of gases. Macroscopic models have the advantage of being simple, easy to manipulate because they need few parameters, making calibration and model validation is easy. Moreover, the execution time of the macroscopic models is acceptable. They are therefore according to an appropriate point of view able to model large-scale systems such as traffic. However, macroscopic models are quite limited in urban areas and they are incapable to model a simple microscopic phenomenon like changing lane, and management of destination of each vehicle is quite difficult with macro models.

iv. Hybrid models [9-10]: this approach integrates different levels of detail (micro, macro, meso) within the same model. These models are generally called multilevel models. It is an approach that generally combines the advantages of macroscopic models and microscopic models, but it is difficult to realize.

1.2 CONCEPTUAL FRAMEWORK

The conceptual framework below shows the conceptual framework of the study, Agent-Based Modelling and Simulation of Street Traffic Caused by Phantom Intersection. In the input component, the traffic situation and occurrences as well as the phantom occurrences and data will be made purposeful to develop the simulation. In the process component, the development of the simulation takes place and the traffic situation and occurrences as well as the phantom occurrences and data will be used as a basis in the creation will be the primary component in the creation of the application. In the output component, the simulated model of the phantom occurrences will be shown and evaluated in order to produce a model that will satisfy the approximations of the real phenomena that is currently happening in the present. In addition, the behavior space will also be evaluated in the application showing the results, the data, and the graph that will be used in discussing certain points in the application. The three components will work chronologically with each other starting from the input component up to the output component. The further processes, however, will not take place if the preceding process was not accomplished in the previous implementation.

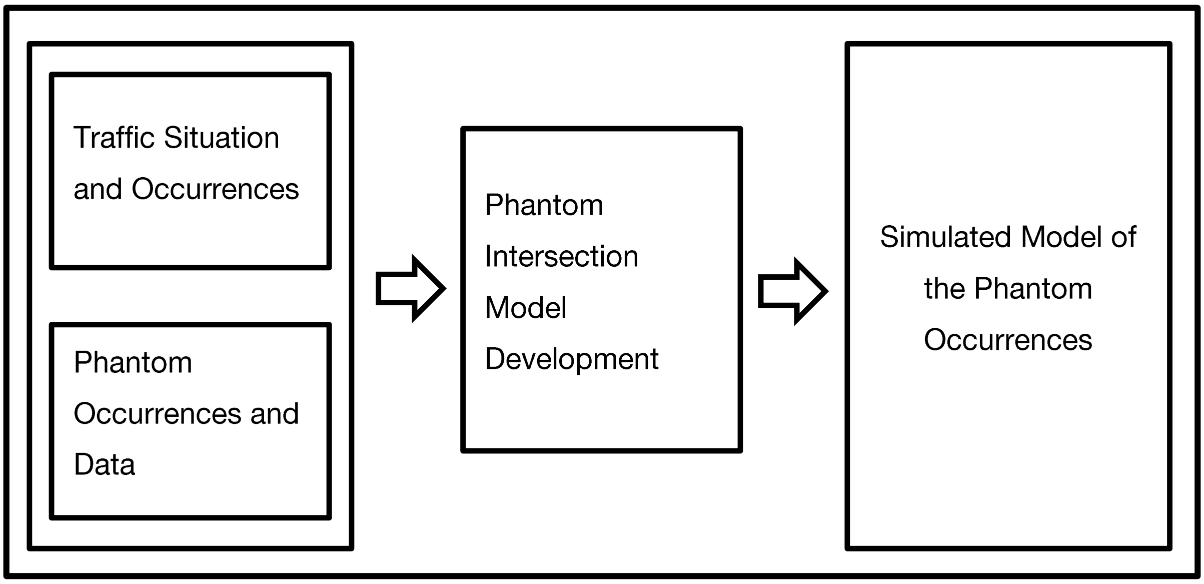

Figure 1. Agent-Based Modelling and Simulation of Street Traffic Caused by Phantom Intersection

1.3 STATEMENT OF THE PROBLEM

Road traffic is a key part of the infrastructure supporting mobility through the transportation of humans and goods. However, at the same time, it is also the cause of various types of urban and environmental issues including traffic jams, accidents, heavy energy consumption, as well as air pollution and global warming due to engine emissions. Promotion of public transportation usage is among the most effective methods for addressing such issues. Herein, we will focus on studying behavior of traffic in metro Cagayan de Oro because the connectivity of public transportation services (such as railways and tramways) is regarded as an index for transportation service accessibility, and because improved transportation services can suppress excessive public dependency on private cars. However, careful consideration must be taken given the fact that policies aimed at improving tram convenience might impair the use of the private cars that must share the same limited road space available. Furthermore, since it is very difficult to restore a road environment to a previous condition once it has been changed, it is strongly desirable to accurately estimate the impact of transportation policies quantitatively. This is why simulations have been playing an important role in the field of traffic engineering, and why various types of traffic simulators have been developed and utilized. A number of mixed traffic simulation models that can be used to support the validity of novel signal control methods or public transport planning efforts have been proposed in recent years primarily because they can ascertain precise traffic properties at specific road environment locations.

1.4 OBJECTIVES

1.4.1 General Objective

The objective of this article is to develop an agent-based simulation of traffic in Cagayan de Oro in hopes to address the current traffic situation and in attempting to find a solution. In addition, the developed simulation will possess uniqueness, autonomy, locality of interaction, adaptive behavior, emergence.

1.4.2 Specific Objectives

Emanating from the general objective from the preceding section, the following are the specific objectives:

- To design and develop an agent-based simulation of the traffic in Cagayan de Oro in hopes to address the current traffic situation.
- To analyze the forecasted effects of the agent-based simulation when applied in the current Cagayan de Oro setup.
- To develop a simulation that will possess uniqueness on its turtles, patches, and other simulation components.
- To develop a simulation that will possess autonomy on its turtles, patches, and other simulation components.
- To develop a simulation that will possess locality of interaction on its turtles,

patches, and other simulation components.

