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# Effect of two-wheeler proportion on passenger car units at four legged roundabouts

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## Abstract

Traffic in developing countries like India is highly random and haphazard, which is characterized by the presence of vehicles of different categories with widely varying physical and operational characteristics. Further the condition becomes more difficult and vulnerable at intersections. Under moderate traffic conditions, a roundabout may reduce delay and enable safer movement in comparison with un-signalized intersections. For the safe driving of vehicles, it is indispensable to understand the operational performance of roundabouts. Studies related to roundabouts are found to be very limited under heterogeneous traffic conditions and this study focuses to address this issue. Past studies show that VISSIM is able to replicate the field conditions in a better way comparatively as the software provides options for creating links without any lane discipline, it can be used easily to represent the Indian roadway conditions. The driving behaviour parameters can also be adjusted to capture the aggressiveness of road users by efficient calibration. To know the accuracy of the model created, it is important to validate the model. Validation is the process of assessing or comparing the field data and the corresponding simulation output. The model thus made, can be further used for various analyses of roundabouts. Present study focuses on modelling roundabout in heterogenous condition and understanding the effect of change in 2-wheeler composition on performance of a typical four-legged roundabout for a mixed traffic scenario. These findings may be used for performance evaluation and thereby planning and designing of roundabouts under heterogeneous traffic flow conditions.

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## 1. Introduction

Traffic in developing countries like India is highly random and haphazard, which is characterized by the presence of vehicles of different categories with widely varying physical and operational characteristics. Since the moving vehicle of such a traffic stream may occupy any convenient lateral position on the road without considering any lane discipline, intersections (a node in network, where more number of traffic streams may conflict with each other) are considered as critical points from safety point of view. Therefore, a major part of road safety challenges involves in making intersections safer for smoother traffic movement, and hence the study of traffic characteristics and its operations at intersections is of paramount importance for effective planning, design, operation, and management of a given intersection. Under moderate traffic conditions, a roundabout may reduce delay and enable safer movement in comparison with un-signalized intersections. Because of lower number of conflict points, there may be a lower potential for accidents, since traffic flow merges and diverges at small angles and at lower speeds. For the safe driving of vehicles, it is indispensable to understand the operational performance of roundabouts. Capacity is an important measure which specifies the performance of a traffic system. The capacity of a roundabout is defined as the maximum number of vehicles that can enter the roundabout in a unit time at a given entry leg for the flow in a circulating roadway.

Studies related to roundabouts are found to be very limited under heterogeneous traffic conditions and this study focuses to address this issue. Being an important working tool for researchers and consultants, simulation is recognized as one of the best tools for modeling traffic flow under homogenous as well as heterogeneous conditions and these models have received a great deal of attention from researchers and other analysts in the field of traffic engineering. VISSIM is a widely used micro-simulation software which helps to model various roadway facilities and past studies show that VISSIM is able to replicate the field conditions in a better way, compared to other micro-simulation tools available in market. As the software provides options for creating links without any lane discipline, it can be used easily to represent the Indian roadway conditions. The driving behavior parameters can also be adjusted to capture the aggressiveness of road users.

Most discussions related to roundabout or network modeling call attention to the need for addressing the calibration and validation of roundabouts, which is lacking. Calibration of the software is the first step in making a simulation model. All the field collected data can be input for this purpose. Calibration can be done by changing the conflict areas or priority rules, speed distribution and fine-tuning can be done by changing driving behavior parameters. To know the accuracy of the model created, it is important to validate the model. Validation is the process of assessing or comparing the field data and the corresponding simulation output. The model thus made, can be further used for various analyses of roundabouts. Apart from obtaining the capacity of roundabouts, it is important to study the performance of roundabouts under various conditions. The results of the present study are expected to also highlight the effect of change in composition on entry capacity of roundabout in existing traffic scenario at a typical four-legged roundabout for a mixed traffic scenario. vehicular movement at weaving zone of unsignalized intersection is closely studied and observation on forced gap is made. From the collected data, accepted gap and rejected gap is obtained and hence critical gap is estimated for different vehicle categories. Capacity of roundabouts is estimated for different composition. These findings may be used for performance evaluation and thereby planning and designing of roundabouts under heterogeneous traffic flow conditions**.**

## 2. Literature Review

Traffic intersections are complex locations on any road. This is because vehicles moving in different directions want to occupy same space at the same time. In addition, the pedestrians also seek same space for crossing. Drivers have to make split second decision at an intersection by considering his route, intersection geometry, speed and direction of other vehicles etc.

Critical gap can be defined as minimum gap that all drivers in minor stream are assumed to accept at all similar locations, or in other words it is that accepted gap which gives maximum capacity at an intersection. Troutbeck and Brilon (2001) defines Critical Gap as the minimum time gap in priority stream that a minor street driver is ready to accept for crossing or entering the major stream conflict zone. They also defined the Follow-up time as the time gap between two successive vehicles from minor stream while entering the conflict area of the intersection during the same major street gap.

The effective control is very important for urban road intersection which impacts the capacity, vehicle delay, operation efficiency and safety of the whole traffic network. Traffic simulation has become an indispensable transportation research technology depending on its specialties of economy, safety, repeatability and usability. Simulation software is an effective evaluation tool to seek a proper method to control the signalized intersection. Traffic simulation models have been studied extensively over the past 30 years.

VISSIM is recommended by users for its easy manipulation capability in the context of complex geometry and traffic control, and transit elements. There are three significant differences between the models. CORISM uses a link-node structure while the network of VISSIM is built over a graphical map. The car-following modeling in CORSIM sets a desired amount of headway for individual drivers but VISSIM relies on the psycho-physical driver behavior model. VISSIM reports total delay by link and not for each turning movement, but CORSIM provides average control delay for each approach.

Traffic simulation models have also found application in transportation planning process, due to their flexibility and feasibility in testing different alternatives that do not currently exist in the real-world. PTV VISSIM is the leading microscopic simulation program for modeling multimodal transport operations. Realistic and accurate in every detail, VISSIM creates the best conditions for testing different traffic scenarios before their realization. VISSIM roundabout models have been widely applied in practice to facilitate analyzing the operational performance of roundabouts. To prepare a VISSIM roundabout model for analysis, an essential prerequisite is to calibrate the model by adjusting parameters until real-world roundabout operations are reproduced in the simulation model.

