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A Study on Saturated Traffic Flow at Signalized Intersections Under Mixed Traffic Conditions

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ABSTRACT

Most emerging nations' motor traffic exhibits heterogeneous traffic flow patterns and non-lane-based behavior on urban highways. Vehicles exhibiting a range of static and dynamic characteristics share a single lane. At signalized intersections, the movement of vehicle traffic from one leg to the next occurs sequentially. Saturated traffic flow is a key factor in signalized junctions for deciding the level of service and traffic signal duration. The method outlined in the Highway Capacity Manual is typically used to calculate saturated traffic flow (HCM). Yet past research has shown that a number of variables, including approach width, turning movements, cycle time, heavy trucks, and others, have an impact on saturated traffic flow. It is discovered that the presence of two-wheelers significantly affects saturated traffic flow in mixed traffic. Thus, the present study made attempt to summarize the literature on saturated traffic flow rate, with emphasis on mixed traffic conditions.

Keywords: Traffic capacity; Traffic signals; Intersections; Saturated traffic flow

1. INTRODUCTION

1.1 General

The number of cars that can travel through a particular location on a road or traffic lane in a specific amount of time, such as vehicles per hour (vph) or vehicles per minute (vpm), is known as the saturated traffic flow when traffic is at or near capacity. This approach is effective because it is based on the concept of saturation headway, which is the minimum headway (time gap) that can be attained while traffic flow is at or near capacity. In traffic engineering and transportation planning, saturated traffic flow is widely used to determine a road's or lane's capacity and identify possible congestion hotspots. The saturated traffic flow can be calculated using the following formula:

Saturated traffic flow (vph) = 3600 / Saturation Headway (seconds/vehicle)

Where the saturation headway is the minimum time gap between vehicles that can be achieved when traffic flow is at or near capacity.

1.2 Saturation flow Rate

Saturated traffic flow rate is a critical parameter used to assess the performance of signalized intersections. It represents the maximum number of vehicles that can pass through an intersection per unit of time under ideal conditions. The saturated traffic flow rate is essential for intersection design and operation as it determines the intersection capacity and identifies potential bottlenecks that may cause delays and congestion. The intersection capacity is a product of the saturated traffic flow rate and the duration of green time allocated to each approach. Efficient and safe signalized intersections can be designed and operated by optimizing the saturated traffic flow rate. The optimization of saturated traffic flow rate can improve intersection efficiency, reduce travel time delays, and enhance traffic safety.

The saturated traffic flow rate has several practical applications in traffic engineering. For example, it is used in designing and optimizing signal timings at intersections. Signal timings are set according to the saturated traffic flow rate of each movement so that the intersection operates at its maximum capacity. Additionally, saturated traffic flow rate is used to evaluate the performance of intersections, identify areas that need improvement, and assess the capacity of roadways.

In today's world, traffic has become a major issue in large metropolitan cities, causing significant barriers to smooth traffic flow even in well-planned communities. Insufficient transit infrastructure is one of the key reasons behind the ever-growing problem of traffic congestion. Due to the abundance of cars on the roads, traffic jams have become a daily routine, leading to an imbalance between supply and demand in the traffic system. Transportation departments and policymakers have tried to address this issue by coming up with typical solutions, such as building new infrastructures and expanding the already existing ones. However, with space becoming scarce in large cities, these solutions are becoming less desirable and economically unviable.

To tackle this challenge, researchers and engineers have been exploring innovative Transportation Management Systems to increase capacity. As a result, several unconventional intersection designs have emerged, including pre-signals, median U-turns, misplaced left turns, tandem intersections, exit lanes for left turns, and Jug Handles. These designs aim to improve the flow of mixed traffic conditions and maximize intersection capacity. Despite the growing number of studies in this area, the issue of traffic congestion at signalized intersections remains unresolved. Therefore, it is important to conduct further research to identify factors that affect intersection capacities, such as traffic composition, signal timings, and intersection geometry. By understanding these factors, policymakers and transportation departments can develop effective solutions to reduce congestion and ensure smooth traffic flow in urban areas.