- To develop a simulation that will possess adaptive behavior on its turtles, patches, and other simulation components.
- To develop a simulation that will possess emergence on its turtles, patches, and other simulation components.

1.5 SIGNIFICANCE OF THE STUDY

Simulation is an important tool for studying traffic flow under various design conditions. Often simulation is the only way as one may not be allowed to experiment with different design on real-world traffic facilities. The most realistic traffic simulators are those which try to simulate the flow of traffic by simulating the behavior of individual drivers of the traffic stream. These type of simulation models are referred here as microscopic traffic simulation models. With the advent of powerful computers realistic size traffic stream can be simulated using microscopic traffic simulation models. Traffic simulation models are useful from a microscopic, macroscopic and sometimes mesoscopic perspectives. Simulation can be applied to both transportation planning and to transportation design and operations. In transportation planning the simulation models evaluate the impacts of regional urban development patterns on the performance of the transportation infrastructure. Regional planning organizations use these models to evaluate what-if scenarios in the region, such as air quality to help develop land use policies that lead to more sustainable travel. On the other hand, modeling of transportation system operations and design focus on a smaller scale, such as a highway corridor and pinch-points. Lane types, signal timing and other traffic related questions are investigated to improve local system effectiveness and efficiency [8]. While certain simulation models are specialized to model either operations or system planning, certain models have the capability to model both to some degree. Whether it is for planning or for systems operations, simulations can be used for a variety of transportation modes.

1.6 SCOPE AND LIMITATION

A traffic simulation study consists of the following tasks:

a) formulation of the aims and scope of the study,

b) input data collection,

c) construction of the simulation model,

d) model verification,

e) model calibration,

f) model validation,

g) alternatives analysis and

h) documentation.

These tasks are common to simulation based studies in other domains. In a traffic simulation study, formulation of the aims and scope of the study involves determination of the traffic system and the alternative solutions to be analyzed. The delimitations of the study, both in terms of time period for the analysis and study area coverage, are also formulated in this first step of the study. Another important issue in this step is to decide on the traffic analysis method to be used. Traffic simulation is one alternative method. Another alternative is the analytical highway capacity manual methods described in the introduction of this paper. It may also be necessary to use a combination of different traffic analysis tools, e.g. use of traffic simulation to generate speed-flow relationships for macroscopic traffic analysis.

1.7 DEFINITION OF TERMS

- Back of Queue
    - Maximum extent of the queue relative to the stop line or give-way (yield)

line during a signal cycle or gap-acceptance cycle. The last queued vehicle that joins the back of queue is the last vehicle that departs at the end of the saturated part of green interval or the available gap interval.

- Capacity
  - The maximum sustainable flow rate at which vehicles or persons reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a specified time period under given roadway, geometric, traffic, environmental, and control conditions; usually expressed as vehicles per hour, passenger cars per hour, or persons per hour.
- Cycle
  - A complete sequence of signal phases.
- Cycle Length (Cycle Time)
  - Time required for one complete sequence of signal displays (sum of phase green and intergreen times). For a given movement, cycle time is the sum of the durations of red, yellow and green signal displays, or sum of Effective Green and Red Times.
- Delay
  - The additional travel time experienced by a vehicle or pedestrian with reference to a base travel time (e.g. the free-flow travel time).
- Demand Flow (Demand Volume)
  - The number of vehicles or pedestrians arriving during a given period as measured at the back of queue (as distinct from departure flows measured in front of the queue). See Stopline Flow Rate.

- Density
    - The number of vehicles per unit distance along a road segment as measured at an instant in time.
- Effective Intersection Capacity
    - An aggregate measure of intersection capacity determined as the ratio of total intersection demand flow to the intersection degree of saturation, where the intersection degree of saturation is the largest lane degree of saturation considering all lanes of the intersection.
- Free-Flow Speed
    - The uninterrupted traffic speed when density is approximately zero, i.e. when only few vehicles are present in the traffic stream.
- Phantom Intersection
    - These are "phantom" bottlenecks or traffic which appear for no apparent reason and then disperse.
- Proportion Queued
    - Proportion of traffic that is queued due to the effects of traffic control and the existence of other vehicles. This is related to the Major Stops or Slow Downs from the approach cruise speed.
- Queue
    - A line of vehicles or pedestrians waiting to proceed through an intersection. Slowly moving vehicles or pedestrians joining the back of the queue are usually considered part of the queue. The internal queue dynamics can involve starts and stops. A faster-moving line of vehicles is often referred to as a moving queue or a platoon. See Back of Queue and Cycle-Average Queue.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Car traffic simulation models are generally classified into two categories: macroscopic models based on continuum fluid dynamics and microscopic models in which each vehicle is modeled as a kind of particle. Since traffic phenomena are regarded as a mixture of complex systems produced by numerous human beings who possess intelligence, goals, intentions, as well as individualities, a multi-agent system is useful for describing microscopic car behavior. Microscopic models can be divided according to the representation of road structure in greater detail. In the continuous road model group, a base structure of road space is modeled as a continuous one-dimensional (1D) link. The behavior of car agents is often implemented by applying car-following theories [3-4] [5-8]. Most commercial microscopic traffic simulators employ the continuous road model. In the cell-type road model group, road space is discretized by homogeneous cells in which the behavior of car agents is expressed using transition rules such as cellar automata [4-5] [6-9]. In a queuing model group, road networks are modeled as queue networks [9].

