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A Review on Performance Analysis of Signalized Roundabout using Micro-Simulation Technique

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Abstract: As a result of urbanization, traffic in an urban area also at its extreme. Roundabout results in a nice solution for smooth movement when flows are balanced but it can have operational difficulties when there are increased flows. The use of micro-simulation tools for performance analysis emerges as an effective solution to understand and modelling vehicle and driver behaviours. It is needed to provide some measures to reduce queue length, travel time and delay at signalized complex roundabout. Different alternatives can be modelled and compared in PTV VISSIM. The main aim of the study is to provide an optimal solution with the help of simulation techniques to ultimately enhance roundabout performance. The present article shows the methodology adopted by different authors to simulate the traffic condition and the provision of the different alternative strategies for enhancing performance. Thereby conclusion was made based on different studies.

Keywords: Micro-simulation, Performance Analysis, PTV VISSIM, Roundabout

I. INTRODUCTION

Over a few years, the population is increased at a very rapid rate in India. Population growth always resulting in urbanization. Due to the advancement in science and technology, it gives hike to the manufacturing Industries. In search of better education, health facilities, and better amenity services; people show an inclination towards the urban area. Industrial and business growth at urban centres leads to a greater number of employments for the people. Hence, for financial betterment, a huge part of the population generally gathered around the major urban centres. These all things lead to urbanization. As the enhancement in the per capita income of the people, their lifestyle improved to a level such that everyone has his/her vehicles for serving various needs of daily life. Hence, the traffic is proportional to the rate of growth of the population.

The traffic flow phenomenon consists of a huge range of complex activities. The fundamental parameter of traffic flow includes speed, density and flow and these are governed by a variety of factors attributable to the geometric features, the vehicle static and dynamic characteristics, and the road user behaviour. The characteristic of traffic flow can be achieved by observing how vehicles move in the traffic stream, collecting volume data, and thereby doing analysis of characteristics through analytical or mathematical models.

The traditional technique requires the collection of data on a greater scale. Suppose, it is needed to understand the behaviour of the complex heterogeneous traffic on Indian roads, then real-life observations have to be conducted on all types of roads for all types of vehicles and composition of the traffic. It requires a huge effort and also at the same time this process is time-consuming and expensive. At the end of the effort, often some uncertainty may happen in finding the relationship between flow parameters. Therefore, it is needed to adopt a new approach for analysis. Traffic engineers are, therefore inclined towards a new technique known as Simulation Modelling. Simulation is defined as making a working analogy of a real-life situation into a computer-based model. It is a technique by which it is possible to represent some part of the real situation of the world dynamically with the help of computer modelling. Then we can run the model over adequate time to solve problems for any given inputs and constraints.

II. LITERATURE REVIEW

Often in place of urban simple road intersections; it is advisable to provide roundabout or rotary intersection. Often the topic of discussion is on the difference between traffic rotary and roundabout. Both of these features have unique characteristics which demarcate from one another. Generally, the traffic rotary has a central island of larger diameter than that of a roundabout. Weaving and lane changing operations are permitted in case of traffic rotary whereas in the case of the roundabout there exists a restriction on the weaving on circulating lanes. Traffic rotary permits the movement of vehicles at a higher speed. Roundabout has some speed limits as well as proper lane markings showing particular directional movements. The rotary may allow pedestrian movement to and from the central island whereas it is prohibited

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on the roundabout. Traffic rotary may consist of approaches that possess two or more lanes whereas roundabout generally has single or two-lane approaches. When the traffic is less, the rotary intersection is efficient for control, but when the traffic increase, it will lead to congestion problems due to its complex nature. This all things leads to major concern about the traffic movement at the rotary intersection.

Fu, Q., Zu, Y., & Hu, J. (2019) [5] aimed design of traffic signal timing at the roundabout. They proposed LWTS (Left turn With Two Stops) technique. One roundabout was selected for the study. The selected roundabout had 5 circulating lanes, due to this weaving operation became critical without signal control. Proper marking, channelization, and signal setting configuration were suggested. A Four-phase system with LWTS was suggested. The signal timing and phasing scheme were simulated with the help of PTV VISSIM. The finding of the study resembled quite acceptable and good. It was found that there was an improvement in traffic flow and a reduction in the delay and queue length. Hence, traffic efficiency was much higher than the un-signalized control mode without much investment.

