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MODELS FOR DELAY ANALYSIS AT SIGNALISED INTERSECTION IN HETEROGENOUS TRAFFIC IN INDIA

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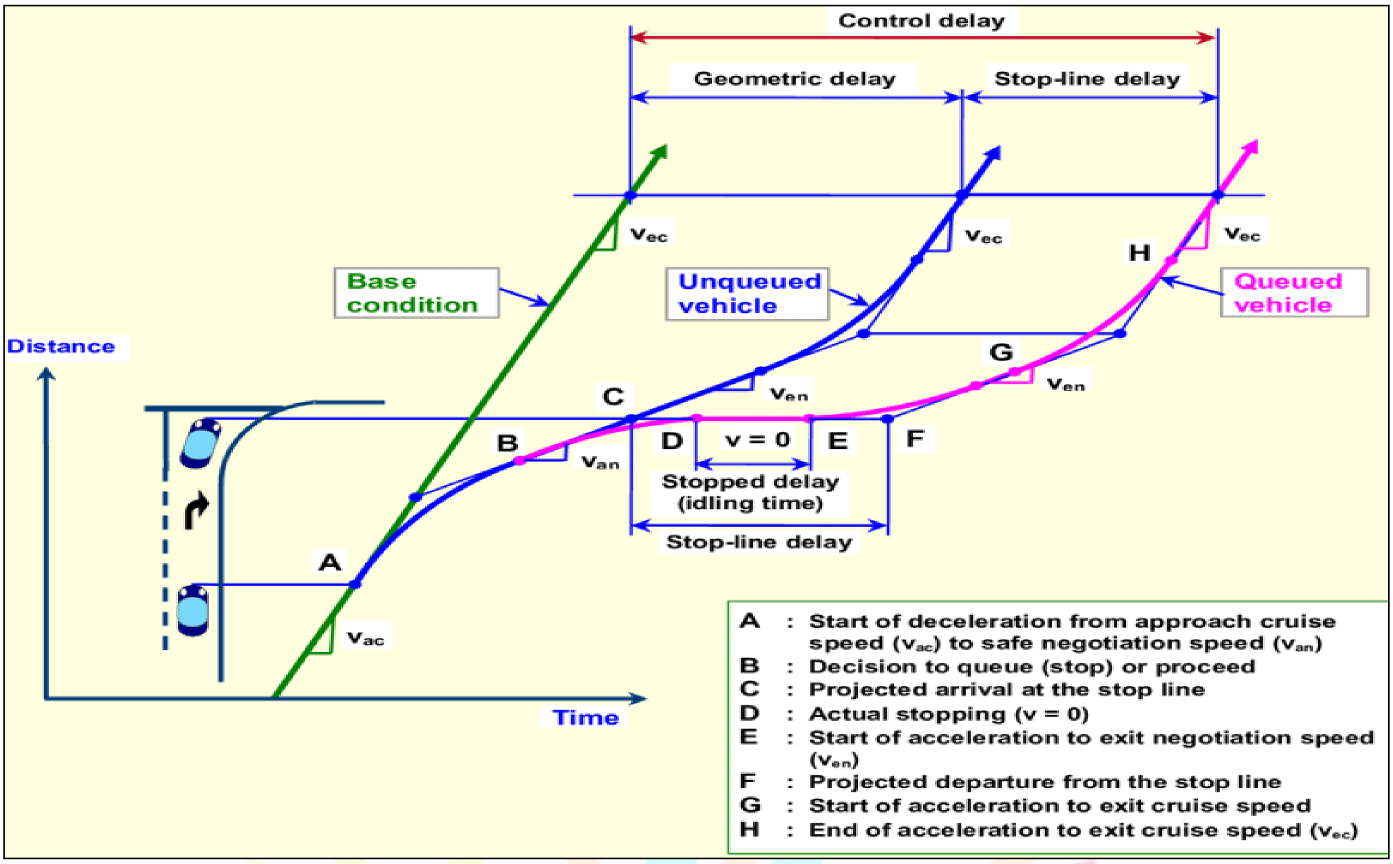
Abstract : Signalized intersection in India is considered as the most time consuming, maximum delay occur at signalized intersection due to heavy and heterogeneous traffic condition. For analysis of delay in heterogeneous traffic conditions can be done by various models and methods. This paper presents a comprehensive review of delay at signalized intersections in heterogeneous traffic conditions. Signalized intersections are critical components of urban transportation networks, and understanding delay factors in mixed traffic scenarios is essential for optimizing traffic flow, reducing congestion, and enhancing overall transportation efficiency. Overview of developed models are elaborated in this paper.

