A review on modelling and simulation of vehicular traffic at signalized intersection

Suni Pegu [#1], Dr. Thuleswar Nath [#2]

[1] *M.E student,* [2] *Associate Professor*

 # Department of Mechanical Engineering, Jorhat Engineering College, Jorhat, Assam, India

Abstract *— The purpose of this paper is to make an attempt to review the literature on possible ways to identify and provide optimum measures on modelling the vehicular traffic at signalized intersections. The review covers various areas of observations: traffic flows at intersections of a road, waiting time of vehicles, peak times, bottlenecks, traffic distribution, traffic signals, and delay time.*

Keywords-*Traffic intersections, Simulation*

I. INTRODUCTION

Modern lifestyle consists of fast and rapid transport mediums which play a vital role in economic development for any nation. All developed nations have a well-developed transportations system with efficient traffic control on road, rail and air. Transportation of goods, industrial products, manpower and machinery are the key factors which influence the industrial development of any country. Hence, traffic congestion leads to long waiting hours along with fuel and money wastage.

Under ordinary conditions when the traffic lane waits for the green light, time setting is same and fixed. With increasing number of vehicles on roads congestion substantially increases. This is observed usually at main junctions in morning, office hours and after office hours. Hence the main effect of this increases the waiting time of people on road. In order to alleviate the problem, a large number of methods and approaches have been suggested in the literature. Simulation of traffic systems by the use of computer software is most common method adopted these days. More recent methods use either discrete event simulation or continuous-time simulation.

Discrete event simulation (DES) is a method of simulating the behaviour and performance of a real-life process, facility or system. DES is being used increasingly in health-care services and the increasing speed and memory of computers has allowed the technique to be applied to problems of increasing size and complexity. Traffic lights with single server queues can be modelled using discrete event simulation, as servers are usually at a single location and so are discrete. Many software packages like Extendsim, Flexsim, Simevents, Promodel, Plant simulation, Arena etc., are available for discrete event simulation.

II. LITERATURE REVIEW

Grether and A. Neumann, K. Nagel (2012) [1] developed a computationally efficient traffic actuated control model which aims at an agent-based simulation of the interplay between two types of agents within a transport system: travellers and traffic signals. A combined model is proposed that captures advantages of existing approaches while deficiencies were avoided. The calibration of the model via the sampling time implied that flow rates are equal for all links. Waiting queues for distinct turning movements, including their spatial extension are modelled explicitly. Thus, in case of spill-back mutual blocking effects between several turning directions were captured. The combined model for signalized intersections at Germany was implemented within the MATSim framework. The simulation was run with the commuter population until the outcome seems stable, in this case for 500 iterations. In each iteration, 10 % of the commuters can choose new routes while another 10 % can vary their departure times. The only available mode was car. The proposed model was tested in a real world scenario using a multi-agent modelling approach. The results showed that the model could be used to test traffic-actuated or adaptive signal control strategies in feasible computation times.

Manraj. et al (2012) [2] developed a model of traffic flow on Mumbai-Pune Expressways in Western India by evaluating Passenger Car Unit (PCU) or Passenger Car Equivalents (PCE) of different vehicle categories at different volume levels in a level terrain using the micro-simulation model, VISSIM. The field data input required for the model were collected at an expressway with the help of a digital video camera for capturing the traffic flow movement for a total duration of one hour. The video was then analyzed at a speed of one-eighth of the actual speed to enable recording and measurement of data. For the study hour, the traffic volume observed was 1087 vehicles per hour. The speeds of the different categories of vehicles were measured by noting the time taken by the vehicles to traverse a trap length of 30 m. The free speeds of the

different categories of vehicles were also measured for the traffic under free-flow conditions. This information was used for building the simulation model in the software VISSIM 5.30. Then the model was calibrated and validated for rendering it suitable for replicating the conditions at site. Using this validated simulation model, roadway capacity estimation and PCU estimation were done. The capacity of the six-lane expressway facility is found to be approximately 7595 PCU/hour/direction as simulated under heterogeneous traffic conditions in VISSIM.

Youngtae Jo, et al (2012) [3] proposed a new Variable Speed Limitation (VSL) algorithm to enhance the effectiveness of VSL for multiple stations in Minneapolis, Minnesota, USA. . It is based on the cooperation of stations and the real-time road information. To simulate the traffic environment on the freeway, Vissim simulator was used supported by PTV Corporation. The proposed algorithm consists of 4 steps namely searching of bottleneck station, secondly calculating a size of congestion, thirdly calculating the number of controlled stations and lastly calculating VSL. It was confirmed in the experiments that the speed variances were decreased and the speed differences between stations were also reduced. Based on these results, the road safety was improved. In addition, the increase of travel time was very trivial. To prove the consistency of the algorithm, five simulations were performed with different random seed values. The experiment results showed reductions of 14.2% in speed variance and 20.1% in average maximum speed difference between stations. A 0.3% increase in travel time was shown in the experiments.