Gallelli and Vaiana (2008) conducted a study on evaluation of geometric and behavioral features of roundabouts using VISSIM. The authors introduce the results of a wide survey conducted on an ample range of roundabout scenarios by the use of the simulation software VISSIM. Each scenario describes a fixed roundabout phenomenon using the following variables: geometric elements (inscribed circle radius, circulatory roadway, central and splitter islands etc.); characteristics of the traffic flow (dynamic traffic assignment, approach speed, circulatory speed and reduced speed zones, etc.); behavioral features (priority rules, minimum gap, minimum headway, etc.).

Pruthvi et al. suggested a methodology for the calibration of VISSIM in mixed traffic. Calibration parameters were identified using multi parameter sensitivity analysis, and the optimum values for these parameters were obtained by minimizing the error between the simulated and field delay using a genetic algorithm. Zhixia et al. developed roundabout models using VISSIM based on critical gap and follow up headway approach. Researchers studied the impact of VISSIM parameters on critical gap and follow-up headway, and quantitatively analyzed them through sensitivity analysis of minimum gap for PR, speed distribution and deceleration rates for RSA, and additive and multiplicative settings for the Wiedemann 74 model. Based on the sensitivity analysis results, recommendations were given for calibrating VISSIM roundabout models. These recommendations were used in the current study for easy calibration of the model with some modifications as these parameters were developed based on homogeneous traffic conditions. Gallelli et al. introduced the results of a wide survey conducted on an ample range of roundabout scenarios using simulation software VISSIM. Researchers studied the variation of stop-line delay with respect to geometric elements, characteristics of traffic flow and behavioral features. Results provide an insight into the sensitivity of model to different input parameters. Kang and Nakamura studied the impact of conflicting pedestrians in the estimation of roundabout entry capacity. Based on the gap acceptance theory, which is the main concept of capacity estimation, critical gap was calculated for validation which is from accepted gaps and rejected gaps. Sisiopiku et al. conducted studies for evaluating roundabout performance using SIDRA. The performance of roundabouts was evaluated in terms of delay and capacity in comparison with the performance of intersections with various types of control. Considering the performance in terms of delay and sensitivity to the left-turn volumes, roundabouts with two lane approaches prove to work better than any other alternative for heavy left-turn volume. On the other hand, signalized intersections with one lane approach and heavy left-turn volume demonstrate lower total delay values than their roundabout counterparts. Akcelik R. discussed issues related to calibration of models for analyzing roundabout capacity and performance, and studied the delay criteria for level of service definition of roundabouts. Also, they added various methods for queue calculation and showed how it varied with different flow rates.

In summary, the existing literature shows that ample number of studies have been carried out under homogeneous lane-based traffic conditions. Previous calibration researches have used qualitative analysis to study the impact of VISSIM parameters on roundabout capacity. Also, the importance of VISSIM as a powerful simulation software for developing models for various field conditions is explained.

## 3. Study Area

Field studies are carried out so as to assess the present condition of traffic and its behavior so that one can take traffic management decisions to study, analyze and improve the traffic performance. A four-legged roundabout having diameter in the range of 25 m has been considered located at Chandigarh (Northern part of India). Intersection selected is free from any curves and gradients on all four approach roads. Data collection was carried out using videography so as to enable collecting all the traffic flow characteristics simultaneously and facilitate data extraction at both microscopic as well as macroscopic levels. Data was collected on a typical weekday covering off-peak as well as peak hours. During morning and evening peak hours, substantial queue formation was observed due to which there was a considerable delay to traffic streams in both roundabouts. This aspect was focused to get data on traffic operation at roundabouts over varying traffic conditions.

**Table 1. Details of selected roundabout**

| | Location | Diameter | Circulating roadway width | Entry width | Exit width | Approach width | Departure width | Weaving Length |
|---|---|---|---|---|---|---|---|---|
| **R1** | Chandigarh<br>30°43'45.98"N<br>76°45'26.51"E | 25 | 8 | 7 | 7 | 6.7 | 6.7 | 28 |

The city of Chandigarh was one of the early planned cities in the post-independence India and is known internationally for its architecture and urban design. The circle is situated near the Khukhrain cold storage and ice factory. The intersection is four legged almost symmetrical and having traffic majorly composed of two-wheeler and car. Following image shows the image of round about R1 considered in the study.

Figure 1: Showing image of Intersection R1

It is to be noted that Indian Traffic condition is heterogeneous in nature. All the vehicles are free to use every lane. The no: of vehicles from each leg for 1-hour traffic and their relative flow in each direction according to vehicle category has been depicted in the figure 2.

