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A Review on Optimization of Design and Safety of Intersection

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Abstract - *Intersection have essential role for the flow of vehicles. When Vehicles move on the road, they cross several intersections and users abide delay, congestion and conflict points since all the operations like merging, diverging, weaving and crossing operations are performed at the intersections. This paper aims to review the various ways to reduce the conflict points, congestion and delay at the intersection. To achieve the desired results of intersection, several researchers suggested the various ways that should be adopted during the intersection design. The intersection parameters such as entry radius exit radius, right turn traffic, sight distance, setback distance, design speed, gradient, channelized island, design vehicles consideration, marking and sign boards near the intersection, and luminous intensity are studied. Intersections must be designed to accommodate vehicular traffic, non-motorized traffic, pedestrians and cyclists for their efficient movement with minimum delay at the intersection. The flow of traffic near intersections should be in the way, they create minimum conflict during the crossing at the intersection. There are software's available which we can use to assess the flow of traffic and study all the conflict points and suggests the remedial measures for the particular problem. For minimizing the conflict points proper widening, marking and channelization, and signals at the intersection should be provided to flow all the traffic with efficient way. Under mixed traffic conditions, there should be consideration of all factors of an intersection so that vehicles follow the desired path and cross the intersection with minimum delay and conflict.*

Key Words: **Delay, Level of Service, Sight Distance, Conflict Points, Modelling of Intersection**

1. INTRODUCTION

Heterogeneity and poor lane discipline are the prime traffic characteristics of developing countries. Level of Service at a signal-controlled intersection is generally measured in terms of delay caused to an individual vehicle. When an intersection is carrying a traffic equal in volume to its capacity under ideal roadway and traffic conditions, the operating conditions become extremely poor. Speed drops down and the delay and frequency of stops mount up. The service which an intersection offers to the road users can vary under different volumes of traffic [1]. Intersection design can significantly improve traffic flow and decrease the crash frequency, particularly in congestion-prone urban areas. Intersection safety analysis, like road segment safety analysis, is conducted to identify factors that contribute to the safety of road users at intersections, and therefore, help designers to develop effective countermeasures to improve safety [3].Network-wide signal timing optimization could be potentially effective if degrees of saturation of intersections in a street network are comparatively low where the remaining intersection capacities could still accommodate a significant amount of traffic. In this case, fine-tuning of signal timing plans for intersections in one or more subarea networks could help improve the efficiency of intersection capacity utilization with delay reductions [5]. Long et al. highlighted that the parked cars blocked the sightlines towards the pedestrian crossings. Hence, their removal would be beneficial to provide reciprocal visibility between pedestrians and motorists. However, it is common to find spaces where on-street parking is banned, filled with flower pots, trash containers, or other elements. These elements could enforce the ban because empty spaces could be used unlawfully. Pedestrian's actual crossing behavior, pedestrians are divided into three types, including adventurous, conservative and ordinary. Taking the risk cost and time utility as the behavior decision basis, the decision-making models of three types of pedestrians are established. Parameters of the models for three types pedestrians are calibrated according to the collected data [6]. VISSIM simulation software, creates a traffic simulation model of the intersection, looks optimised signal timing scheme for the intersections and lane improvement programme. Results showed that the two types of channelization proposed in this paper performed better than the currently popular design [19]. Enhancing travel efficiency for left-turn movements was important as the urban road network developed [20]. The vehicle conflict values calculated by the improved model are the unbiased estimations of observed conflict values. The model also describes well the evolution trend of traffic conflict quantities according to traffic volumes at an unsignalized intersection [28]. The study recommends that the proposed model works well for the signalized intersection operating with a high proportional share (above 30%) of vehicle type Two-wheeler in the mixed type traffic

stream. The present study suggested a simple method for estimating the number of vehicles accommodating in queue formed at an approach of signalized intersection and it is limited to the intersections operating under higher volume condition [32]. acceleration and deceleration rate models are developed for four vehicle categories under mixed traffic conditions. The correlation analysis showed good relation between the acceleration rate/ deceleration rate and speed. Linear models are developed for estimating acceleration rate and deceleration rate by considering average travel speed as independent variable.[33]