Ansari M., et al (2013) [4] presented a simulation modelling and analysis of an urban traffic signal control in one of the main intersections of Bushehr. A traffic signal system is described as a set of Arena modules. It has been shown that Arena, a simulation software, could be used to model urban traffic if it is carefully utilized. The result of this research is used to improve the traffic flow of the intersection. The results showed that the proposed modelling approach could be used as a basis for the analysis of different control policies such as the timing of green or red periods of traffic lights.

M.Anokye, et al (2013) [5] presented a model of vehicular traffic flow and explore how vehicular traffic could be minimized using queuing theory in order to reduce the delays on roads. Data were recorded within the working periods of morning, afternoon and evening where roads are normally congested at the intersection of Ghana. Computations of parameters to determine the behaviour of traffic were done using the M/M/1 queuing model. It is assumed that time interval between successive arrivals and serving time is independent and identically distributed. In any sufficient interval of time at most, only one arrival can occur. The system is also assumed to reach a steady state, a condition that the rate of arrival and service is constant. Critical analysis of the data collected at intersections revealed a smooth flow of traffic and perfect system, since the server at each channel was able to serve more than the cars in waiting queue when servers resume work. Moreover, there seems to be heavy traffic in the evening than in the morning and afternoon.

Xiaochun Lu (2013) [6] studied the traffic flow at Beijing West railway station North area by survey and programmed traffic simulation to find out the causes of traffic congestion and provide some optimization proposals with VISSIM. It was found that the traffic of the area considered for survey is upto 1800 vehicles/hour. The survey data of traffic flow mainly are cars. They are over 83%. Buses are about 15%~4%. In the area, only taxi and bus can provide public transportation service. It was found that when a taxi drops off passengers and a bus drives away from bus hub will cause traffic jam. In order to build simulation model, random distribution of bus departure time and taxi dwelling time must be given out. The traffic system were evaluated from two aspects: indicators that reflect fluency such as vehicle average queue length, maximum queue length, the total number of vehicles in queue; indicators that reflect efficiency such as average delay time, average stopping time, average travel time, times of stops. By simulation it was found that if the studied area could share some cars parking, and could cut down traffic flow to 1500 vehicles/hour, this area congestion will be improved. Meanwhile, adjusting bus interval departure time, extending to 10 minutes, could improve traffic condition as well.

Kumar S, J. Ranjitha (2013) [7] presented a case study to improve the performance operation of the signalized intersections by investigating the proper alternatives to enhance the traffic capacity. To achieve this objective, Bilekahalli signalized intersection in Bangalore city, along the Bannerghatta road, were selected. The required data for the study purpose like Road Inventories and Traffic Volume Counts were collected. Traffic Volume Counts were collected by the video footages through the cameras installed at the signalized intersections by the Traffic Management Centre, Bangalore City Traffic Police Department. The results of the study revealed that the selected traffic facility currently undergoes serious degradation causing breakdown conditions. Thus, urgent considerations must be given regarding the upgrading in the Level of Service (LOS) by suggesting many alternatives.

Hasugian T., et al (2014) [8] represented a traffic light system model of traffic flow by using both algorithm, Branch & Bound and Ant Colony. A specific constraint, delay time was taken into consideration which affected the effectiveness of

traffic light system. The result obtained indicated that greater the time delay on a traffic light system, greater is the waiting time of each vehicle that affected less number of vehicles to cross from one intersection to another intersection of the road. With constraint delay time to the program, the feasible algorithm can be chosen to reduce the risk of traffic jam. This model then can be implemented in a sensor system of a traffic light & therefore increase in the efficiency of time can be performed.

Wang F., et. al (2014) [9] developed a model of the vehicle queuing system for a five-fork intersection Jiangdong Road and Hunan Road by queuing theory based on Monte Carlo algorithm & carried out simulation and analysis of the vehicle queuing system in the intersection by MATLAB. Based on the principle of random sampling, the traffic flow on each intersection, vehicle arrival interval time, the time taken by vehicles to pass through the intersection, time and duration of each sidewalk traffic light, the changing direction of the traffic lights were observed and measured. Monte Carlo's method was used to generate random numbers, combined with the MATLAB language to simulate the intersection vehicles queuing system. Finally, a verifiable model of the system has been established which can accurately represent the actual system.