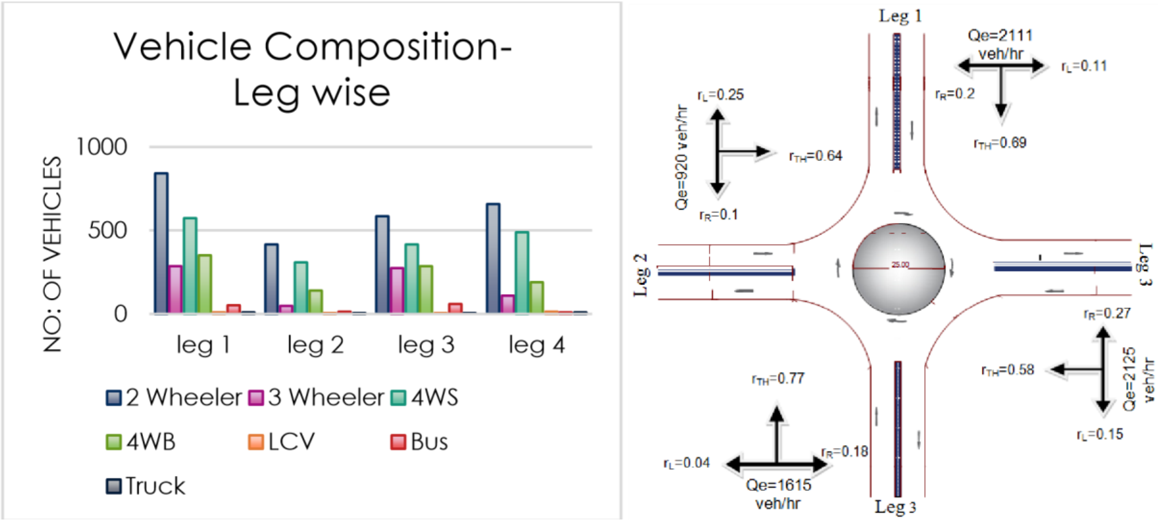


**Figure 2. Vehicular Composition at Intersection R1**

The proportion of 2-wheeler and 4-Wheeler are usually dominating in Indian roads. Similar observations have been observed in the intersection studied. The following charts shows the proportion of different vehicles at roundabout R1.

## 4. Gap Analysis

Raff's method was employed for evaluating critical gap from the observed, accepted and rejected gaps. However, in order to determine the critical gap, forced gap were not considered. In the present study, to understand the effect of forced gap on the critical gap, the statistical analysis was carried out to check the similarity between the accepted gap and forced gap. The following table shows the Mean and standard deviation values for the Rejected, Accepted and Forced Gap.

**Table 2. Mean and standard deviation for various vehicle categories**

| | | Rejected gap | Accepted gap | Forced gap |
|---|---|---|---|---|
| **2-Wheeler** | Mean | 1.082 | 2.050 | 2.071 |
| | Std. Dev | 0.389 | 0.786 | 0.823 |
| **Small Car** | Mean | 0.270 | 2.688 | 2.839 |
| | Std. Dev | 0.494 | 0.581 | 0.505 |
| **Big Car** | Mean | 0.202 | 3.026 | 3.105 |
| | Std. Dev | 0.440 | 0.932 | 0.761 |
| **3-Wheeler** | Mean | 0.201 | 2.734 | 2.415 |
| | Std. Dev | 0.379 | 1.010 | 1.019 |

It is observed that the means of accepted and forced gap by the vehicle categories are quite similar. However, the mean of forced gap values is found higher than the accepted gap values. It is very clear since the major vehicles at forced gap tend to slow down or stop before crossing the conflict point. In case of three wheelers, the mean of accepted gap is slightly lower than the mean of forced gap which may be due to the acceleration rate and the speed of three-wheeler. Further T-test was carried out between the samples of accepted and rejected gap and the result is tabulated in following table 3 for each category of vehicle.

**Table 3. T-values for different vehicle categories**

| **Vehicle Category** | T-Value |
|---|---|
| **2- Wheeler** | 0.732055 |
| **Small Car** | 0.070577 |
| **Big Car** | 0.297647 |
| **3-Wheeler** | 0.133391 |

It is clearly observed that the T-Value for samples of each vehicle category for accepted and forced gap is less than 1.96, and hence it can be concluded that the values are quite similar. To gain further surety, the ANOVA test was carried out for each vehicle category mentioned above the results are tabulated as below.

**Table 4. Results of ANOVA test between accepted and forced gap**

| | *F* | *P-value* | *F critical* |
|---|---|---|---|
| **2-Wheler** | 0.118675 | 0.730806 | 3.884271 |
| **Small Car** | 2.193471 | 0.141154 | 3.918178 |
| **Big Car** | 0.245951 | 0.620778 | 3.913989 |
| **3-Wheeler** | 0.695552 | 0.406466 | 3.945694 |

The F Values for all the vehicle category samples of accepted and forced gap can be observed to be lower than the F Critical signifying that the samples are similar. The similarity of samples proves that there would not be much difference caused on critical gap values due to non-consideration of forced gap values.

## 5. Estimation of PCU Values Using Occupancy

The capacity of a roundabout with heterogeneous traffic flow with vehicles of widely varying static and dynamic characteristics is best expressed in terms of PCU/h. This dictates an accurate estimation of PCU, which varies dynamically with various traffic flow parameters such as stream speed, vehicle composition and traffic volume. The PCU values of different types of vehicle are determined by keeping the small car as a standard vehicle. Chandra and Kumar developed the concept of dynamic PCU considering the various traffic interactions and flow characteristics. The PCU for a vehicle can be calculated using equation (1)

$$PCU_i = \frac{V_c / V_i}{A_c / A_i} \tag{1}$$

Where, $PCU_i$ is the PCU of the subject vehicle i; Vc =Average speed of cars in the traffic stream, Vi= Average speed of subject vehicles i; Ac= Projected rectangular area of a car as reference vehicle and Ai= Projected rectangular area of the vehicle type i.

In a roundabout area, it is difficult to measure the running speed of a vehicle as there are subsequent delays while the vehicle meets the entry flow from different legs. Further, the merging and diverging operation will lead to cover the various longitudinal path of a vehicle in the roundabout area. Hence, occupancy time was used to estimate the PCU values for different roundabouts. Time occupancy in a given direction of movement is defined as the time taken by the subject vehicle to clear the roundabout separately, for left-turn movement, straight movement or right-turn movement. A vehicle which occupies lesser time in the roundabout area will create less impedance to the circulating flow. Therefore, the PCU will be different for each vehicle category on the basis of time taken to clear the roundabout. It may be noted that by using this approach, the critical parameter for performance evaluation at intersections, delay, is also incorporated in the clearing time. Considering the above concept, the dynamic PCU equation proposed by Chandra and Kumar (2003) is modified and the total occupancy time of a vehicle type is compared with the occupancy time of standard car for estimation of dynamic PCU. The modified equation is given as Equation 2.

$$\text{PCU} = \frac{\boldsymbol{Clearing\ time(occupancy)ratio\ of\ i^{th} vehicle\ to\ standard\ car}}{\boldsymbol{Space\ ratio\ of}\ \textbf{standard}\ \boldsymbol{car\ to\ the\ i\ th\ vehicle}} \qquad (2)$$

$$\boldsymbol{PCUi} = \frac{\boldsymbol{Ti/Tc}}{\boldsymbol{A_c}/\boldsymbol{A_i}} \qquad (3)$$

Where, PCUi is the PCU of the subject vehicle i; Tc = Average time occupancy of standard car in seconds; Ti= Average time occupancy of subject vehicle in seconds; Ac= Projected rectangular area of a car as reference vehicle in $m^2$ and Ai= Projected rectangular area of the vehicle type ‘i’ in $m^2$.