1.3 Signalized Intersection

Signalized intersections are a vital component of urban transportation systems, providing a critical means for vehicles and pedestrians to safely and efficiently navigate complex intersections. By regulating traffic flow, reducing congestion, and ensuring efficient movement through a network of interconnected roads, signalized intersections facilitate the movement of people and goods within urban areas. They are particularly important in areas with high traffic volumes, complex traffic patterns, and heavy pedestrian activity. However, managing mixed traffic conditions at signalized intersections can pose a challenge. The presence of different types of vehicles, such as cars, buses, trucks, motorcycles, and bicycles, sharing the same space can create issues around intersection capacity and efficiency. Each type of vehicle has its own characteristics, such as size, speed, and maneuverability, that can impact how quickly and safely they can cross the intersection.

Saturated traffic flow rate is an important metric that traffic engineers and policymakers use to evaluate the performance of signalized intersections. It represents the maximum number of vehicles that can pass through an intersection in ideal conditions over a given unit of time. To optimize intersection design and operation, it's essential to consider factors such as traffic composition, signal timings, intersection geometry, and pedestrian crossing times. Understanding these factors is crucial for improving saturated traffic flow rate, which can reduce congestion, minimize travel time delays, and promote sustainable mobility. Therefore, it's crucial to continue conducting research and developing innovative solutions to improve saturated traffic flow rate and make our transportation systems more efficient and effective.

In addition to improving traffic flow and reducing congestion, optimizing saturated traffic flow rate at signalized intersections also helps to improve traffic safety. By ensuring that vehicles can move through intersections quickly and efficiently, we can reduce the risk of accidents and collisions that can occur when vehicles are forced to wait in long queues. Mixed traffic conditions can pose additional safety risks at signalized intersections, particularly for pedestrians and cyclists who are vulnerable road users. Careful consideration of the factors that influence saturated traffic flow rate under mixed traffic conditions can help to improve safety for all road users and reduce the number of accidents that occur at signalized intersections.

Managing mixed traffic conditions at signalized intersections can pose significant challenges for traffic engineers and policymakers. Mixed traffic conditions refer to situations where different types of vehicles, such as cars, buses, trucks, motorcycles, and bicycles, share the same space, which can lead to issues around intersection capacity and efficiency. One of the primary challenges of managing mixed traffic conditions is that each vehicle type has unique characteristics that can impact how quickly and safely they can cross the intersection. For example, buses and trucks require more space to make turns than smaller vehicles, while bicycles and pedestrians may have slower speeds and need more time to cross the intersection. These differences can cause conflicts, delays, and safety issues, particularly during peak traffic hours.

Another challenge is the complexity of traffic patterns at signalized intersections, which can vary significantly depending on the time of day and the day of the week. During peak traffic hours, traffic volumes may exceed the intersection capacity, leading to congestion and delays. In contrast, during off-peak hours, intersection capacity may be underutilized, leading to inefficient use of road space.

Moreover, signal timings and intersection geometry must consider the diverse needs of all users, including pedestrians, cyclists, and public transport users, in addition to motor vehicles. For instance, allocating more green time for pedestrians and cyclists may reduce the saturated traffic flow rate for motor vehicles, leading to congestion and delays. Finding the right balance between the needs of different road users is critical for designing and operating safe and efficient signalized intersections.

1.4 Saturated traffic flow Rate Determining Factors

Several factors affect the saturated traffic flow rate, such as traffic composition, intersection geometry, signal timings, and pedestrian crossing times. Traffic composition refers to the type of vehicles using the intersection, such as cars, buses, trucks, motorcycles, and bicycles, each having distinct characteristics that impact the saturated traffic flow rate. Signal timings and intersection geometry also affect the intersection capacity by allocating the amount of green time to each approach. Traffic engineers and policymakers must analyze these factors to identify the optimal saturated traffic flow rate for a particular intersection.

1.4.1 Percentage of Two Wheelers

Two-wheelers like motorcycles and bicycles are a common sight on the roads of many countries around the world. The number of two-wheelers in traffic can vary from place to place, depending on various factors like culture, population density, and so on.