Keywords-Delay, Signalised, intersection, heterogenous, simulation, HCM, webster**,** model.

1.INTRODUCTION:

In developing countries, the traffic scenario is significantly different from the developed countries. Predominantly the traffic is composed of passenger cars in developed countries and can be termed as “homogeneous” traffic, whereas in developing countries the traffic is composed of various vehicle types with a wide variety of static and dynamic characteristics, which occupy the same right of way, resulting the vehicle movement in an unsynchronized way. Apparently, other characteristics of this traffic are the absence of lane-discipline, resulting from the wide variation and maneuvering abilities of the vehicles. These also result in phenomena called vehicle creeping which allows the engine of the vehicle to rest at idle. They are absent in the homogeneous traffic. Therefore, this kind of traffic characteristics can be termed as “heterogeneous” traffic or “mixed” traffic. Most of developing countries, the traffic have a fair share of two and three-wheeler motor-vehicles and non-motor vehicles with different characteristics such as static and dynamic, which results in a different flow characteristic or traffic stream. It is mostly because of the differences in sizes and maneuverability of the vehicles. In normal traffic stream scenario, the vehicles in the developing countries do not follow the lane-discipline, whereas, in developed countries, the lane-discipline rules are very strict.
Vehicle delay is the most important parameter used by transportation professionals in evaluating the performance of a signalized intersection. Delay is a parameter that is not easily determined due to the non-deterministic nature of the arrival and departure processes at the intersection. But lot of research has been done in this field to define delay by a number of analytical delay models, including deterministic queuing, steady state stochastic and time dependent stochastic models. There are assumptions in these models that help in simplifying the complex conditions to a quantifiable model which gives an approximate measure of average delay faced by a vehicle crossing an intersection. Some research has been done that tries to predict the variance of overall delay that individual vehicles may experience at signalized intersection due to large variation and randomness of traffic arrivals and interruption caused by traffic signal controls.



(Source: website.)

2.DELAY ANALYSIS METHODS:

HCM Models:

The Highway Capacity Manual (HCM) from 1958 introduced one of the earliest and most fundamental delay models used in traffic engineering. This model, known as the "HCM 1958 Delay Model," was developed to estimate the delay experienced by vehicles at signalized intersections. While it is an older model and has been replaced by more sophisticated methods in later editions of the HCM, it laid the foundation for delay analysis at signalized intersections. The formula for estimating average delay per vehicle using the HCM 1958 Delay Model is as follows:

D=C/2*(1−C/G)*(S/V)^2

Where:

- D is the average delay per vehicle (in seconds).
- C is the cycle length (in seconds).
- G is the effective green time (in seconds) for the movement being considered.
- V is the flow or volume of the traffic stream (vehicles per hour) for the movement being considered.
- S is the saturation flow rate (vehicles per hour) for the movement being considered.

The HCM 1958 Delay Model, while relatively simple compared to modern delay models, was groundbreaking at the time and provided valuable insights into delay estimation at signalized intersections. It served as a foundational concept for subsequent editions of the HCM, which introduced more refined and accurate methods for delay analysis.

Since the 1958 edition, the HCM has gone through several updates and revisions, with the latest edition being the HCM 6th Edition, published in 2016. Each new edition has incorporated advances in traffic engineering research and technology to provide more accurate and comprehensive methods for analyzing delay and capacity at intersections.

Webster Models:

Webster's delay formula, named after F.V. Webster, is one of the classic methods used to estimate delays at signalized intersections. The formula was developed in the mid-20th century and is considered a fundamental component in the field of traffic engineering for evaluating the performance of signalized intersections.Webster's delay formula calculates the average delay per vehicle at an isolated signalized intersection during a single cycle, considering uniform arrivals.