1.1 Delay at Intersections

High traffic growth, lack of proper road traffic management and lane indiscipline lead to delay to the vehicles particularly at intersection locations. One of the effective attempts towards traffic as well as pedestrian control at intersections is signalization [21]. Intersection delay has a massive influence on the proper operation of an intersection The delay of traffic signals is one of the serious challenges affecting road users in developing countries such as India in their regular lifestyle. Generally, at intersections, the cause of the delay is due to various motives [4]. The capacity and level of service of an intersection can be assessed by saturation flow. HCM 2010 has introduced a procedure to estimate saturation flow, assuming that the vehicles follow lane discipline. However, in developing countries like India, traffic is heterogeneous in nature, and very poor lane discipline is maintained. Due to fundamental variation in traffic characteristics and driver behavior, the models developed in USA and UK for estimating saturation flow are not applicable for developing countries like India [22].

1.2 Conflict Points

Conflicting traffic maneuvers are most common near intersections, making them more prone to crash occurrence. An accurate knowledge of the interactions between various geometric characteristics, traffic flow, and crashes at the intersection influence region could aid in reducing these crashes by identifying effective countermeasures. The instruments for understanding these correlations are safety performance functions [3].

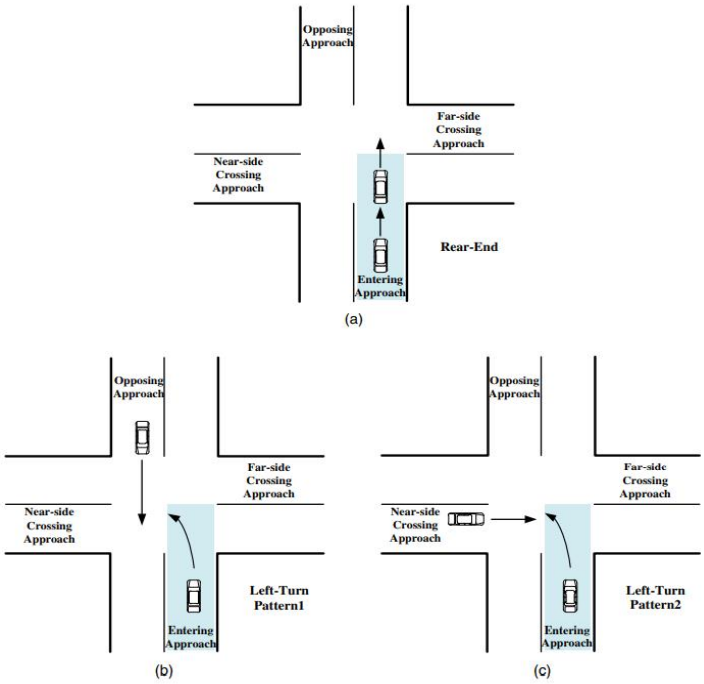

Fig -3: Crash types classified by conflicting vehicle maneuvers

Many previous studies mainly focused on developing models to evaluate the vehicle delay of signalized intersections and on designing signal control systems. Transportation professionals generally categorized the vehicle delay at the signalized intersections into the stop delay and deceleration-acceleration delay [4]. To eliminate or reduce the conflict point, improve traffic safety, cut down on delays, and increase intersection capacity, it is, therefore, necessary to analyze the traffic situation at the main intersection of the road network to identify the root causes of traffic jams. Once this is done, it is possible to implement appropriate traffic management or signal control optimization. By doing this, the city's traffic congestion can be effectively reduced.

Unsignalized T-intersections are liable to conflicts due to complex turning vehicular maneuvers and varied vehicular speeds in developing countries. Due to the mixed traffic conditions in India, the operational characteristics and speeds of the vehicles are different. Moreover, at unsignalized T-intersections, major road traffic movements have been given more priority, while minor road vehicles have to find a suitable gap between the conflicting streams on major roads to complete their maneuvers.