The number of two-wheelers on the roads can affect the saturated traffic flow rate of an intersection. Two-wheelers have several advantages that can help increase the capacity of an intersection. They are typically smaller and more maneuverable than cars, which means they can move through traffic more quickly, allowing more vehicles to pass through the intersection in a shorter amount of time. Two-wheelers also take up less space on the road than cars, which can reduce congestion and improve traffic flow.

However, the presence of two-wheelers on the roads can also have some drawbacks. For instance, if there are too many two-wheelers on the road, it can create safety concerns or conflict with pedestrians, which can reduce the overall capacity of the intersection. Additionally, the presence of bicycles or motorcycles on the road may require additional infrastructure, like dedicated lanes or parking facilities, which can impact the overall design and operation of the intersection.

Another factor to consider is how two-wheelers can affect the behavior of other drivers on the road. The presence of two-wheelers can affect the speed and flow of traffic, as drivers may need to slow down or change lanes to accommodate them. This can impact the saturated traffic flow rate by reducing the number of vehicles that can pass through the intersection in a given amount of time.

In conclusion, the number of two-wheelers on the road can have a significant impact on the saturated traffic flow rate of an intersection, but the overall impact depends on various factors. It's important to consider these factors when designing and operating intersections to accommodate different types of traffic safely and efficiently.

1.4.2 Percentage of Heavy Vehicles

The presence of heavy vehicles in traffic can significantly affect the saturated traffic flow rate at an intersection. Heavy vehicles, such as trucks and buses, are larger and require more space on the road, which can affect the capacity of the intersection. Intersections with a higher percentage of heavy vehicles may experience a lower saturated traffic flow rate compared to those with a lower percentage, as heavy vehicles generally have slower acceleration rates and require more time to cross the intersection. This can cause a backlog of vehicles and lead to traffic congestion, reducing the overall capacity of the intersection. In addition, heavy vehicles may require more space to turn or manoeuvre, which can further slowdown traffic and reduce the saturated traffic flow rate.

However, the impact of heavy vehicles on saturated traffic flow rate also depends on other factors such as intersection design, traffic volumes, and pedestrian activity. Intersections with dedicated turning lanes or larger curb radii may be better equipped to accommodate heavy vehicles, which can improve the saturated traffic flow rate. It's essential to consider the specific context and factors to determine the optimal intersection design and operation. Specialized infrastructure or other measures may be necessary to accommodate heavy vehicles safely and efficiently. In conclusion, while the presence of heavy vehicles can reduce the saturated traffic flow rate at an intersection, it's crucial to consider the specific context and employ innovative solutions to optimize intersection design and operation.

1.4.3 Signal Timing

One of the most crucial factors to take into account when controlling traffic at an intersection is signal timing. This describes the duration of the green, yellow, and red signal phases, respectively. The "saturated traffic flow rate," which is the greatest number of cars that can pass through an intersection in a given amount of time under ideal circumstances, can also be significantly impacted by it.

The length of the green phase is perhaps the most critical factor. If it's too short, not enough vehicles will be able to make it through the intersection, leading to long lines of cars and increased delays. If it's too long, though, drivers may get stuck in the intersection during the next phase of the cycle, causing similar issues.

The yellow phase also plays a role in the saturated traffic flow rate. It's meant to provide a warning to drivers that the signal is about to turn red and give them enough time to safely clear the intersection. If the yellow phase is too short, though, this can lead to more accidents and slower traffic flow.

Finally, the red phase can indirectly impact the saturated traffic flow rate. Longer red phases give pedestrians more time to cross the intersection safely but also mean less time for cars to pass through. On the other hand, shorter red phases can improve vehicle flow but may put pedestrians at risk.

There are many other factors to consider when optimizing signal timing, including the number of lanes, the presence of turning lanes, the types of vehicles using the intersection, and the presence of pedestrians or bicycles. But by tweaking the timing of each signal phase, traffic engineers can work to find the best balance between safety and efficiency, and ensure that traffic flows smoothly through the intersection.