Anuradha S G., et al 2014 [10] presented a system that detects the vehicle in real time in highway by using image processing and Mat lab software. This is done by using the camera images captured from the highway and videos taken are converted to the image sequences. Each image is processed separately and the number of cars has been counted. The speed and the arrival rates of the cars are estimated by setting a threshold value. If the number of cars exceeds the specific threshold, warning of heavy traffic will be shown automatically. One of the most important disadvantages of this method is extreme sensitivity to light. Although this problem can be resolved by using specific filters during Image Processing or changes in Mat lab code.

Sayyed S. et. al (2014) [11] designed a dynamic traffic signal controller on a four junction road having specific functions along with hardware interface. The proposed Dynamic Traffic Light Control (DTLC) operations have Infrared sensors mounted on road to detect frequency of the vehicles. The presence or absence of a vehicle is sensed by the sensor assembly mounted on each road, which acts as an input to the DTLC unit. This input signal indicates the density of vehicles on each road. In this system, the basic operations are implemented using Microcontroller89c51AT. For communicating with the external signals, additional ports like computer links and pull up array are used. The DTLC unit generates output signals for Red, Green and Yellow Signal and monitor their timings taking into consideration the length of vehicles on each road. The information as input to microcontroller will be given in form of already prepared database entries for typical model working, which would determine vehicle density on each lane. Therefore, the on and off signal time at the four junctions will be calculated by the microcontroller. This system aims at saving a large amount of waiting hours caused by traffic deadlocks, where control can save time and property.

Ugwu C. and Bale, Dennis (2014) [12] developed an intelligent fuzzy logic model control system for dealing with the road traffic congestion problem at YKC(Young Kennedy Centre) junction, Nigeria. Eight sensors were introduced in the four intersections road to capture the vehicles in queue at any point in time, the fuzzy system takes decision on the necessary action based on the information from the sensors. The first sensor was placed behind each traffic lights and counts the number vehicles coming to the intersection and the second sensor was located behind the first sensor and counts the cars passing the traffic lights. A sensor network normally constitutes a wireless ad-hoc network meaning that each sensor supports a multi-hop routing algorithm. The number of vehicles between the traffic lights is determined by the difference of the reading of the two sensors. The fuzzy traffic controller receives data from the counter queue arrival and traffic lights interface and controls the light cycle. There is one default state which takes place when no incoming traffic is detected. A sensor based fuzzy logic model has the potential of eliminating the road traffic congestion to bearest minimum. This was achieved by its ability to take decisions whether to extend or terminate the current green light time based on a set of fuzzy rules and real-time traffic information. The results from experimentation showed that the system eliminated 80% of the problems observed in the manual and conventional traffic control system as the flow density was varied according to real life traffic situations. It was observed that the fuzzy logic control system provided better performance in terms of total waiting time as well as moving time.

Ngoc-Hien Do. et al (2015) [13] used a specific traffic simulation program. Two types of intersections were studied. The first one, 4-intersection, is a common intersection of any traffic system where the two roads cross. Another one has more than 4 sub roads, and in this case a 6-intersection is considered as a representative, where three roads cross. Actually, when the number of sub roads at intersections increases, conflicting points increase simultaneously. The impacts of three alternatives were respectively considered at two intersections. At the beginning status, input data are set up at a low number of vehicles travelling into the system. It is, then, increased step by step and simulations scenarios are built and run. Outputs are recorded and analysed. With the 4-intersection, there are two stages of the system depending on Density

factor's value. With the 6-intersection, there are three stages of the system that depends on the density factor. The study showed that the coordination alternative should be used to control traffic flows at intersections. Both of the traffic circle and traffic light system should be constructed. Depending on the density of vehicles on the roads of system's busy level, the traffic light system whether operates or not.

Kalla H. et al (2015) [14] designed Real time traffic light control system (RTTLCS) by using microcontroller with smart algorithms aided by IR sensors which not only optimize the traffic flow of vehicles as well as pedestrians but also considered the safety and time management according to traffic flow. The IR sensors were interfaced with Microcontroller AT89c51 and this interface is synchronized with the whole process of the traffic system which was done on simulation tool Proteus Professional. In this method, instead of fixed-time traffic control, followed the variation in the time allocation base on the volume of traffic at each road. This design can be easily implemented in real life situations which gives equal importance to pedestrians when compared to vehicle traffic. It was observed that this system provided better performance in terms of total waiting time as well as total moving time to control the vehicle traffic efficiently.