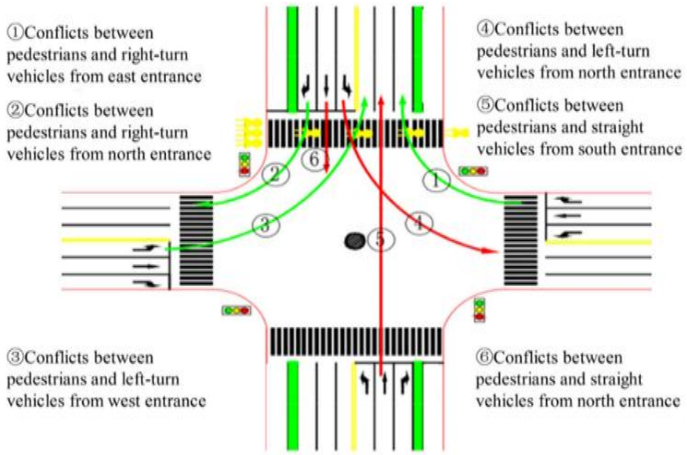

Fig –1: Conflict diagram of Intersection

Turning vehicle trajectories depend on the width of the road, available vehicular gaps on major roads, waiting time, speed of the vehicle on major roads, type of subject vehicle, and speed of the subject vehicle. Moreover, the vehicular driver's behavior depends upon the interaction of the subject vehicle with approaching vehicles on major roads while crossing the road at a T-intersection [7].

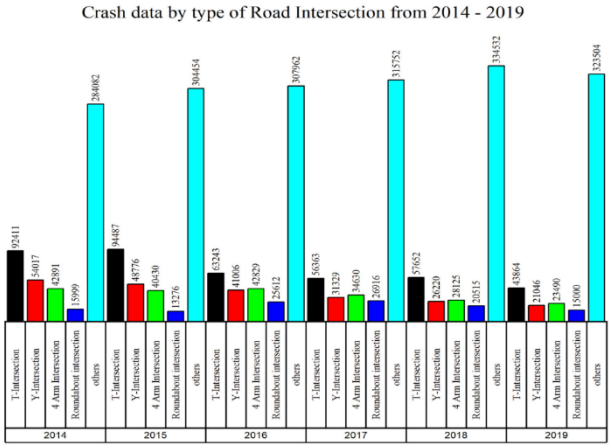

Fig -2: Shows crash data by type of road intersection from 2014-2019 [7]

Adequate sight distance at intersections is one of the most crucial road design elements in an urban environment, which is represented by an area that needs to be clear from obstructions. Road obstructions impact the driver's visibility when a vehicle is approaching an intersection. When a driver fails to observe a yield or stop sign at a two-way-controlled sign intersection or observe oncoming traffic from the major road due to visibility issues from the intersection, it may increase their collision risk. Sight distance is an element associated with visibility and central to the inherent safety of intersections. The ISD is specified in the road design guidelines, based on conservative values of speed, deceleration rate, perception reaction time (PRT), and gap time acceptance [8].

2. LITERATURE REVIEW

2.1 Geometric features of Intersection

Hummer and Mehrara demonstrated that the double contraflow intersection (DCI) has the ability to provide slightly better capacity than the continuous flow intersection (CFI) and median U-turn (MUT)[9]. The prediction model of potential traffic conflicts at an uncontrolled intersection is a way of using traffic conflict technology to evaluate the safety performance in designing or improving future traffic facilities and road networks. In an existing potential traffic conflicts prediction model for unsignalized intersections, there is an important assumption that conflict spots are independent [23]. The average length of comer clearance, traffic flow, land-use types, the number of left-turn lanes for main streets, the number of through lanes for main and minor streets, the posted speed limit on main and minor streets, and leg grades were among the nine variables identified by the panel data RENB as having a significant impact on the safety at signalized intersections [11]. An intensive study on the intersections of mixed traffic for the high-density development of a city, in order to make mixed traffic operate effectively, safely, and orderly, we must quickly overcome the challenges of making the best use of available resources and channelizing traffic for right turns of motorized vehicles, non-vehicles, and pedestrians. The challenges that we must quickly overcome involve how to make the best use of already available resources and channelize for the traffic right turn of motorized vehicles, non-vehicles, and pedestrians [24]. In order to address the issue of excessive channelization for left-turn traffic, three different types of channelization at signalized intersection approaches. The operating characteristics of the traffic flow in various types of channelization, potential safety, and impact on intersection capacity were examined [12].

2.2 Importance of Sight Distance at Intersection

The safety assessment found that intersections with short accessible sight distances (ASD) had a higher probability of collision. One of the most important road design components in an urban context is enough sight distance at crossings, which is represented by an area that must be free of barriers [8]. Adequate sight distance at intersections is one of the most crucial road design elements in an urban environment, which is represented by an area that needs to be clear from obstructions, impact the driver's visibility when a vehicle is approaching an intersection. Parked autos obstructed sightlines to pedestrian crossings. As a result, their removal would be advantageous in terms of providing reciprocal visibility between pedestrians and automobiles [13].