1.4.4 Percentage of Turning Movements

The impact of turning movements on intersection performance is a critical factor that transportation planners and engineers must consider when designing and operating signalized intersections. Higher percentages of turning movements, whether left or right, can significantly reduce the saturated traffic flow rate of an intersection. Turning vehicles require more space and time to maneuver, which can lead to delays, queueing, and safety concerns for other road users. However, the effect of turning movements on saturated traffic flow rate depends on the specific intersection layout and traffic patterns. For example, dedicated turning lanes or longer green signals can help accommodate high volumes of turning traffic. On the other hand, turning movements can also improve traffic flow by distributing traffic and reducing congestion. Thus, a holistic approach is required to optimize intersection performance while balancing the needs of all road users.

1.4.5 Geometry of the Intersection

The design of an intersection plays a big role in how well traffic flows through it. The geometry of an intersection, or its physical layout, can affect the saturated traffic flow rate, which is the maximum number of vehicles that can pass through an intersection in a given time period under ideal conditions.

One of the main things that affect saturated traffic flow rate is the number and width of lanes. If lanes are wider, cars can go faster, but there may be less space for more lanes. If lanes are narrower, cars may drive more slowly, but there could be more lanes, which would increase the saturated traffic flow rate.

Another factor that impacts saturated traffic flow rate is turning lanes. Having separate lanes for turning can make the intersection safer and reduce delays for turning vehicles. However, it could also limit the number of lanes for through traffic and therefore lower the saturated traffic flow rate. Additionally, the presence of median strips or other barriers can limit the width of the intersection and reduce the number of lanes.

The angle and curvature of an intersection can also affect saturated traffic flow rate. Sharp angles or "doglegs" can make it hard for drivers to see and reduce speeds, resulting in lower saturated traffic flow rates. On the other hand, roundabouts can reduce speeds, but often lead to smoother and safer traffic flow.

Finally, pedestrian and bicycle facilities can also impact saturated traffic flow rate. These features can improve safety and reduce conflicts between different modes of transportation, but may reduce the number of lanes available for vehicular traffic, thereby lowering the saturated traffic flow rate.

The Indo HCM is a valuable resource for traffic engineers looking to optimize intersections for safe and efficient traffic flow. Estimating saturated traffic flow rate is crucial for achieving this goal, and the manual provides detailed guidance on how to accurately estimate it based on a variety of factors. One key consideration is the geometric design of the intersection, including the number of lanes, turning radius, and lane width. Careful attention to these elements is necessary to ensure an accurate estimation of saturated traffic flow rate. Traffic control devices also have a significant impact on saturated traffic flow rate, with signalized intersections generally providing higher rates due to more efficient traffic control. Timing and placement of signals are also essential considerations. Engineers must use appropriate models to ensure a precise estimation of saturated traffic flow rate based on the specific traffic control devices used at the intersection. The Indo HCM provides a comprehensive framework for considering these and other factors, ultimately enabling engineers to optimize intersections for safe and efficient traffic flow.

As traffic congestion continues to be a growing concern, the importance of designing efficient and safe intersections cannot be overstated. The Indo HCM provides valuable guidance for traffic engineers looking to estimate the saturated traffic flow rate accurately, which is crucial for optimizing intersection design and improving traffic flow. Considering the various factors that affect saturated traffic flow rate, such as geometric design, traffic control devices, and traffic composition, engineers can make informed decisions to maximize intersection capacity and minimize delays. By using appropriate methods to estimate saturated traffic flow rate for different types of vehicles and road users, engineers can ensure that intersections are safe and efficient for all. Overall, the Indo HCM serves as a critical tool for improving transportation infrastructure and enhancing the quality of life for commuters and communities.

2. LITERATURE REVIEW

2.1 General

The introduction discusses the saturated traffic flow rate and the determinants that affect it. Several research studies have been conducted on the factors that influence saturated traffic flow rate and different methods to calculate it have been developed.