The formula is:

D=C/2*(1−C/G)*S/V*(S/V−C/G)

Where:

- D is the average delay per vehicle (in seconds),
- C is the cycle length (in seconds),
- G is the effective green time (in seconds) for the movement being considered,
- V is the flow or volume of the traffic stream (vehicles per hour) for the movement being considered,
- S is the saturation flow (vehicles per hour) for the movement being considered.

Assumptions of the formula:

1. Arrivals are uniformly distributed across the cycle.
2. The initial queue at the start of the green phase is serviced before the vehicles that arrive during the green phase.
3. The traffic signal operates in a fixed-time mode, meaning green times and cycle lengths do not change.
4. No other intersections influence the operation of the intersection being studied.

While Webster's delay formula provides a simple and straightforward method to estimate delay, real-world scenarios might require more complex models or simulation techniques. This is particularly true in networks where intersections are closely spaced and where traffic arrival patterns are non-uniform. Nonetheless, Webster's formula remains a foundational tool in traffic engineering coursework and is often used as a starting point or reference in signal timing and intersection analyses.

Queuing model:

Queuing models are widely used in traffic engineering and transportation planning to analyze delays at signalized intersections. These models help estimate queue lengths and delay times for vehicles waiting at signalized intersections, taking into account factors such as signal timing, traffic volumes, and vehicle arrival patterns. One commonly used queuing model for delay analysis at signalized intersections is the "M/M/1 Queue Model.

M/M/1 Queue Model:

The M/M/1 queue model is a mathematical model used to analyze the behavior of a single-server queue, where "M" stands for "Markovian" (indicating memoryless arrivals and service times), and "1" signifies a single server (intersection with one lane or one approach). This model is often used to estimate the average queue length (number of vehicles waiting) and the average delay (time spent waiting) at a signalized intersection.Here's the formula for calculating the average delay (Wq) at a signalized intersection using the M/M/1 Queue Model:

$$Wq = \lambda^2/[2*\mu*(\mu-\lambda)]$$

Where:

- Wq is the average delay per vehicle (in hours or time units).
- λ is the arrival rate of vehicles at the intersection (in vehicles per hour).
- μ is the service rate or capacity of the intersection (in vehicles per hour).

Please note that in practice, traffic engineers often work with units of seconds or minutes rather than hours for delay analysis, so you may need to convert the units accordingly. To convert the delay from hours to seconds, multiply the result by 3600 (since there are 3600 seconds in an hour).In this formula, the arrival rate (λ) represents the rate at which vehicles arrive at the intersection, while the service rate (μ) represents the rate at which vehicles can pass through the intersection during the green phase. When λ exceeds μ, indicating that vehicles arrive faster than they can clear the intersection, delays start to accumulate.

Vissim simulation model:

VISSIM is one of the most widely used microscopic traffic simulation software packages developed by PTV Group. As a microscopic simulation tool, VISSIM models individual vehicles and their interactions, making it particularly suitable for detailed delay analysis among other performance measures. Here's how VISSIM is typically used for delay analysis at signalized intersections:

1. **Model Creation:** Engineers use VISSIM to create a detailed model of the road network, including the geometry of the intersection, traffic lanes, and signal timings.
2. **Traffic Inputs:** VISSIM allows users to input various traffic parameters, including traffic volumes, vehicle types, driver behavior characteristics, and turning movements at the intersection.
3. **Signal Control:** Users can program the signal timings and control logic for the intersection. VISSIM supports various signal control strategies, such as fixed-time signals, actuated signals, and adaptive signal control.
4. **Simulation:** VISSIM simulates the movement of individual vehicles through the intersection, considering factors like vehicle acceleration, deceleration, lane changes, and interactions with other vehicles.
5. **Data Collection:** The software collects a wealth of data during the simulation, including delay times, queue lengths, travel times, and other performance metrics.
6. **Analysis:** Engineers can analyze the simulation results to evaluate delay, queue length, and overall intersection performance. VISSIM provides detailed information on the behavior of each vehicle during the simulation.
7. **Scenario Testing:** Users can test different scenarios, signal timings, and traffic management strategies to assess the impact on delay and intersection efficiency.