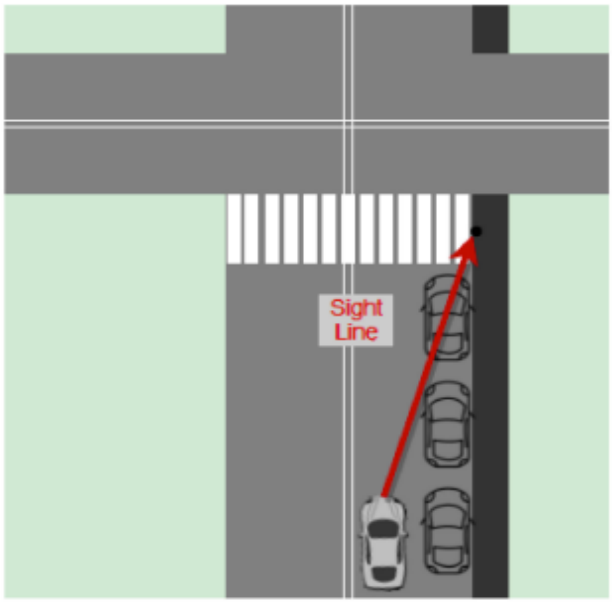

Fig -3: Sightline blocked by on-street parked traffic [13]

2.3 Movements of Pedestrians

The study establishes a decision model of pedestrian crossing based on risk-cost and time-utility during flashing green-countdown signal. The calculation methods of potential and direct risk in each direction of the intersection are proposed according to the traffic operation status and analyzed the relationship among the arrival time, remaining duration of flashing green signal and the actual crossing behaviors, pedestrians are divided into adventurous, ordinary and conservative types [6]. In metropolitan cities where both must share a common area on the road, the interaction of pedestrians and right-turning automobiles at a signalised crossroads is a typical occurrence. Conflicts between pedestrians and vehicles are growing as a result of the rapid development of motor traffic in emerging nations like India [14]. The role of impact factors on pedestrian crossing decision-making is examined in light of the model's findings. After that, advice is provided on three fronts road facility setting, pedestrian traffic management, and safety education initiatives to lower the number of pedestrian violations and improve the pedestrian traffic environment [25].

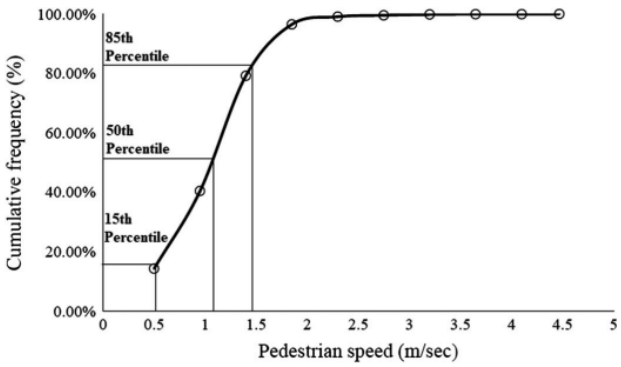

Fig -4: Cumulative percentage distribution of pedestrian speed [14]

2.4 Causes of delay at Intersection

Delay is a function of a number of factors, including geometry, signal timings, and approach volumes. Some of these factors, particularly, peak hour volume, can be considered to be random variable, and therefore the distribution of intersection delay is a function of the distribution of these random factors [12]. Intersection that is the vehicle together and steering is the key to urban transport, whose complex traffic features make it easy to be continued confusion and traffic accidents with multiple points and reduce the ability of the road network. It becomes bottleneck in the entire city roads [16]. The queue length was determined directly from the field, and the delay was calculated using Simpson's one-third formula based on the queue length of a cycle. It gives the distance between the length of the queue and the time of a single cycle, showing the overall delay of the cycle. The proposed model, HCM method, Webster's delay model, modified Webster's delay model, and probabilistic delay model results were compared to the field delay. It was found that the suggested model produces the best outcomes [26]. The collection of queues estimating models created in this work provides highway builders with a useful tool for calculating the correct link lengths for both through and left-turn movements in CFI [27].