Chand et al. (2016) there was a study conducted in India to analyse the traffic conditions at signalized intersections, which cater to a mix of different vehicles on the roads. The aim was to develop a methodology for calculating the PCU and saturated traffic flow, which are important factors in determining the capacity of the intersection and timing the traffic signals. Now, as you might know, traffic conditions in India are quite unique, with a lot of heterogeneous mix of vehicles and drivers who often do not follow any lane discipline. Furthermore, urban intersections in India are also known for accommodating slow-moving traffic, including pedestrians. So, to accurately calculate the capacity, it is essential to have a clear understanding of the saturated traffic flow, which helps in determining the optimal timing of the traffic signals. However, the study revealed that traditional methods that rely on average queue discharge headways to estimate the saturation headway might lead to an underestimation of the saturated traffic flow rate.

Anusha et al. (2013) study has found that the empirical formula 525w, which was suggested for Indian traffic conditions in the Special Publication (SP)-41 of the Indian Roads Congress in 1994, is not appropriate for determining the saturated traffic flow. The study analysed various approaches and found that the saturated traffic flow does not solely depend on the approach width (w). Interestingly, the study also calculated the correlation coefficient between vehicle type and saturated traffic flow, and found that two-wheelers have a significant association with saturated traffic flow on most approaches, with the coefficient ranging from 0.42 to 0.94. In contrast, while the volume of two-wheelers increased directly with the intersection's capacity, the volume of all other vehicle types increased inversely. To obtain more accurate results, the study recommends considering the effects of two-wheelers and approach volume while modelling saturated traffic flow in Indian traffic conditions. The study also found that the calibrated US-HCM 2000 model's estimated saturated traffic flow is closer to the actual field measurements, further emphasizing the need for a more nuanced approach to modelling saturated traffic flow in Indian traffic conditions.

Suweda et al. (2021), the authors conducted a case study in Bali to create discharge headway models to investigate how motorbikes impact saturated traffic flows at three signalised junctions with mixed traffic. They found that discharge headways are influenced by factors such as approach lane width, intersection design, traffic composition, and traffic characteristics. The study suggests that further research is needed to determine the relationship between heavy vehicle acceleration and speed characteristics and saturated traffic flows at signalised junctions. The authors also observed that larger approach widths lead to higher saturated traffic flows due to increased traffic volume. The differences in passenger car equivalents (PCE) values and saturated traffic flow at each intersection indicate that these signalised intersections experience mixed traffic circumstances.

Paulose et al. (2018) conducted a field study to analyze saturated traffic flow at an intersection and found that the obtained saturated traffic flow was higher than the saturated traffic flow predicted by the generalized formula of IRC SP-41. The study revealed that saturated traffic flow at an intersection is not solely dependent on the width of approach. Additionally, the empirical formula provided in IRC SP41-1994 by the Indian Road Congress was found to be inappropriate for determining saturated traffic flow. The study also highlighted that the proportion of two- and four-wheelers in traffic has a significant impact on saturated traffic flow. The proportion of two-wheelers has a positive impact on saturated traffic flow per meter width due to heterogeneity and filling goals, while the proportion of four-wheelers has a negative impact due to increased homogeneity.

Biswas et al. (2018) where proposed a novel concept for creating a saturated traffic flow model using Kriging. Now, Kriging is a pretty neat technique that uses both a trend function and a covariance function to generate a global and local approximation respectively, which ends up yielding much better results than traditional regression techniques. One thing I found particularly cool about this model is that it accounts for right-turning vehicles, which really improved its overall performance. Plus, it can also help to reduce the standard deviation of saturated traffic flow, which is pretty neat. Another interesting thing the study found was that in non-lane-disciplined traffic states, wider approach roads tend to increase individual vehicle freedom, which can lead to lane indiscipline. The ratio of 3-wheelers and 2-wheelers also greatly impacted the expected saturated traffic flow for the same approach road conditions. Smaller vehicles tend to take up less space and can maneuver more easily, which can actually lead to reduced saturation traffic at signalized intersections. On the other hand, an increase in the proportion of heavy vehicles tended to increase the saturated traffic flow, but their overall impact was negligible due to their subpar operational features.