Osei, K., Adams, C., Ackaah, W., & Oliver-Commey, Y. (2019) [13] explored the micro-simulation technique for the improvement of roundabout performance. They had selected two roundabouts for study. Both these roundabouts had single-lane approaches. Classified volume count was done by the video-graphic method at morning and evening peak hours. According to Ghana Highway Authority Classification, the vehicle compositions were grouped into three categories namely small (taxis, saloon cars), medium (mini-buses), and large (long buses, heavy goods vehicles). In this study, an innovative solution allowing through movement in the central island with two circulating traffic lanes was suggested. Signal timing and phasing system were explored and their effect on operational capacity, safety, and the delay was analysed. The cycle length was kept short and that's why they suggested only a three-phase system including an all-red phase. The existing and proposed options were modelled and simulated in VISSIM. Ultimately, it was found that this unconventional strategy was a better improvement option for reducing congestion at the roundabout.

Qadri, S., Gökçe, M., Öner, E., & Gökçe, E. (2019) [15] had done a predictive study in which use of micro-simulation tool was proposed. A complicated roundabout scenario was modelled in VISSIM. Existing and proposed situations were modelled in PTV VISSIM. The existing situation comprised of a roundabout and the proposed situation was comprised simple intersection. With the help of three different traffic demand data for three different cycle lengths, they had tested the scenarios in PTV VISSIM. Average delay per vehicle, average queue length, maximum queue length, and average travel time were some of the performance measures that had been chosen for the measurement of performance of these two scenarios. Results indicated that simple intersection was much better than roundabout regarding the flow of traffic and minimizing the average delay time per vehicle.

Klos, M., & Sobota, A. (2019) [10] focused on the design of geometrical parameters of the roundabout. The author had selected one roundabout in Gdansk for the research work. Two different variants were tested with the existing state. The first variant was to change the geometry of the intersection on one of its inlets. The second variant was to change the geometry of the intersection on one of its inlets while eliminating traffic on one intake. The results from the VISSIM simulation indicated that changes in the geometry of one of the inlets had a good effect on traffic than that of the existing state. However, it increased the average value of time losses on the other inlets.

An, H., Yue, W., & Stazic, B. (2017) [1] derived model for the queuing length estimation at the roundabout. Queuing lengths were recorded using two drones at the 'Old Belair Road' roundabout which is located in Adelaide of South Australia. Estimated lengths were then compared with predicted AIMSUN software results. Two detectors' locations were analysed and concluded with new position suggestions which could result in a reduction in queuing length on both approaches. After the R2 test it was found that the queuing models can be used to evaluate metering signal roundabouts performance.

Nikitin, N., Patskan, V., & Savina, I. (2017) [12] derived a model for estimation of queue length at the roundabout. For this study, they had selected one roundabout at 'Vasilevsky Square' and two nearby crossroads. They had taken two cases namely i) with pedestrian stream ii) without pedestrian stream. VISSIM model for both scenarios was developed by them. It was evidenced that performance of the roundabout was affected directly by the pedestrian's presence in the stream. After comparison, it was concluded that roundabout had more efficiency than that of intersection with signals during peak hours.

Basu, B., & Reddy, D. (2017) [2] had taken two roundabouts of Hyderabad City for their research work. The author estimated critical gaps for various vehicle types separately and the effect of circulating flow on critical gaps was analysed. A comparison between MLE (Maximum Likelihood Estimation) method and Raff's method for critical gap estimation was made. The capacity of the roundabout was estimated using three models namely HCM 2010 model, ARRB model, and ARRB model for the Indian condition. The scope of their work was limited to the comparison of Raff's and MLE

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methods of critical gap estimation. It was evidenced that as the island diameter increased, the critical gap also increased. It was found that RMSE (Root Mean Square Error) values of the MLE method in all three models were comparatively less than Raff's method. Hence, it was concluded that MLE was the best method for critical gap estimation.

Bie, Y., Cheng, S., Easa, S., & Qu, X. (2016) [3] developed a new method, Stop-Line-Set-Back (SLSB), for improving the capacity of the signalized roundabout. A comparison was made between existing and new SLSB techniques for evaluating the operational performance of the roundabout. According to the traditional method, the roundabout has only one stop line at the entry of each approach, but they proposed a new SLSB strategy. According to this, there were two lines at one of the four approaches. One line was a give-way line and another line was the stop-line. The area enclosed between these two lines is named a waiting area. If an acceptable gap was found, the vehicles present in the waiting area could proceed though the signal was displaying a red light. Results showed that this technique was best suited to reduce delay and enhancing capacity. The author concluded that the SLSB method provided the best result in peak hours to enhance the operational performance of the signalized roundabout. However, SLSB was not recommended to all the approaches of signalized roundabout simultaneously.