It may be considered as a real representation of the overall interaction of a given vehicle type (for which PCU is to be estimated) in reference to standard vehicle category as cars in the presence of other vehicle types. Hence, the clearing time variable represents the roundabout occupancy in comparison to a conventional car. The PCU values for different categories of vehicles were computed for all three possible movements considering entry from all four legs and the values are given in following table 5.

**Table 5: PCU values for various Vehicle categories**

| Vehicle type | Left | Straight | Right | Average |
|---|---|---|---|---|
| 2W | 0.20 | 0.20 | 0.20 | 0.20 |
| 3W | 0.73 | 0.70 | 0.63 | 0.69 |
| S CAR | 1 | 1 | 1 | 1 |
| B CAR | 1.60 | 1.74 | 1.76 | 1.70 |
| LCV | 2.20 | 1.90 | 2.59 | 2.23 |
| BUS | 6.10 | 5.98 | 5.79 | 5.96 |

From Table, it is observed that PCU values for each vehicle categories in different directions are nearly same. Hence paired t-test was carried out between PCU values for left, right and straight movement. The t-test result concludes that PCU values obtained for each vehicle category are significantly similar. Hence, the weighted average values for the vehicles was determined and is shown in Table above.

## 6. Determination of Entry Capacity

The relationship between entry capacity and circulating flow is developed since substantial queue formation and considerable delay have been observed in the field. Entry capacity is considered as dependent variable whereas circulating flow is considered as an independent variable. For this purpose, the entry flow values and circulating flow values of each observed queue formation is first converted into the equivalent entry capacity and circulating flow using the corresponding aggregated PCU values of different vehicle categories. The entry capacity is calculated based on the conflicting flow in the circulatory roadway space, which comprises the various turning movements for different vehicle categories from other approaches that pass in front of the subject approach leg for which entry capacity is to be estimated. Data for circulatory flow and entry flow for congested period was extracted for R1. Exponential plot was carried out for estimating the capacity of roundabout. Plot is shown in figure 3.

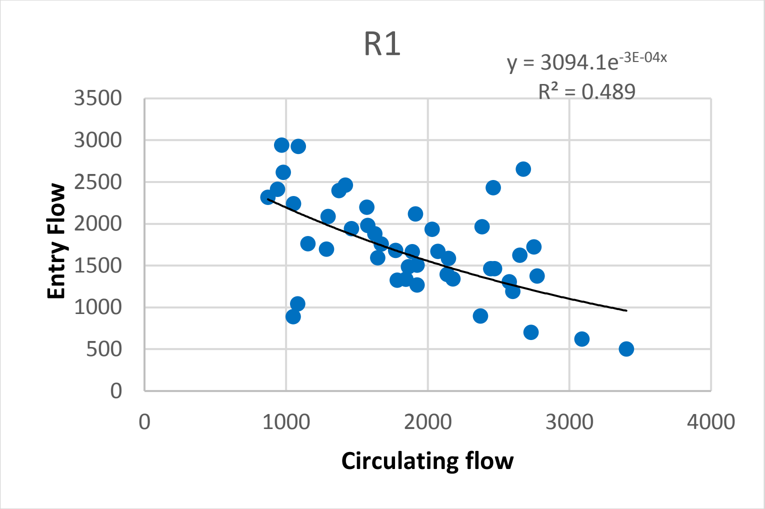


**Figure 3. Plot for field observation of entry capacity**

From the above plot, it can be concluded that for the intersection studied, the relationship between entry capacity and circulatory flow is found to be negative exponential. It shows that the entry capacity reduces exponentially with the increase in circulating flow. The functional forms are found to be acceptable with respect to $R^2$ value of the estimated equation. The relationship obtained is supporting the general trend that when the flow on circulating space is low, more number of vehicles can enter from given approach, as the vehicles in circulating flow increases it causes hindrance to the entry vehicle and hence lesser number of vehicle will find suitable gap to enter into the roundabout area.

## 7. Development of Simulation Model

Modelling of roundabouts under heterogeneous and non-lane disciplined traffic conditions is a difficult task as several factors are to be taken care of which will not arise under homogeneous and lane-based traffic conditions. Hence model requires the process of adjusting and fine-tuning model parameters by using real world data to reflect local traffic conditions. This process is termed as model calibration. Validation is the determination that a model is an accurate representation of the real system. It is a crucial element in assessing the model's value for making policy decisions and is aimed to produce a model that represents true system behaviour so that the model can be used as a substitute for the physical system. Validation is usually achieved through the calibration of the model, an iterative process of comparing the model to actual system behaviour and using the discrepancies between the two, and the insights gained, to improve the model. This process is repeated until model accuracy is judged acceptable. So many studies were carried out earlier to model roundabouts using VISSIM, but studies are limited under Indian conditions. In present study, the roundabout R1 is modelled and effect of change in composition is studied using VISSIM model.

A model which accurately represents the design and operational attributes of the study stretch in the simulation software is known as the "base model". When this base model is calibrated and validated to replicate the actual or ground conditions, the model can be used to study different characteristics that were not defined by the user as an input. The base model development involves the following steps:

(a) Development of Base Link/Network.
(b) Defining Model Parameters.
(c) Calibrating the Model.
(d) Validating the Model.

The intersection is created using links and connectors by overlapping it over the aerial map of the study section in VISSIM. Figure shows the intersection made in VISSIM for R1

**Figure 4. VISSIM model of R1**

Dimensions of vehicles have great effect on the results obtained and therefore it is very important to modify the default settings of the software according to the field condition. So, to cater the issue for Indian road way conditions Indian vehicular models were added as a 3D models along with standard Indian vehicular dimensions as shown in the table 6.