Mondal et al. (2019) highlighted the different methodological approaches used to frame saturated traffic flow models for developed and developing nations. Initially, researchers used the Saturation Headway approach due to the lower heterogeneity in the saturated traffic flow model, to study and analyze the stream of traffic. However, over time, the applicability of this method has declined due to the comprehensive nature of traffic and flow characteristics. Therefore, researchers have developed a number of methodological approaches based on the traffic in their area. The Highway Capacity Manual's (HCM) methodology is commonly used to evaluate the saturated traffic flow in both homogeneous and heterogeneous traffic situations. Nevertheless, some adjustments are necessary before the HCM methodology can be applied directly to the mixed traffic stream. This study highlights the need to consider the specific traffic and flow characteristics in a particular region to develop appropriate saturated traffic flow models that can aid in designing and optimizing traffic intersections.

Sushmitha et al. (2020) proposed a workshop to investigate the saturated traffic flow of signalized junctions in three cities in India, namely Calicut, Raipur, and Warangal. The researchers identified various influencing variables for saturated traffic flow, including green time, the percentage of two-wheelers, the percentage of right-turning vehicles, and the percentage of heavy vehicles. Interestingly, the study found that these cities did not fit into the category of metropolitan cities, and therefore, their intersection characteristics differed from those of cities with designated bus bays, right-turn lanes, and parking facilities. To develop intersection improvement methods, the researchers proposed that these cities be further researched to understand their unique characteristics. The study utilized a Linear Regression model to predict saturated traffic flow rates that were similar to identified field saturated traffic flow. The findings of this study can help determine the design principles for signal phasing that can be applied to existing traffic conditions in developing nations like India, where mixed traffic with non-lane behavior is common. Additionally, the study's results can serve as inputs to simulations to examine the effects of various factors and variations. Overall, this research is a valuable contribution to understanding saturated traffic flow and developing effective intersection improvement strategies in urban areas of developing countries.

Susilo et al. (2011) to verify the formula for saturated traffic flow, the researchers observed several signalized intersections in Bandung, Indonesia. During the peak hours of morning, noon, and afternoon, observations were made to obtain the values of observed saturated traffic flows for road approaches with varying widths from 3 to 12 meters. The researchers then compared these values with the results obtained from formula computations. The study found that the observed and predicted values of saturated traffic flows were similar when the rank width of road approaches was small to medium. However, the observed and predicted values significantly diverged when the rank width of road approaches increased. For road approaches with widths of 9, 10, 11, and 12 meters, a closed formula was derived using observed values, which indicated that saturated traffic flow can be estimated using the formula S=500We+400 using a computerized program. These findings highlight the importance of accurately estimating saturated traffic flow, which can help in designing and optimizing signalized intersections for efficient and safe traffic flow.

Hamad et al. (2015) conducted a study that suggests the use of the HCM for saturated traffic flow rate estimation. However, they also recommend that local factors, such as traffic patterns and driver behaviour, should be considered when determining intersection capacity. The accuracy of signal timing design is highly dependent on precise saturated traffic flow rate determination for a specific location. The researchers calculated the base saturated traffic flow rate for Doha, Qatar by collecting data from three different signalized intersections. Based on the data collected from 1,431 through moving vehicles in 86 line-ups, they determined the mean headway to be 1.55, resulting in a basic saturated traffic flow rate of 2,323 pc/h/ln. This value is notably higher than the 1,900 pc/h/ln suggested by the HCM, but comparable to results observed in other countries with similar traffic conditions and driving behaviour.

Arasan et al. (2006) conducted a study to explore the potential of the software program HETEROSIM in predicting saturated traffic flow rates for various highway and traffic conditions prevalent in developing nations like India. The study found that increasing the width of the approach road leads to a significant increase in the saturated traffic flow rate (measured in PCU per meter width) under heterogeneous traffic conditions. However, the study only focused on the calculation of the saturated traffic flow rate for straight-on traffic, and the authors are currently working on extending the simulation technique to estimate the saturated traffic flow rate of turning traffic streams under heterogeneous traffic conditions.