M.Kabir, et al (2016) [15] formulated an optimization model which was a minimization problem of the difference between the measured number of vehicles and the sum of portions of vehicles from all entrances of First Ring Road, Saudi Arabia, that moved out from each road. A detailed assessment study was presented regarding traffic flow within the central area of Madinah along First Ring Road during Hajj and Umrrah seasons to reflect the maximum vehicle flow in this area. The study entailed a comparison among the roads leading to this area in terms of traffic flow nature, peak times, bottlenecks, and traffic distribution. In addition, a new optimization model for the traffic distribution along the roads intersecting with First Ring Road was formulated in order to determine the traffic characteristics on the road network. Traffic movement data was collected from manual counting and machine measurements. The data were analysed and verified using statistical analysis. A simulation program for the computational model was developed using Mat lab. The simulation results showed good agreements. Thus the model can be used as a prediction model of vehicle movements.

K. Nellore, et al (2016) [16] presented a survey of urban traffic management schemes for priority-based signalling, and reducing congestion and the Average Waiting Time (AWT) of vehicles. The main objective of the survey was to provide a taxonomy of different traffic management schemes used for avoiding congestion. The main challenges associated with congestion control, average waiting time reduction, prioritizing emergency vehicles and the design requirements of intelligent traffic system are discussed to provide an insight into the goals of urban traffic management. A real-time traffic management system cannot be guaranteed. Processing of large amounts of real time traffic data, the run time of the control system and reliability are the problems to be solved to ensure real-time demand of the urban traffic management system. There is a need to design an intelligent traffic cloud by making use of cloud computing to solve the problems related to real-time.

Giriyalkar, A. and Goyal, K. (2015) [17] used VANET (Vehicular Ad-Hoc Network) as a means to describe a wireless communication between vehicles. This new system will provide notification to the vehicle well ahead of an incident happening in the nearby location, so that the vehicle can choose an alternate route based on the provided information. The Android application "Trust Model" was created for evaluating the trust factor which was calculated based on the ratings given by its users. Better the ratings, the more legitimate is the news from the source thus preventing anyone from posting hoax updates. The simulation was done using MATLAB.

Chauhan, P. et al (2013) [18] proposed a new system based upon Intelligent Transportation System (ITS), to efficiently monitor and analyse the traffic scenario in real-time. The Dijkstra's algorithm was used in the experimentations for finding shortest path between any two possible nodes depending on the prevailing traffic conditions. By taking the real time Traffic Density along various road segments, Dijkstra's algorithm is implemented for all-source shortest path and maintained a common database of all the shortest paths between all possible nodes.

Ch.Sravani, et al (2017) [19] proposed a method to pave a way for intelligent transportation systems which is of low cost and gives high accuracy. Receiving the images through video surveillance camera in first phase, Gaussian Mixture Model (GMM), which is a parametric probability density function was used for each frame to achieve a precise background image. This process was repeated as long as an accurate background images could be seized. This phase is called training phase. In the second phase, the received images will be analyzed along with the trained images to extract the vehicles (moving objects) based on this analysis. In third phase, a green block will surround each vehicles to enable the researches count them. Either inaccurate training of the background images or the shadow of moving vehicles might cause problems in detecting vehicles in motion in the second phase. To solve these problems, the blocks are merged which overlap the other blocks to compute the volume and density of traffic accuracy. Finally, the report of traffic can be presented by post processing.

Panchal, S.G. and Apare, R.S., (2017) [20] implemented a real time traffic detection using twitter tweets analysis and maintained lists like, accident, traffic jams, vehicle breakdown etc. The proposed system was divided in two modules, first module was web service and second module was android mobile application. Web service took twitter tweets as input and classified the traffic related tweets from the twitter using NLP algorithm. In web service, they have HDFS (Hadoop dynamic file subsystem) database. Hadoop is used for fast processing and storing high amount of data in to HDFS. Module 2 was an android application where the user has to search location and get route. That route is send to the web service and traffic in that route is checked & if yes, notification is given and also alternate route.

III. CONCLUSIONS

From the above literature review, it can be concluded that various methods are involved and has been able to reduce congestion of the vehicular traffic in the signalized intersection to some amount. Mat Lab is most popularly used in the process. Although various algorithms and simulation techniques are practiced to deal congestion problem from time to time. To eliminate traffic congestion is not possible in urban roads but it can be controlled with proper measures taken, both by the travelers and by changing traffic management policies.

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