**Table 6. Vehicular Dimensions adopted in present study**

| **Sl. No.** | **Vehicle category** | **Average dimensions of vehicle (m)** | | **Projected area (m2)** |
|---|---|---|---|---|
| **1** | Two- wheeler | 1.87 | 0.64 | 1.2 |
| **2** | Three- wheeler | 2.6 | 1.4 | 3.64 |
| **3** | Small car | 3.72 | 1.44 | 5.36 |
| **4** | Big car | 4.58 | 1.77 | 8.11 |
| **5** | LCV | 5.00 | 1.90 | 9.5 |
| **6** | Bus | 10.3 | 2.5 | 25.75 |
| **7** | Truck | 7.2 | 2.5 | 18.0 |

For any vehicle type the speed distribution is an important parameter that has a significant influence on roadway capacity and achievable travel speeds. If not hindered by other vehicles, a driver will travel at his desired speed (with a small stochastic variation called oscillation). The more vehicles differ in their desired speed; the more platoons are created. If overtaking is possible, any vehicle with a higher desired speed than its current travel speed is checking for the opportunity to pass - without endangering other vehicles, of course. Stochastic distributions of desired speeds are defined for each vehicle type within each vehicle composition. To give speed as stochastic form, S curves were plotted for each category irrespective of the composition.

VISSIM provides additional settings for modelling roundabouts which can be calibrated according to the field conditions. These settings include:

1. Reduced speed area
2. Conflict areas and/or
3. Priority rules

These functions facilitate to replicate the behaviour of vehicles at roundabouts as the accepted and rejected behaviour of vehicles are dependent on these values which in turn affects the capacity. Speed maintained by different vehicles at the intersection were obtained from the entry and exit time of each vehicle in the intersection and the corresponding distance travelled by the vehicles are got from Google Earth. Speed reduction areas are not clearly available from field as vehicles are seemed to be randomly behaving while approaching the intersections. Thus, speed distributions are plotted for each category of vehicles and are input in VISSIM. The speed values for R1 are shown in Figure 30. The obtained distributions are given for the model as a whole without giving reduced speed areas.

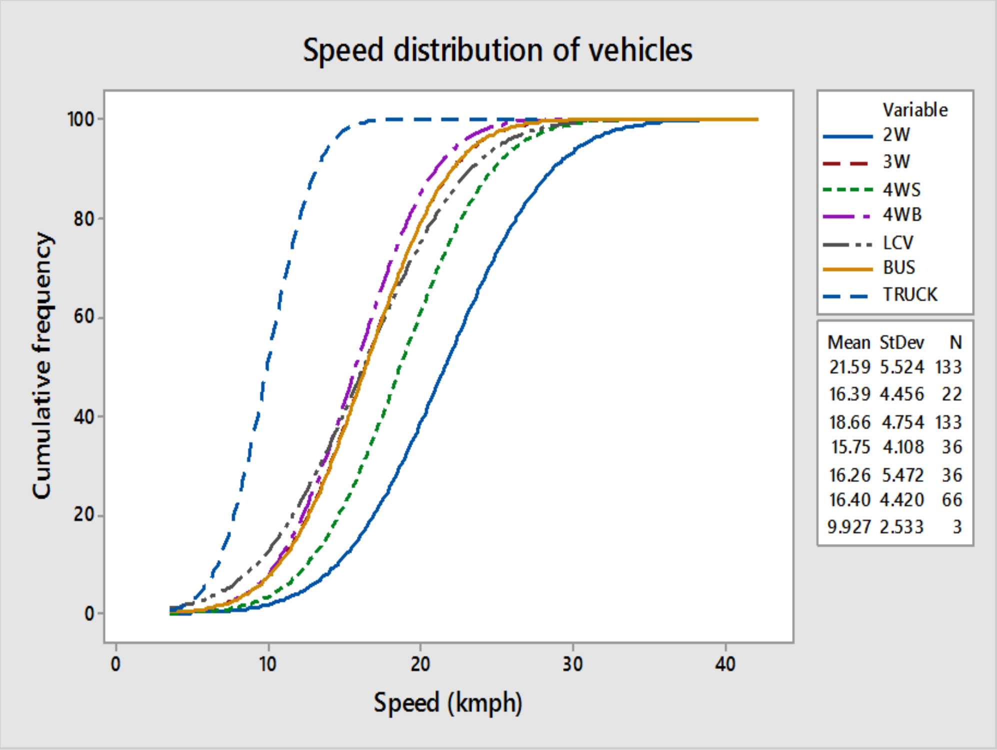
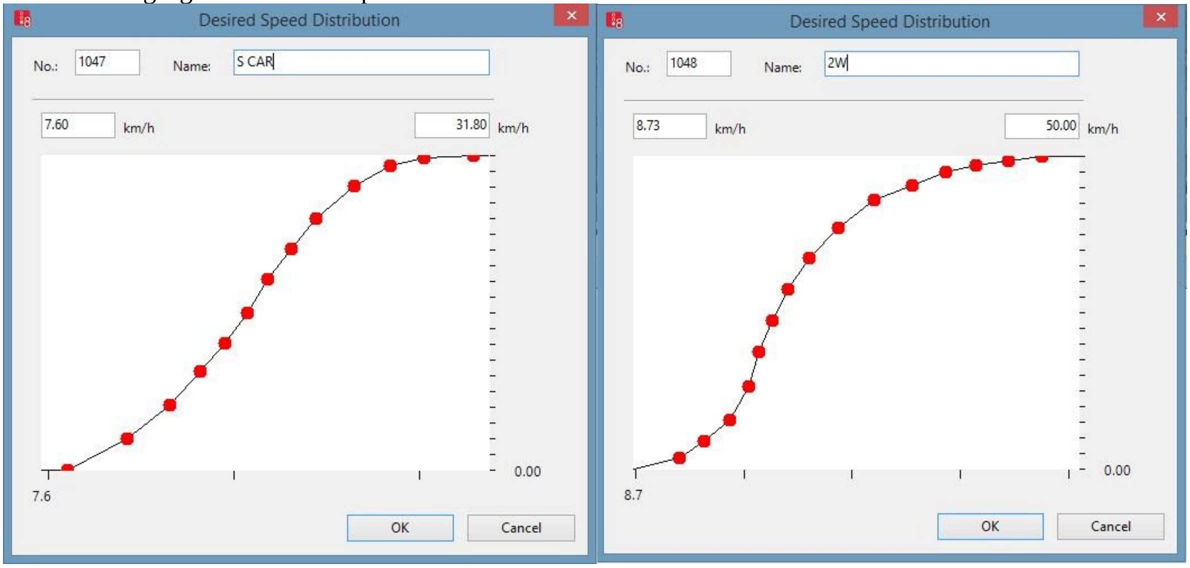


**Figure 5. Speed distribution of vehicles in R1**

The following figure shows the Speed distribution fit for VISSIM.