Microscopic models used for pedestrian (or crowd) simulations are classified as well. The social force model (SFM) [8] and centrifugal-force based models (CFM) [8,12], in which pedestrian agents move in two-dimensional (2D) road space, have been successfully used in continuous road model groups. The predictive performance of those models was enhanced by introducing the capability to anticipate pedestrian actions [9] and stride adaptation mechanisms [2,3]. A 1D pedestrian model [10] in which the SFM spatial dimensions are compressed into one, has been applied to evacuation simulations. Furthermore, the discrete choice model [15] is among the continuous road models with discretized decision-making rules for each pedestrian agent. The floor field model [8-9] [12] and Muramatsu's lattice-gas-based model [4] belong in the group of cell-type road models. In addition, several researchers have proposed simulation frameworks for mixed traffic of two or more models. For example, [8] proposed a framework for pedestrian road crossing behavior in Chinese cities in which they determined the criterion used by pedestrians to decide whether start crossing a road after considering vehicle flows. While the model itself was relatively simple, the simulation results (with adjusted parameters) agreed well with the observed values. Meanwhile, [13] modeled pedestrian-vehicles interactions at crosswalks by adding external force to the SFM in order to minimize pedestrian-vehicle collisions. [15] used the SFM to model mixed car and pedestrian traffic scenarios by extending the SFM for car dynamics and integrating a car-following model. [7] also developed a 2D car behavior model based on the SFM and integrated it with the proportional-integral-derivative (PID) control algorithm, while [9] extended the SFM to model the behavior of motorcycles, passenger cars, and buses for use in a mixed traffic simulation at a signalized intersection. These SFM-based car models are capable of being naturally integrated with the SFM-based pedestrian models. However, a major disadvantage of existing car traffic simulators based on car-following models is that they are hard to apply to this approach. Furthermore, generally speaking, the computational load of 2D models is much higher than that of 1D models. Additionally, [6] proposed an integrated simulation model by combining a 1D car-following model and a 2D floor field pedestrian model in which they employed a hierarchical road environment structure to exploit the different representations of cars and pedestrians. The specific types of agents are situated in the lower level and comprehensive views of the overall situation are given at the higher level. [11] integrated multi-modal simulation modules to the existing framework of MATSim, which is a largescale traffic simulation framework based on the queueing model [3-4]. Their integration approach was based on locally replacing simple queue structures with continuous 2D space at sections with higher traffic flows. The behavior rules of agents

in the 2D space are based on the SFM. Finally, [13] introduced pedestrian and bicycle agent models into SUMO, which is widely used traffic simulator belonging to the continuous road model group [15], and were able to consider and verify their agents qualitatively, even though the pedestrian and bicycle agents had relatively simple behavior rules by which they move in 1D virtual trajectories.

CHAPTER 3

PROPOSED METHODOLOGY

A. Purpose

“Why are we stuck in traffic when there is no traffic light or accidents?”. The purpose of the model is to observe, analyze, and give solutions to the phantom intersection which causes traffic and accidents. Phantom intersection is the result when one driver brakes suddenly and affects the driver behind him to brake. This causes a domino effect to all the drivers behind the first driver thus creating a traffic.

B. Entities, State Variables and Scales

a. Entities
    i. Car
b. State Variables
    i. Car
        1. speeds – the velocity of the car
        2. acce – the acceleration of the car
c. Global Variables:
    i. stops- number of cars that stopped
    ii. accel- incremental acceleration
d. Global Monitors
    i. Speed for each Car
    ii. Number of Cars that stopped
    iii. Number of Cars accelerating
    iv. Average Speed of all Cars

e. Scales

    i. Number of Cars 1:1

    ii. Speed of Cars 1:1kmph

    iii. Radius 1:1m

C. Process Overview and Scheduling

a. Moving Car

    i. Acceleration – Accelerates from 0kmph to the desired speed.

    ii. Constant Speed - zero acceleration when at the desired speed

    iii. Braking - braking when the distance of the car in front is less than or equal to 2.5

D. Design Concepts

a. Basic principle

    i. Acceleration is the change of velocity or speed

    ii. Speed is the distance traveled over time.

b. Emergence

- The model's purpose is to simulate the phantom intersection which emerges from the individual agents when they brake causing other agents to brake as well.

c. Adaptive Behavior

- The agents will trigger a brake when a car in front of it is 2.5 m or less.

d. Objective

- The agents' objective is not to crash to other agents.

e. Sensing

- The agent brakes when the agent in from of it is too close to it.

f. Interaction

- Interaction occurs when the agents crash into each other causing a collision.

g. Observation

- The global monitors will show the speed of each car, the average speed, the number of cars that stopped, the number of cars that are accelerating and a plot that shows the min, max, and standard deviation of the speed. The model also stops and alerts the user when a collision happens.

E. Initialization

a. The model gets input from the sliders to get the values of the speed, number of cars, and the distance between cars.

b. The model sets the acceleration to 2 per ticks.

F. Input Data

a. There is no input data used.

G. Submodels

a. Circumference of the Road = C

$$Initialization\ of\ circumference = C = 50\ \frac{km}{hr}$$

b. Forward (Car Movement)

$$forward = F = \pi\left(\frac{R}{180}\right)\left(\frac{S}{50}\right)$$

$$where\ R = radius\ and\ S = speed$$

c. Right Turn (Car Movement)

$$right\ turn = R = \frac{S}{50}$$

d. Acceleration

$$acceleration = A = \pi\left(\frac{R}{180}\right)(F + R)$$

e. Standard Deviation

$$standard\ deviation = s = \sqrt{\frac{\Sigma|X - \bar{X}|^2}{n-1}}$$

f. Derived Formula

$$radius = R = \frac{S(B)(c)}{5}$$

$$where\ R = Radius$$

$$S = Speed$$

$$B = Break\ time$$

$$c = number\ of\ cars$$

CHAPTER 4

RESULTS AND DISCUSSIONS

Figure 2 Phantom Intersection Exhibiting no Collision at an Equal Speed

Figure 1 shows the simulation of the intersection showing no collision and at an equal speed. The parameters being set in the application are number (number of cars), speed (speed of cars), and radius (how wide the cycle radius is).