Nguyen et al. (2016) revealed that the turning movements have a significant impact on the saturated traffic flow rate of a traffic stream. While the right-turning motorcyclists did not have any significant impact on the saturated traffic flow, the four-wheel vehicles obstructed the motorcycle flow and decreased the saturated traffic flow rate. Left-turning vehicles also affected the saturated traffic flow rate, but to a lesser extent than right-turning vehicles. The study also considered how opposing left-turning traffic could affect the movements of through traffic. The impact is negligible when the traffic volume and the relative proportion between the two streams are low, but significant when they are high. The study provides valuable insights into the factors that affect the saturated traffic flow rate and can help improve traffic flow in congested areas.

Roshani et al. (2017) study, the researchers found that the linear regression model was the most effective after evaluating multiple regression models to determine the correlation between pedestrian flow and vehicle flow during right-turn movements. The results of the model were consistent with prior research and highlighted the negative impact of pedestrians on the movement of vehicles making right turns. However, the study also revealed that the influence of pedestrians on right-turn movements in Rasht, the study location, was lower compared to other areas around the world. This could be attributed to the fact that pedestrians are not given adequate consideration by city vehicles, which often ignore designated pedestrian crossings and attempt to manoeuvre around them.

Branston et al. (1978) found that the synchronous and asynchronous counting methods yielded consistent parameter estimates, and the values were consistent with those previously published. However, the synchronous method requires bias correction, as discussed in Section 4, which may be a disadvantage. Thus, the asynchronous counting method may be more appealing to engineers who require immediate results without further manipulation. Regardless of the approach used, data collection is straightforward since only counts and timings need to be recorded. The simplicity of data collection is a significant advantage over traditional methods, especially considering the number of factors evaluated using regression techniques.

Saha et al. (2018) aimed to provide a comprehensive analysis of four different saturated traffic flow models suitable for heterogeneous traffic situations. These models include universal Kriging, pseudo-likelihood Kriging, blind Kriging, and co-Kriging-based models. Instead of relying on the passenger car unit, which is often dynamic in nature, the saturated traffic flow is expressed as the number of cars per hour of green/lane. The models take into account all possible factors that can affect saturated traffic flow at a signalized intersection, unlike most existing models. The study provides a valuable contribution to the field of traffic engineering and could potentially be used to improve the accuracy of saturated traffic flow rate estimates at signalized intersections.

Rajgor et al. (2016) developed a reliable model that accurately estimates the saturated traffic flow rate of urban signalized intersections. The model uses data gathered from field observations, where the saturated traffic flow rate is counted after three seconds of the green time. The model was developed using traffic patterns and geometric features of Ahmedabad city, and it has the potential to be applied to other Indian cities with similar weather conditions. It is recommended to gather data from a significant number of intersections to build a comprehensive model for the base saturated traffic flow rate. Compared to previous models, this newly developed model shows better performance in estimating the saturated traffic flow rate.

Chandra et al. (2003) highlight the crucial role of lane width in determining the capacity of two-lane roads, which constitute a significant portion of the world's road networks. The study shows that narrow lanes, which are common in many parts of the world, can have a substantial impact on vehicle speeds and, consequently, traffic flow. When different types of vehicles share the same lane, the effect of lane width on vehicle performance is even more pronounced. The research findings indicate that wider lanes lead to higher PCU for each vehicle type, with the degree of impact varying depending on the type of vehicle. The study also reports that the capacity of a 7.2 m wide road is estimated to be 2818 PCU/h, which is lower than the capacity estimates provided in the Highway Capacity Manual. The researchers attribute this discrepancy to the characteristics of mixed traffic and the legal framework governing traffic on Indian roads. Overall, the study highlights the importance of considering the impact of lane width on traffic flow when designing and managing two-lane roads.

Sun et al. (2013), the saturated traffic flow rate and start-up lost time of dual-left lanes at signalized intersections were analyzed using video data under clear and rainy weather conditions. The ANOVA statistical method of SPSS software was used to compare these parameters under different weather conditions and lane locations. The study found that in rainy weather, both left lanes experienced a decrease in saturated traffic flow rate and start-up lost time by 3-7% and 21-33%, respectively. The inner left lane was more affected by the weather than the outer left lane overall. The change ranges of saturated traffic flow rate and start-up lost time of each lane of dual-left lanes under different weather conditions was different on average, but there were no statistical differences between these parameters for light-medium rain weather conditions or lane locations.