Desired Speed Distribution
No.: 1047 Name: S CAR
7.60 km/h 31.80 km/h

Desired Speed Distribution
No.: 1048 Name: 2W
8.73 km/h 50.00 km/h

**Figure 6. Speed Distribution fit for VISSIM**

Conflict areas are those zones in the roundabout area where merging and diverging occurs. Vehicles from on link are required to yield for the other vehicle at conflict areas for smooth operation of roundabout. As per the standards, at entry vehicles in the major stream (circulating flow) are given priority to the minor stream vehicles (entry flow). That is, vehicles stop at the entry when there is flow in the major stream. To set these conditions, conflicts areas are set accordingly to obtain the field condition. But most of the cases, in Indian condition, the circulation flow stops for the entering traffic. The same trend was observed in the all study sections and various combinations of parameters are adjusted by trial and error method for obtaining a model which replicates the field conditions. The software has limitations in replicating the exact randomness observed in the field. However, the parameters shown below showed results staying close to field are calibrated as shown below. The exit priority was made as passive as shown in Figure 7, so as to replicate the field condition. The default and calibrated values are shown in Table 7.

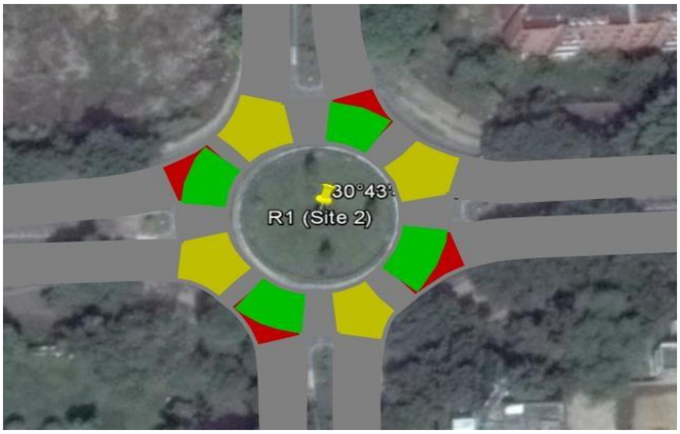


**Figure 7. Conflict areas for Intersection R1**

The model was run with the default settings initially but as these values seemed higher for the field condition, by trial and error the values were calibrated so attain the field condition. The default and calibrated values are shown in the table 7 below:

**Table 7. Conflict area settings**

| **Parameter** | **Default** | **Calibrated** |
|---|---|---|
| **Front gap** | 0.5 | 0.1 |
| **Rear gap** | 0.5 | 0.1 |
| **Meso critical gap** | 3.0 | 2.5 |
| **Safety distance factor** | 1.5 | 0.6 |
| **Additional stop distance** | 0 | 0 |

Following and lateral behavior of vehicles are important factors to be calibrated especially for Indian conditions. These take care of the driving characteristics of vehicles while conflict areas and priority rules determine the way in which vehicles behave in the roundabout. The lateral behavior parameters enable vehicles to travel at different lateral positions and overtake other vehicles within the same lane if it is wide enough. Based on the literature (S Arkatkar 2010) and available secondary data lateral clearance values were taken as shown in the table 8.

**Table 8. Lateral clearance share adopted based on vehicle category (S Arkatkar 2010)**

| **Sl. No.** | **Vehicle category** | **Lateral clearance share (m)** | |
|---|---|---|---|
| | | @standstill condition | Moving @50 kmph |
| **1** | Two-wheeler | 0.25 | 0.3 |
| **2** | Three-wheeler | 0.25 | 0.3 |
| **3** | Car | 0.3 | 0.5 |
| **4** | LCV | 0.3 | 0.5 |
| **5** | Bus | 0.4 | 0.7 |

For calibrating following behavior, Wiedemann 74 Model is used. From previous literature work done, the ranges of parameters have been found and by trial and error, the values of these parameters are finalized. The values calibrated are shown in the table 9 below:

**Table 9. Calibrated Wiedemann 74 parameters**

| **Sl. No.** | **Following vehicle category** | **Wiedemann 74 parameters for R1 and R2** | | | **Wiedemann 74 parameters for R3** | | |
|---|---|---|---|---|---|---|---|
| | | AX | bx_add | bx_mult | AX | bx_add | bx_mult |
| **1** | Two-wheeler | 0.5 | 0.3 | 0.35 | 0.3 | 0.25 | 0.3 |
| **2** | Three-wheeler | 0.5 | 0.4 | 0.45 | 0.3 | 0.35 | 0.4 |
| **3** | Car | 0.5 | 0.6 | 0.7 | 0.3 | 0.5 | 0.6 |
| **4** | LCV | 0.5 | 1.2 | 2.0 | 0.3 | 0.4 | 0.6 |
| **5** | Bus | 0.5 | 1.5 | 2.0 | 0.3 | 1 | 1 |
| **6** | Truck | 0.5 | 1.5 | 2.0 | 0.3 | 1 | 1 |

It can be observed that driving behaviour at two study locations situated in the same city is matching even though the island diameter varies. It shows that island diameter has a negligible effect on the driving behavior. The calibration was repeated till the entry capacity Vs circulating flow curve matches for both field and simulated models. The curves obtained for R1 is shown in Figure for reference.