2.5 Modelling and Analysis of Intersection

The vehicle conflict values calculated by the improved model are the unbiased estimations of observed conflict values. The model also describes well the evolution trend of traffic conflict quantities according to traffic volumes at an unsignalized intersection [28]. VISSIM simulation software, creates a traffic simulation model of the intersection, looks optimised signal timing scheme for the intersections and lane improvement programme. Results showed that the two types of channelization proposed in this paper performed better than the currently popular design [19]. Enhancing travel efficiency for left-turn movements was important as

the urban road network developed. Engineers may find additional useful references from this paper [20].

3. CONCLUSIONS

This paper presents conclusions drawn after having a thorough study-

1. The PCU of a vehicle is a complex parameter and depends on all factors influencing the behavior of a vehicle in the traffic stream. This provides the the concept to take the different vehicles into a single unit.

2. The design of the intersection should be done considering proper sight distance, lane widening, channelizing, proper radius of turning of vehicles so that vehicle can stop before collision in any kind of situation.

3. The model indicates that a platoon in a mixed traffic condition, after crossing the stop line of an upstream signal, gets completely dispersed at a distance of 450 m. Therefore, if the upstream signal is located within 450 m from the downstream signal, dense or moderately dense platoon will be witnessed, thereby reducing the vehicular delay [26].

4. Capacity of a two-lane road under mixed traffic conditions has already been a challenge to traffic engineers. It is due to variation in vehicular interaction at different levels of traffic mix. Speed of a stream of cars reduces as another type of vehicle is introduced in the stream. The amount of reduction in speed depends upon the type and proportion of the second category of vehicle and the total traffic volume. The capacity of a two-lane road decreases as the proportion of 3-wheeler, tractor, or heavy vehicles increases in the traffic stream.[29]

5. When pedestrian cannot cross the street completely due to the width of street, it is necessary to have a pedestrian safety island. It is also advised to have pedestrian safety island when there are more than 5 entrance or exit lanes.

6. The lowest level of delays for each traveler by dynamically altering green splits of signal timing plans designed for individual intersections in the network hour-by-hour in response to varying vehicle and pedestrian traffic entering the intersections.

7. The driver's eye location is relatively close to the intersection and requires a smaller sight triangle clear from obstruction. The driver's decision point begins at some point between 4.4 m and 5.4 m from the major road's intersection edge, given the vehicle stop location behind the stop line and the distance of the driver's eye from the front of the vehicle. The gap time acceptance is 0.5 s less than for yield-controlled intersections, resulting in a shorter leg distance of the sight triangle along the major road.

8. The simulation results show that the design system gives better clearance to vehicles, emergency transit and also to pedestrians in all traffic flow conditions throughout the day. This system can be realized and implemented on any major traffic intersection to address all types of movements and enhance the traffic as well as pedestrian handling capability of the intersection.

9. The number of lane changes is increased with traffic volume to a certain extent, but as further traffic volume increased, the number of lane changes are decreased. When traffic volume reaches capacity, the number of lane changes are stagnated. This is because of not enough free space available for the movement of vehicles. The frequency of lane changes increases as the number of lanes added to the lane increases, yet the capacity of one lane per lane reduces as the number of lanes increases.[31]

10. 10.When approaching an intersection controlled by a yield sign, the driver requires a certain distance to observe a potential conflicting vehicle and to slow or stop before entering the intersection, and this distance forms a large area that needs to be clear from obstruction.

11. Traffic signals are one of the most effective and flexible active control of traffic that is widely used in several cities worldwide to ensure safe and orderly traffic flow; the conflicts arising from movements of traffic in different directions is solved using time sharing principle [35].

12. The traffic guide sign plays an important role in the traffic sign system. However, in the junction area between highway and urban road, the driver often takes the wrong way due to the different layout of the signage [36].

13. The severity of conflicts varied significantly with the pedestrians' interactions with different vehicle types. The maximum number of conflicts occurred with LMVs such as cars, SUVs, and light commercial vans. The severity of conflicts was also higher with LMV-related conflicts. The lowest severity was observed with heavy vehicles because of their lower speeds at intersections and the yielding behavior of pedestrians after perceiving such large vehicles [14].

14. At signalized intersections, LOS is an operational condition index influenced not only by traffic flow, but also by geometric design features and signal timing. That is, a given traffic flow may be associated with different intersection capacities due to differing intersection configurations and signal timings. Correlations between LOS and traffic flow were tested before developing the models [37].

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