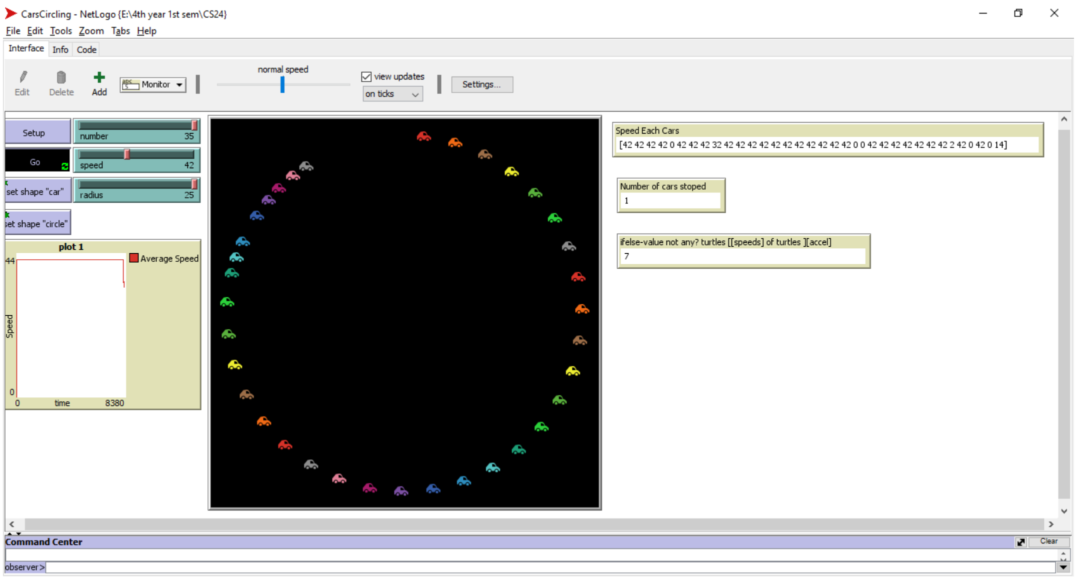

Figure 3 Phantom Intersection Exhibiting Collision at an Equal Speed

Figure 2 shows a phantom intersection simulation that shows collision at an equal speed. As the figure shows, there are cars starting to collide with each other.

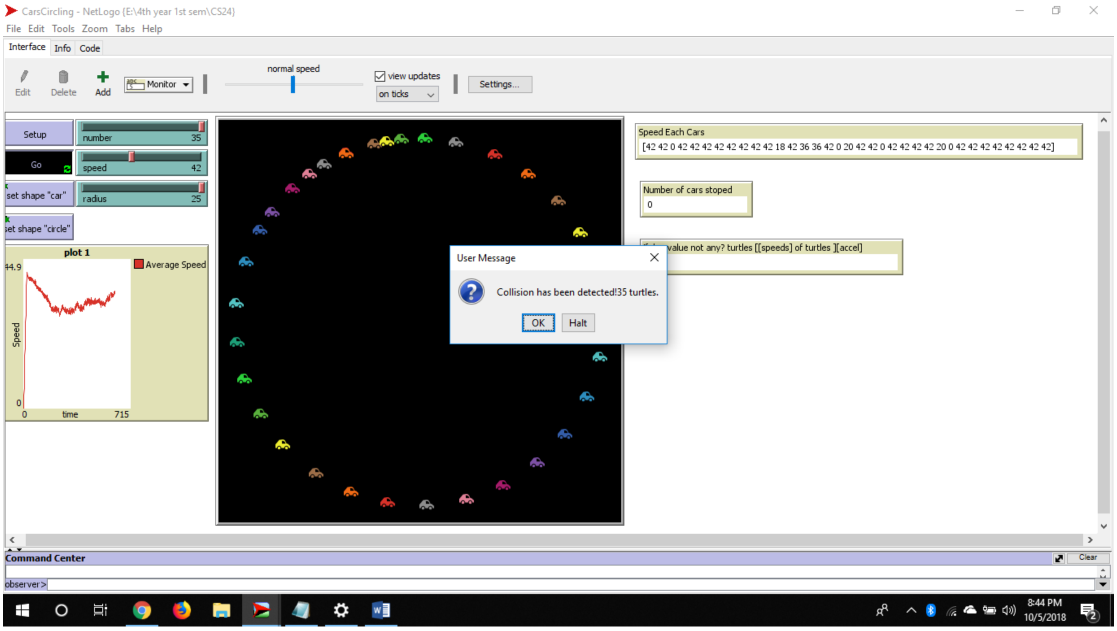

Figure 4 Simulation User Message Showing the Number of Collisions that Occurred

The simulation shows a user message that collision have been found in the simulation. The prompt also shows the number of cars that have collided. In our simulation we have tested a Behavior Space with the following specifications and parameters and were run on five (5) iterations. The parameters specified are the following:

a) ["number" 7 14 21 28 35]

b) ["speed" 20 40 60 80 100]

c) ["radius" 20 20 20 20 20]

The space, in addition, evaluates the average speed that occurs during the simulated phantom intersection and were run across five (5) repetitions or iterations. Table 1-5 shows the speed, radius, and average speed simulation of 7, 14, 21, 28, and 35 cars respectively. In addition, a speed of 20 is incremented across repetitions which means the speed starts from 20 and runs up to the maximum value which is 100.