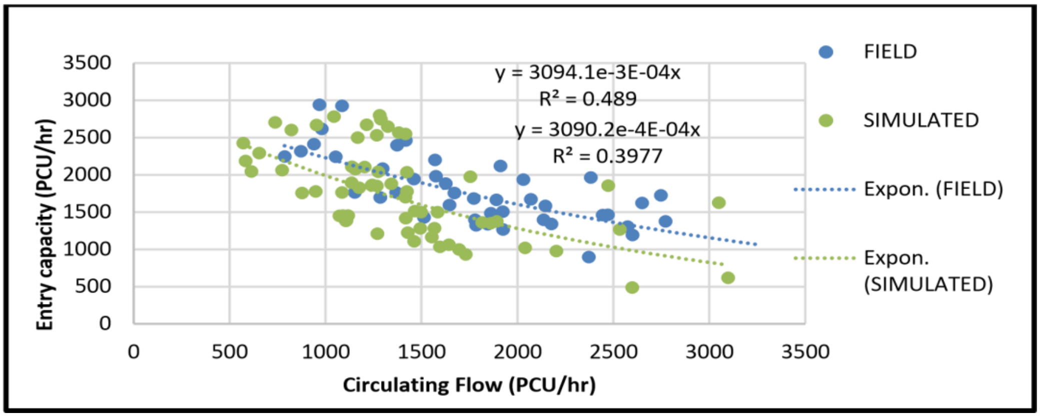


**Figure 8. Plot for field and simulation observation of entry capacity**

It can be noted that the difference between field and simulated entry capacity are almost matching at low circulating flows and the difference between them increases as the circulating flow increases. The reason behind this can be explained with the prevailing traffic conditions in the field as vehicles were entering into the major stream even though there is flow in the major stream. Also, VISSIM model performs well under low circulating flow conditions as the software has limitations in fully representing the exact field conditions.

Simulation models were made and simulation was run for 1 hour with 20 seeds and a seed increment of two. Results were collected by setting nodes, data collection points and travel time counters. For obtaining the entry capacity, the flow during queue formation was collected for both circulating and entry flow. Validation was done by using the travel time or occupancy time of vehicles from entry to exit of the roundabout. Occupancy time in a given direction of movement is defined as the time taken by the subject vehicle to clear the roundabout separately for left-movement, straight movement, or right-turn movement. So, time difference between two time stamps (entry time stamp at which the front bumper of the subject vehicle enters into the roundabout at a particular entry point and time stamp at which the back bumper of the same vehicle exits out of roundabout) is considered as time occupied by each of the vehicle categories in the extraction process. Also, the variable occupancy time (time for which the subject vehicle occupied the roundabout expressed in seconds) incorporates the effect of various roadway geometries and traffic factors affecting the movement of a vehicle in a given roundabout. Data were extracted from the field and was compared with VISSIM travel time results. Statistical validity was done using t-test analysis for each vehicle category which is shown in Table 10. It was observed that the model is performing reasonably well.

**Table 10. Paired t-test results for travel time in R1**

| Vehicle category | left movement | | | straight movement | | | right movement | | |
|---|---|---|---|---|---|---|---|---|---|
| | **t value** | **t critical** | **p value** | **t value** | **t critical** | **p value** | **t value** | **t critical** | **p value** |
| **2w** | 0.6 | 1.96 | 0.551 | 0.16 | 1.96 | 0.879 | 1.15 | 1.96 | 0.258 |
| **3w** | 0.3 | 1.96 | 0.768 | 0.42 | 1.96 | 0.674 | 0.98 | 1.96 | 0.344 |
| **Small car** | 0.37 | 1.96 | 0.717 | 0.63 | 1.96 | 0.533 | 0.99 | 1.96 | 0.328 |
| **Big car** | 0.38 | 1.96 | 0.705 | 0.51 | 1.96 | 0.612 | 1.62 | 1.96 | 0.114 |
| **LCV** | -0.35 | 1.96 | 0.733 | 1.57 | 1.96 | 0.134 | - | 1.96 | - |
| **Bus** | - | - | - | 0.15 | 1.96 | 0.884 | -1.9 | 1.96 | 0.1 |

Microscopic validation was performed using critical gap obtained from field and simulation. Variation of critical gap from field, and which obtained from simulations, follows a similar pattern in all the selected roundabouts. Critical gap estimated for R1 using Raff's Method is shown in the Figure as an example. Critical gap obtained from the field is 1.5s, whereas, from simulation, it is reported as 1.7s. The variation can be explained due to the abnormal behavior of two-wheelers in the field. Two-wheelers are accepting all the possible gaps available for them, but in simulation vehicles behave according to the predefined settings.