Aoyama et al. (2020) highlight a concerning trend of a decrease in the saturated traffic flow rate, as reported by recent literature and observations. However, due to the variability of observed values across different intersections, it is challenging to establish a single base saturated traffic flow rate. To effectively evaluate this rate, continuous investigations, and analysis are necessary to identify the reasons for the apparent drop in the saturated traffic flow rate. Additionally, the current standard values for right- and left-turn lanes are set at the same value, despite evidence suggesting that turning-radius impacts must be taken into account. In particular, based on earlier Australian findings, the right-turn probability used in Japan is now shown to overstate actual capacity. Therefore, there is a need to establish an appropriate reduction value based on the real gap characteristics in Japan.

Nguyen et al. (2016) conducted a study to understand the traffic patterns in cities with a high dependence on motorcycles. By using theoretical approaches and field observations, the study found that the homogeneous motorbike saturated traffic flow rate in a 3.5 m approach width is approximately 11,300 MCU/h, which is 5.8 times higher than the homogeneous automobile flow's saturated traffic flow rate of 1900 PCU/h. In addition, the study estimated that a homogenous flow of bikes, with an occupancy of 1.2, can carry around 13,000 passengers to pass via a 3.5 m wide approach. These findings suggest that motorcycles are far more efficient in terms of capacity than cars or even buses. To calculate the observed saturated green time, the study measured the duration from the sixth second until all cars in the line of traffic had completely left the stop line. This approach helped to reduce the impact of lost time and faults in driving behavior on the saturated traffic flow rate. Overall, the study sheds light on the importance of considering the specific traffic patterns in motorcycle-dependent cities and highlights the potential capacity benefits of motorcycles over other vehicles.

Bargegol et al. (2016) conducted a study to determine the saturated traffic flow rate at the nearside and far-side legs of five signalized crossings in Rash, using both macroscopic and microscopic techniques. The study found that the saturated traffic flow rate values of the far-side legs were lower when using a macroscopic approach compared to a microscopic method. In contrast, the saturated traffic flow rate values at the far-side legs were higher when using the microscopic approach compared to the near-side legs. Specifically, the saturated traffic flow rate values at the far-side legs ranged from 1621 to 2181 vphgpl, while those at the near-side legs ranged from 1512 to 1773. Moreover, for lane widths ranging from 2.8 to 4.45 meters, the calculated saturated traffic flow rate using the macroscopic approach ranged from 905 to 1733 pcu/hr/In. In both macroscopic and microscopic techniques, the saturated traffic flow rates at the far-side legs were found to be a function of lane width. Thus, an increase in lane width at the far-side legs was observed to cause a rise in the saturated traffic flow rate. Overall, this study highlights the importance of considering both macroscopic and microscopic approaches in determining saturated traffic flow rates, as well as the impact of lane width on the flow rate at signalized crossings.

3. CONCLUSION

There has been some fascinating exploration directed at the immersed traffic stream and limit of signalized crossing points in Indian urban communities. A couple of these examinations have demonstrated that customary strategies for assessing soaked traffic stream rate might misjudge it and that it is critical to consider the impacts of bikes and move toward volume while displaying immersed traffic stream in Indian circumstances. Another review has investigated what motorbikes mean for immersed traffic streams at signalized intersections and observed that different elements can influence release degrees of progress. One more investigation discovered that the exact recipe given by the Indian Street Congress for deciding the soaked traffic stream isn't relevant and that traffic creation can significantly affect immersed traffic stream. Nonetheless, some encouraging examination is being finished in this field. For instance, one review proposed another soaked traffic stream model utilizing Kriging that has displayed to beat customary relapse strategies. Also, one more review took a gander at various strategic structures for displaying soaked traffic streams in both homogeneous and heterogeneous rush hour gridlock circumstances. Generally, these investigations have underlined the need to foster more nuanced and setting explicit models and systemic structures that can more readily represent the intricacies of Indian traffic. In that capacity, further exploration in this space is probably going to be important in further developing rush hour gridlock the executives and foundation arranging in Indian urban areas.

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