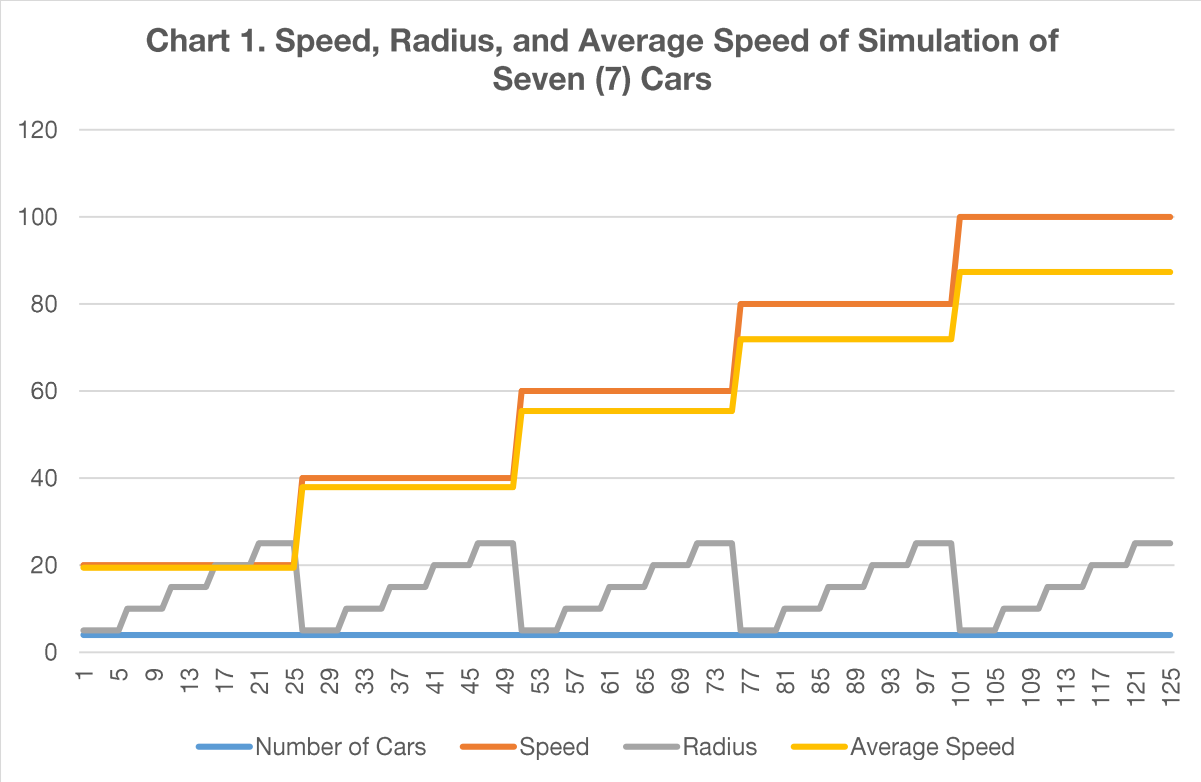

Chart 1. Speed, Radius, and Average Speed of Simulation of Seven (7) Cars

Chart 1 shows the speed, radius, and average speed simulation of seven (7) cars in the animation in the behavior space, no collision has been found, and as a result, the speed is just consistent. The average speed are as follows:

Table 1. Mean speeds of various speeds having seven (7) cars.

Number of Cars	Speed	Radius	Mean Speed
7	20	20	19.45274
	40	20	37.91045
	60	20	55.37313
	80	20	71.8408
	100	20	87.31343

Chart 2 shows the speed, radius, and average speed simulation of 14 cars in the animation in the behavior space, no collision has been found, and as a result, the speed is just consistent.

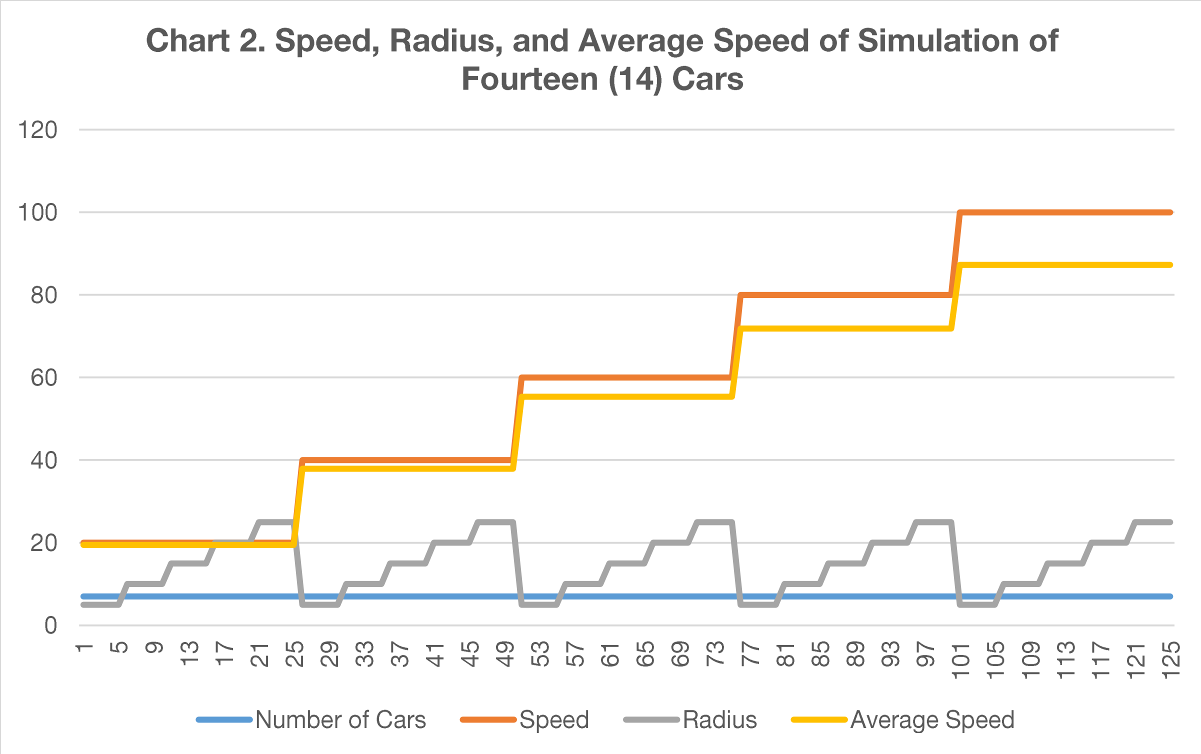

Table 2. Mean speeds of various speeds having 14 cars.