Martin-Gasulla, M., Garcia, A., Moreno, A., & Llorca, C. (2016) [11] analysed operational improvements on roundabouts by using traffic micro-simulation technique. For this, a roundabout in the Valencia area of Spain was selected. The fifth leg was local unpaved, hence neglected due to less demand. Manual and video recording counts of every 5 minutes were worked out. A total of 2997 headways were measured. For calibration and validation at all approach queue lengths were measured. They used VISSIM 5.30 for micro-simulation. Stop line positions, the number of observed vehicles, look ahead distance, reduced speed zone length was calibration parameters in VISSIM. The logic of signal design was developed and executed in the VisVAP. The capacity obtained by the simulation technique was near to the field data, whereas HCM models underestimated capacity. The most important findings of the study were that metering systems increased capacity on roundabouts.

Chen, X., & Lee, M. (2016) [4] had selected one roundabout at 'East Dowling Road' in Anchorage, Alaska, which was a high-demand roundabout. The site consisted of different traffic movements under winter and summer operating conditions. Hence videotaping was done during three consecutive weekday evenings under both winter and summer situations. For winter data collection, 6 camcorders were used and for summer data collection, 17 camcorders were used. To measure the field delay, a vehicle on each lane of a queued approach was randomly sampled for each minute during evening peak hours. The actual travel time of the same was measured. The author had used different software like VISSIM, RODEL, and SIDRA for performance measurement. On comparing, it was found that VISSIM and SIDRA had underestimated the delays whereas RODEL tends to show higher delay and queue length at most inlets.

Qu, Z., Duan, Y., Song, X., & Xing, Y. (2014) [16] analysed different capacity models for the roundabout. The author mainly focused on the empirical regression model, Gap acceptance model, and Simulation model. The gap acceptance model had systematically macro-structure and comprehensive theoretical connotation and hence selected to model roundabout capacity. The present study was analysed by two approaches. The first was based on SIDRA and RODEL which were macroscopic. The second was based on microscopic simulation software such as PARAMICS, SimTraffic, and VISSIM. Based on their research work, it was summarized that calibration of empirical regression model needed massive field data but still had good applicability to local roundabouts. The simulation-based method created randomness nearly to the reality and overall operational patterns of roundabout nicely grasped. The Gap acceptance model had strong theoretical property, but it oversimplified the real situation hence it was restricted in the conditions of priority reversal. Finally, in combination with other control objects, a review and outlook were proposed for future studies on the capacity of the roundabout.

Yousif, M., & Zhang, Z. (2012) [17] evaluated the performance of 'Kahtan Square (KS) Roundabout' which was located in Baghdad City. Traffic count was carried out at KS roundabout from morning to evening period during the workday. They classified the vehicles into two categories namely small and larger vehicles. Geometric data was also found and SIDRA software was used for analysing and evaluating the roundabout performance. Webster's method was used to calculate the lane saturation flow in each direction. Three alternatives were proposed in the study. The first was the replacement of the existing roundabout by a signalized 4-leg intersection. The second alternative was to execute the flyover on heavy demand main path with signalized at grade roundabout. The third alternative was the same as the second but the only difference in the operation of the roundabout as it was un-signalized. After evaluating different alternatives, the present study concluded that the second alternative enhanced the operation of the intersection and increased the flow capacity to its high value to achieve an acceptable LOS for the future.

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III. CONCLUSION

Several methods were used to mitigate traffic congestion at a rotary intersection by different authors. Signal timing and phasing system were emphasized by the author with the help of the left turn with the two stops (LWTS) technique. Some conventional, as well as unique approaches, were analyzed in a different study. Geometric changes were also made to cater to the traffic congestion problem at signalized traffic rotary.

A microscopic simulation approach was adopted in the studies for simulating driver and traffic behavior. After collecting traffic data, it is possible to represent the real-life situation in a computer-based model. Different parameters like speed, queue length was used to calibrate the VISSIM model by the authors. The effect on traffic was studied by two cases such as intersection with roundabout and intersection without roundabout. Different methods for finding critical gaps at roundabout were analyzed. The Maximum Likelihood Estimation method, as well as Raffs' method for finding a critical gap, were studied. Various ways to calculate the capacity of roundabouts were explored.

Several ways to mitigate the traffic congestion at the approaches of the rotary were developed. These different scenarios were studied and an analysis of their findings was made. The use of PTV VISSIM software is explored to replicate real-life traffic behavior closely. Also, comparative studies were made to know which simulation tool gives correct optimum results. Various parameters like, queue length, travel time, and delay were emphasized to select the most effective alternative which gives the best result. The alternative which had shown a reduction in delay, travel time, queue length was selected to enhance the performance of the rotary.

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