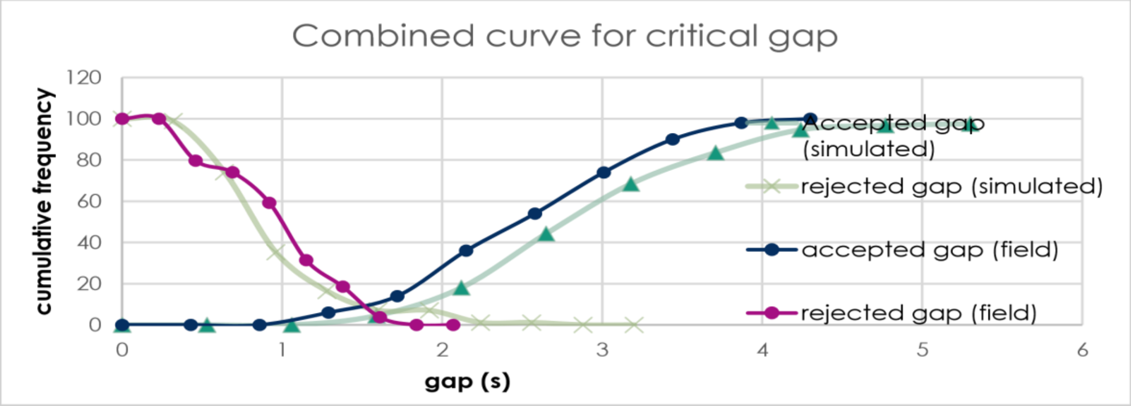


**Figure 9. Raff's method for field and simulated values**

Thus, the validation of the models was done using microscopic and macroscopic parameters. The models were finalized and the study was further extended to study the effect of change in composition on the passenger car unit values. For this, the proportion of 2-wheeler was modified and the observation were made for entry flow and circulatory flow. For the study, the proportion of 2-wheeler was modified twice with increase of 5% each time. For this, the proportion of small car was reduced by 3%. The proportion for big car and 3-wheeler was reduced by 1% each with perception that there is shift of mode in the same pattern at the study area. The proportion of 2-wheeler was analysed at different time of observation and it was found that the 2-wheeler proportion was ranging between 30% to 55%. Hence the simulation was run for the increase in proportion of 2-wheelers for 5% twice. The average proportion of 2-wheeler for the study section was 40% hence with increase of 5% as discussed above, the PCU values were found with 2-wheeler proportion of 45% and 50%. The PCU value was determined with the same methodology as explained earlier and the PCU values were noted as shown in the table 11 below.

**Table 11: Showing PCU Values of different Vehicle Categories**

| Proportion of 2-Wheeler | **40%** | **45%** | **50%** |
|---|---|---|---|
| **2w** | 0.22 | 0.21 | 0.21 |
| **3w** | 0.84 | 0.82 | 0.80 |
| **SC** | 1.00 | 1.00 | 1.00 |
| **BC** | 1.91 | 1.93 | 1.94 |
| **LCV** | 2.20 | 2.19 | 2.22 |
| **BUS** | 6.10 | 6.29 | 6.70 |

The above values of PCU were further utilised for determining the entry capacity. For this purpose, the entry flow values and circulating flow values of each observed queue formation are first converted into the equivalent entry capacity and circulating flow using the corresponding aggregated PCU values of different vehicle categories obtained from occupancy method. The graphs thus plotted for the entry capacity from field and simulated samples and along with the modified composition and the plot is shown below.

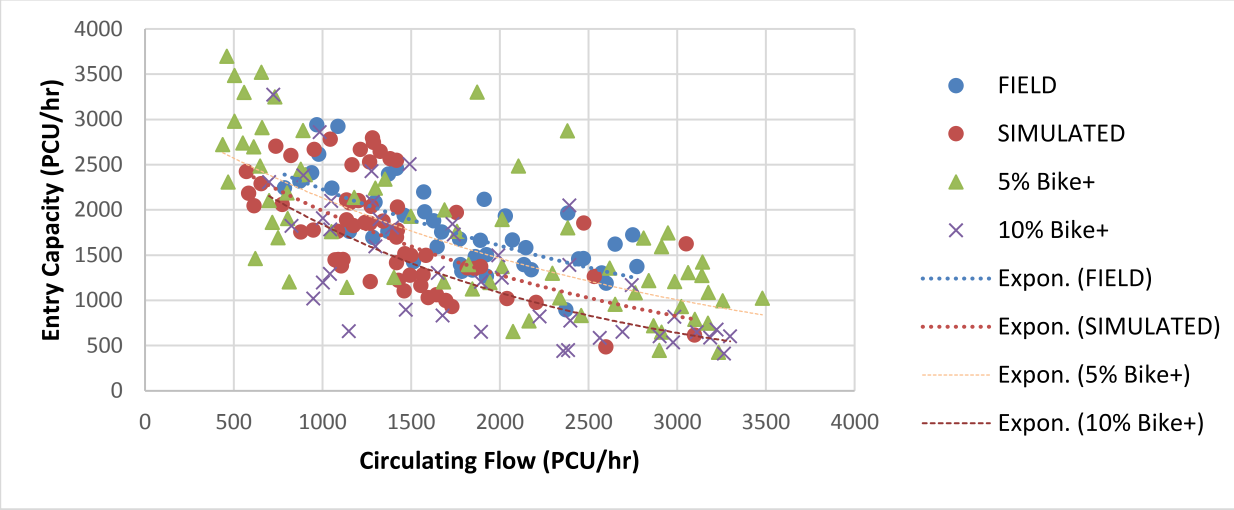


**Figure 10. Plots for field and simulated values with 5 and 10% increase in 2-wheeler**

Simulation samples were obtained from running the simulation for 3 random seeds and the points collected thus was utilized for the plot. The capacity values were found to increase with increase in the proportion of 2-wheelers.

**Table 12. Entry capacity values**

| **Observation** | Entry Capacity (PCU/Hr) | R$^2$ Values |
|---|---|---|
| **Field data** | 3094.1 | 0.489 |
| **Simulated data** | 3090.2 | 0.397 |
| **5% increase in 2-Wheeler** | 3102.5 | 0.519 |
| **10% Increase in 2-Wheeler** | 3112.2 | 0.556 |

From the above result, it can be observed that there is no considerable change in capacity values for 5% and 10% increase in 2-wheeler when compared to the values obtained through simulation. the capacity values are obtained through converting the traffic in terms of PCU per hour hence the reason for no considerable change in capacity value is due to insignificant change in PCU values of different vehicle categories. However more observations are required to check the effect of increase in small car and big car in the composition which may result in change in PCU values of different vehicle categories.

## CONCLUSION

The results of the present study show that there is no significant difference in values observed for accepted gap and forced gap hence excluding the forced gaps in determining capacity and critical gap for intersection shall not affect the result. For this purpose, an important tool is simulation. The model simulated is found to depict the field condition closely through validation using microscopic and macroscopic parameters for the roundabout studied. The model thus calibrated can be used for various further studies varying the elements of roundabout and its composition. Present paper studies the effect of change in PCU values of various vehicle categories using occupancy method. Present study shows that there is low variation in PCU values of vehicles by varying the composition of two-wheeler by 5% and 10% suggesting that increase in two-wheeler proportion does not affect other vehicle movements considerably. Similarly, the study was also carried on determining the entry capacity of roundabout. It was further found that due to insignificant change in PCU values, there is no considerable change in entry capacity of roundabout. The study can be further extended by changing the composition of three-wheeler and larger vehicles at roundabout.

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