Number of Cars	Speed	Radius	Mean Speed
14	20	20	19.45274
	40	20	37.91045
	60	20	55.37313
	80	20	71.8408
	100	20	87.31343

Chart 3 shows the speed, radius, and average speed simulation of 21 cars in the animation in the behavior space, no collision has been found, and as a result, the speed is just consistent.

Table 3. Mean speeds of various speeds having seven 21 cars.

Number of Cars	Speed	Radius	Mean Speed
21	20	20	19.45274
	40	20	37.91045
	60	20	55.37313

	80	20	71.8408
	100	20	87.31343

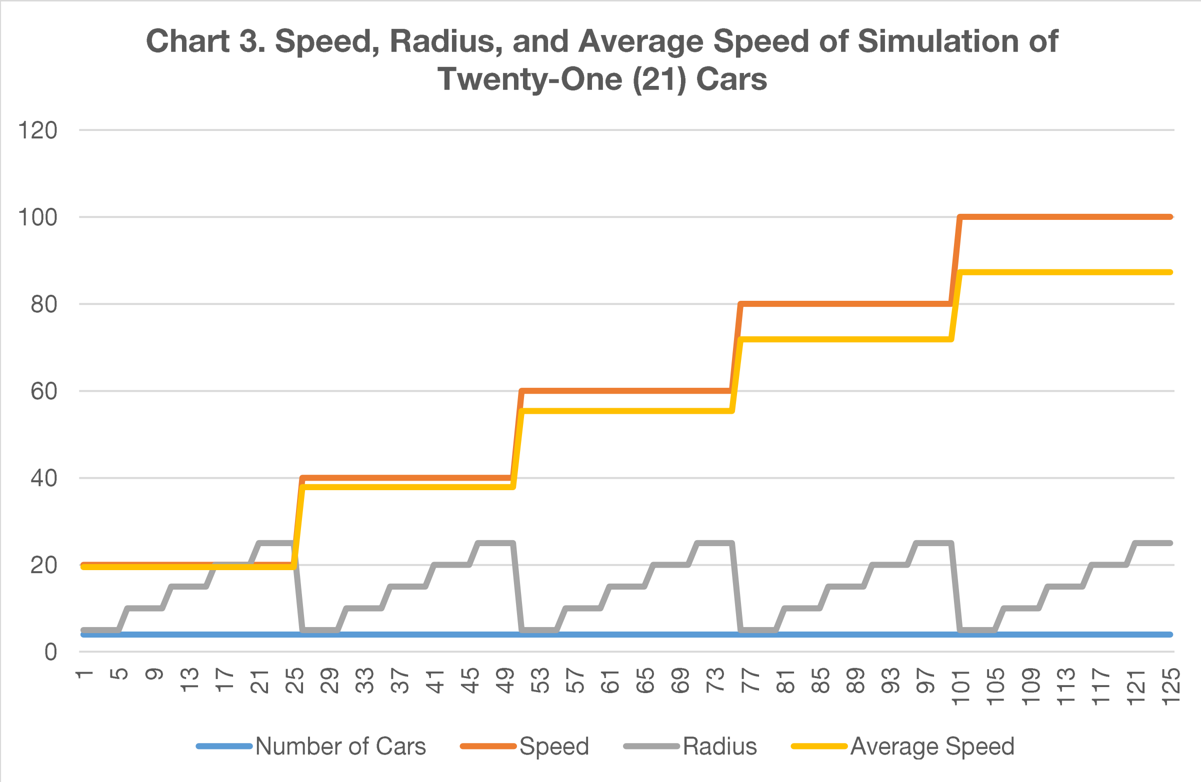

Chart 3. Speed, Radius, and Average Speed of Simulation of Twenty-One (21) Cars

Chart 4 shows the speed, radius, and average speed simulation of 28 cars in the animation in the behavior space, no collision has been found, and as a result, the speed is just consistent.

Table 4. Mean speeds of various speeds having 28 cars.

Number of Cars	Speed	Radius	Mean Speed
28	20	20	19.45274
	40	20	37.91045
	60	20	55.37313
	80	20	71.8408
	100	20	87.31343