Data-Driven Methods:

1. **Connected Vehicle Data**: Analyzing real-time data from connected vehicles to assess traffic conditions, identify delays, and predict congestion.
2. **GPS and Mobile App Data**: Leveraging GPS data from vehicles and mobile apps to track travel times, delays, and congestion patterns.
3. **Big Data Analytics**: Utilizing big data analytics techniques to process and analyze large volumes of traffic data from various sources, identifying delay patterns and trends.

Machine Learning and AI Methods:

1. **Machine Learning Algorithms**: Employing machine learning models to predict delays based on historical traffic data and real-time inputs.
2. **Deep Learning**: Using deep neural networks to analyze video footage and images from traffic cameras to estimate delay and congestion levels
3.

3.LITERATURE REVIEW

Borigarla Barhmaiah1et al. (2022) under paper title "Delay models for Signalised Intersections with Vehicle Actuated Controlled system in Heterogeneous Traffic Conditions". In this study developed mathematical models to estimate the average delay at signalised intersections with the VAC (vehicle activated control) system. The overall delay of vehicles in each cycle was estimated by using Simpson's one-third rule. Furthermore, the variables that influence the delay were identified and a regression-based delay model was developed and modified the Indo-HCM model by changing the incremental delay term in the model.

Prof. Emy Paulose1 et al. (2022) under the paper title "Delay Analysis Of Signalized Intersection Under Heterogeneous Traffic Condition" this study was to analyze delay at four-legged signalized intersections using the HCM delay model equation and validated it using the VISSIM software. The delay was calculated using HCM model equation. The four intersections were created in VISSIM software and the delay obtained from the software was compared with that of HCM model. Validation obtained was matching up to a great extent.

Pranit U. Nage1 et al.(2018) under paper title "Delay Analysis of Vehicles at Signalized Intersection for Assessing the Need and Utility of Signal Redesigning" in this study corridor was selected in nagpur and Data collected were analysed by suitable delay models which suits heterogeneous traffic conditions in spite of choosing traditional models for Delay analysis. The study was use VISSIM simulation software model to compare delays in forms personal delays, overall delays at each individual intersection in the corridor. Along with delays, queue lengths forming were also be studied under study.

Arpita Saha1 et al.(2017) under the paper title **"**study of delay at signalized intersections under mixed Traffic conditions" in this study, Proposed an improved delay model for signalized intersections for heterogeneous traffic conditions. They used Simpson's one third rule in spite of opting traditional delay analysis by Highway Capacity Manual. In their study, they measured the queue lengths directly from the field. In their study, they found that their proposed Model yielded best results and is more useful for Indian heterogeneous traffic conditions.

Preethi P1* et al. (2014) under paper title "Modelling Delay at Signalized Intersections under Heterogeneous Traffic Conditions". In this study Webster's delay model is modified to suit the road traffic condition existing in India. Semi-empirical adjustment term in the Webster's model has been modified and calibrated based on field observation of delay for different control conditions at signalised intersections. Data regarding traffic stream parameters, signal timing details and delay to vehicles are collected from different signalised intersections having varying control conditions using videographic survey and Global Positioning System (GPS). Based on field observed delay, adjustment term is estimated and modelled using Artificial Neural Network (ANN) approach. The input variables selected for modelling are approach width, effective green time, degree of saturation, vehicle arrival rate, proportion of heavy vehicles and proportion of right turning vehicles. The ultimate network architecture is determined based on Root mean Squared Error (RMSE) values and coefficient of determination (R2) values. Comparison of the results obtained using the developed model with conventional methods and field observations shows that the delay estimated by the developed model is in good agreement with observed delay.

Ch.Ravi Sekhara* et al.(2013) under paper title " Estimation of Delay and Fuel Loss during Idling of Vehicles at Signalised Intersection in Ahmedabad" In this selected study area in Ahmadabad city. Further they collected Traffic data which includes vehicle volume counts, speed and delay data, queue length measurements. They considered idling delay also in their study. further they estimated idling delays and consumption at signalized intersections and modelled the data and simulated it into VISSIM simulation. They choose Comparative evaluation between base case and proposed scenario. in which mitigation measures were implemented in VISSIM model. They suggested minor geometric.

4.CONCLUSION:

Depending upon the data collection, site condition and analysis parameters, we can use different methods for analysis of delay at signalised intersection and validation is with software measured.

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