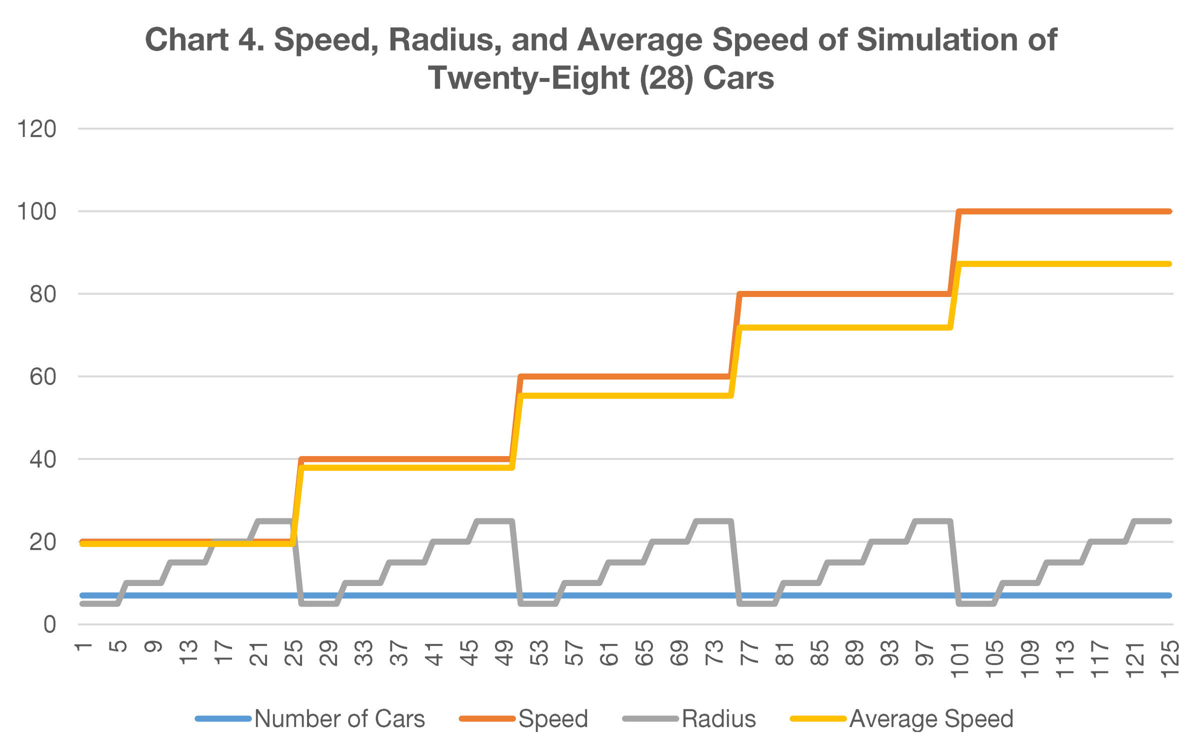

Table 5 shows the speed, radius, and average speed simulation of 28 cars in the animation in the behavior space, no collision has been found, and as a result, the speed is just consistent.

Table 5. Mean speeds of various speeds having 35 cars.

Number of Cars	Speed	Radius	Mean Speed
35	20	20	19.45274
	40	20	37.91045
	60	20	55.37313
	80	20	71.8408
	100	20	87.31343

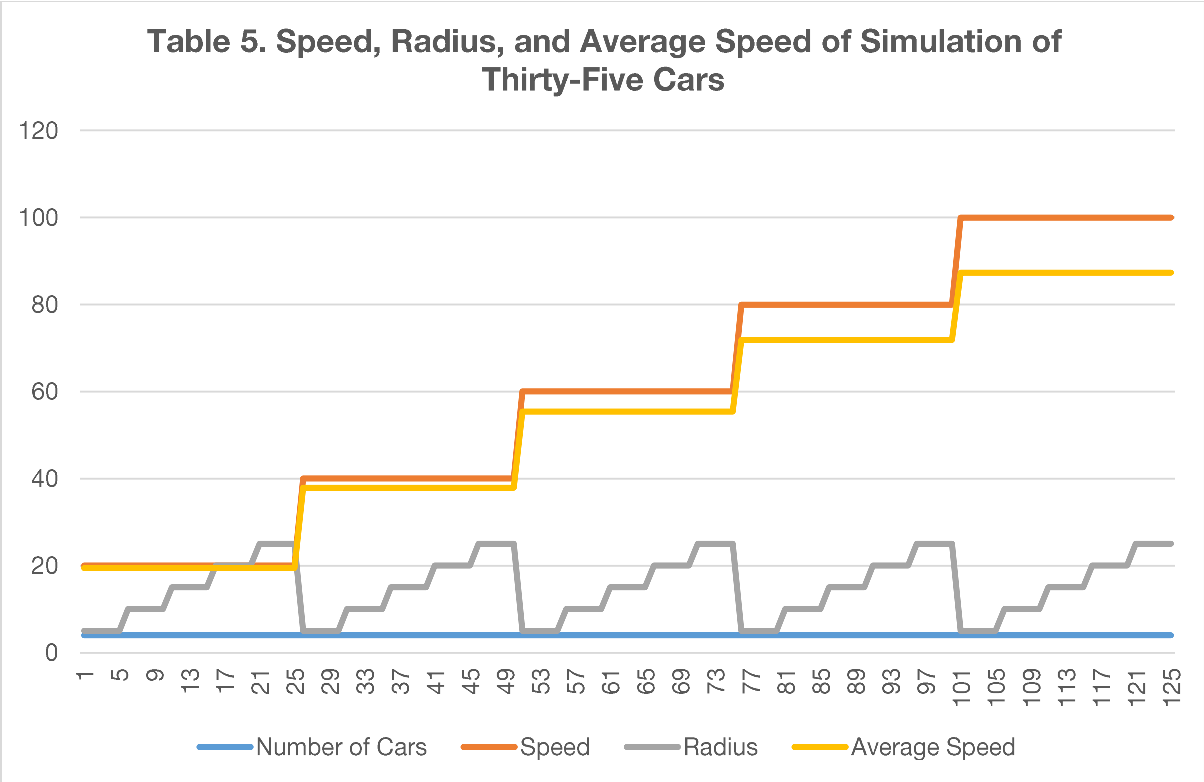
Table 5. Speed, Radius, and Average Speed of Simulation of Thirty-Five Cars
120
100
80
60
40
20
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105 109 113 117 121 125
Number of Cars
Speed
Radius
Average Speed

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Computer traffic simulation is important for making new traffic-control strategies. Microscopic traffic simulators can model traffic flow in a realistic manner and are ideal for agent-based vehicle control. In this paper we describe a model of reactive agents that is used to control a simulated vehicle. To ensure fast reaction times, the agent’s driving task is divided in several competing and reactive behavior rules. The simulator consists of an urban environment with two lane roads, intersections, traffic lights, and vehicles. Every vehicle is controlled by a separate driving agent and all agents have individual behavior settings. The main advantage of agent-based microscopic traffic simulation over the more traditional macroscopic simulation is that it is more realistic. Instead of using general traffic-flow models, traffic becomes an emergent property of the interaction between agents. Another advantage is that agent-based simulation is more flexible. Changes to traffic scenarios can be made quickly by changing agent parameters. Preliminary experiments have shown that our driving agent exhibits human-like driving behavior and is capable of modelling different driving styles.

The simulation environment should be made more realistic by adding new objects, such as busses, trucks, emergency vehicles, pedestrian crossings, cyclists, traffic signs, trees and buildings. Once the simulator is improved with the new objects the agent’s functionality must be extended to deal with these objects

Self-driving cars

This is one reason why many people are proponents of self-driving cars. Drivers aren’t able (and most likely not willing) to consistently monitor the distance between themselves and other cars, but self-driving cars can easily monitor that distance. Not only can self-driving cars tackle the distance issue, but they're able to react much more quickly than humans to changes in traffic. You may question if self-driving cars are the best way to make sure human error doesn't play a role in traffic, but that's one of the big reasons people advocate for self-driving cars. Self-driving cars seem like a viable option for reducing traffic, but there's much more we can do. Since we are nowhere near a consensus at this point, it's worth exploring some of these options.

The researchers also have proposed solutions in order to mitigate phantom intersection situations. They are the following:

a) *Adding more lanes [11-12].* Since one major traffic cause is simply that there are too many cars on the road, adding more roads and widening roads doesn't seem like such a bad idea. While in some cases it probably helps, adding more lanes can sometimes be ineffective, reports Phys.org. In certain cases, when more lanes are added to a road, drivers who previously didn't use that road then begin to take it, and then you have even more traffic than before. This isn't to say that more lanes should never be added to a road, but it does show that it can create some complications — not to mention all the construction.

b) *Roundabouts and diverging diamond interchanges [13].* Roundabouts have been shown to improve steady traffic flow with little congestion. Roundabouts do away with the need for traffic lights at intersections, which we already know can be detrimental to a smooth traffic flow. Of course, building a roundabout requires lots of construction, and there are portions of cities where it isn't practical to build them, but it's something to consider if the location permits.

c) Smart technology in cities [14-15]. Implementing smart technology in cities can help reduce traffic congestion, reports Geotab. Some cities have already started to make use of Vehicle-to-Vehicle technology (V2V) and Vehicle-to-Infrastructure technology (V2I). V2V technology is essentially vehicles communicating with one another on the road, which is how self-driving cars work. V2I technology allows vehicles to send and receive information to surrounding infrastructure like traffic signals and weather alert systems.

d) *Artificial Intelligence [13].* Alibaba's cloud computing arm, Alibaba Cloud, which has a data center in Malaysia, is integrating City Brain with the Malaysian capital's existing traffic management systems. It aims to launch the completely integrated system in May 2018. City Brain sorts through a mass of incoming data from 300 traffic lights, 500 CCTV cameras, public transport systems and other streams in order to minimize road congestion. It will use data mining, video and image recognition and other processes to determine live traffic predictions and recommendations, for instance, calculating the fastest and least disruptive route for an ambulance through the city using the inflow of real time data. The complex system is powered by Alibaba Cloud's Aspara, a computing engine which uses the technology underlying Alibaba's online marketplaces. The City Brain pilot is in partnership with the Malaysia Digital Economy Corporation and Kuala Lumpur City Hall. The system was considered a success following its deployment in Hangzhou, resulting an average traffic speed increase of 15 per cent, and reporting traffic violations with 92 per cent accuracy.

REFERENCES

[1] UNIT KIN. Department for Transport. Perceptions of congestion: report on qualitative research findings. London, UK, 2001;

[2] SALTER, R.J. and HOUNSELL, N.B. Highway Traffic Analysis and Design. Third edn. Palgrave Macmillan, 1996.

[3] BALL, P., Critical Mass. United Kingdom: Arrow Books, 2004.

[4] NAGEL, K., and SCHRECKENBERG, M., A Cellular Automaton Model for Freeway Traffic. Journal de Physique I, **2**, pp 2221-2229, 1992.

[5] SCHULZE, T. and FLIESS, T., 1997. Urban traffic simulation with psycho-physical vehicle following models, WSC '97: Proceedings of the 29th conference on Winter simulation, ACM Press pp1222-1229, 1997.

[6] EHLERT, P. and ROTHKRANTZ, L., 2001. A Reactive Driving Agent for Microscopic Traffic Simulation, ESM '01: Proceedings of the 15th European Simulation Multiconference, SCS Publishing house pp943-949, 2001.

[7] PARUCHURI, P. et al., 2002. Multi agent simulation of unorganized traffic, AAMAS '02: Proceedings of the first international joint conference on Autonomous agents and multiagent systems, ACM Press pp176-183, 2002.

[8] LEMESSI, M., An SLX-based microsimulation model for a two-lane road section, WSC '01: Proceedings of the 33rd conference on Winter simulation, IEEE Computer Society pp1064-1071, 2001.

[9] CHOWDHURY D, SANTEN L, SCHADSCHNEIDER A. Statistical physics of vehicular traffic and some related systems. Phys Rep, 329: 199–329, 2000.

[10] DAGANZO C F. In traffic flow, cellular automata = kinematic waves. Transport Res B-Meth, 40: 396 –403, 2006

[11] JIANG R, WU Q S. Phase transition at an on-ramp in the Nagel-Schreckenberg traffic flow model. Phys A, 366: 523–529, 2006.

[12] SUN T, WANG J F. A traffic cellular automata model based on road network grids and its spatial and temporal resolution's influences on simulation. Simul Model Pract Th, 15: 864–878, 2007.

[13] CICORTAS, A. AND SOMSI, N. Multi-agent system model for urban traffic simulation, 2nd Romanian-Hungarian Joint Symposium on Applied Computational Intelligence Timisoara, Romania, 12-14 May 2005.

[14] WAHLE J, BAZZAN A L C, KLUGL F, The impact of real-time information in a two-route scenario using agent-based simulation. Transport Res C-Emer, 10: 399–417, 2002

[15] ADLER J L, SATAPATHY G, MANIKONDA V, A multi-agent approach to cooperative traffic management and route guidance. Transport Res B-Meth, 39: 297– 318, 2005.