Effect of vehicle characteristics and road geometric interface on capacity of roads

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ABSTRACT
India is the nation with heterogeneous traffic condition and the increasing population day to day, this reduces the capacity of roads. The capacity of the roads is affected by the road geometric condition, driver’s behavior and the traffic condition on the roads. In the following study, the effects of road geometry and vehicle characteristic are seen on the capacity of roads. The study was done on the urban roads of Nagpur, Maharashtra. The roads taken in the study are of different types with different geometric conditions, which are analyzed by their conditions and dimensions of the roads. The second phase of the study deals with vehicular characteristics. The proportion of each type of vehicles has its own effect on the capacity of the roads. The speed of the vehicles is also an important factor for finding capacity. As the traffic in India is heterogeneous the Passenger Car Unit (PCU) is used for calculating the capacity of roads. The regression models are used to find the results of the proportional effects of vehicles and vehicle/speed on the capacity. The final capacity of the roads is done with the Greenshields model. The estimation of capacity is done from the linear equation generated by Greenshields model. And then results are compared with the result obtained from the regression model to find the effects of the roads.

Keywords— Capacity, Geometric condition, Traffic condition, Vehicle characteristic, Heterogeneous, Passenger Car Unit, Regression models, Greenshields model

1. INTRODUCTION
India has the massive road network of over 5.9 million km counted on 31 January 2019. At every 1.70 km of roads are present as per square kilometre of land. Which shows that the roads in cities are all connected to each other properly. The road network has a different type of roads such as the Arterial roads, Sub-Arterial roads and Collector roads, with their different characteristics like lane width, shoulder condition and width and gradients of roads. These roads derived on their speed, traffic, distance and parking space available.

Nagpur is the 3rd largest city in Maharashtra with a population of 2.872 million, which is increasing continuously. The 13 lakh and still counting vehicles are moving on the streets of Nagpur. With such a huge number of vehicles, it becomes hard for the vehicles to have a free flow. This results in such a way that vehicles occupy all the lateral position on the roads depending which are available at that time without any lane discipline. Therefore, finding the traffic volume at the specific time on a specific section of roads on the basis of the static and dynamic characteristics of vehicles which varies on such a large extent becomes impossible. So, the vehicles are expressed on the ‘standard unit’ which is the Passenger Car Unit (PCU) per hour. The PCU is adopted in all the heterogeneous traffic condition countries for finding the traffic volume or capacity. The dynamic characteristics affect the PCU values of the vehicles. The vehicles have their dynamic characteristics which make there PCU different.

The study is done to identify the effects of vehicles and road geometric conditions on the capacity of the heterogeneous roads. The regression models are used to estimate the capacity based on their vehicle characteristics.

2. BACKGROUND STUDIES
There are various research work and case studies have been done for the estimation of capacity with road geometry and vehicles interactions for the developed and developing countries. Here some of the paper is revised.

The requirement of overtaking lane can increase the traffic volume, and increase the speed of vehicles. But vehicles passing on the opposite lane reduces the volume of the vehicles get affected which shows that there is the effect of one lane on other. The roads condition also affects the capacity of roads. As the traffic is heterogeneous problems for overtaking side becomes more affected. [1]
The road geometric characteristics such as the Tangent and Horizontal curves effects were considered in the study to find there influencing in the capacity of the roads. A regression model was used to find the relation between the geometric characteristic (tangent, curves and loss between the two elements) and capacity. The best regression model was considered. [2]

The Geometric measures like the width of carriageway, sidewalks, service roads medians, and verge and road reserve and traffic pattern to different roads. The passenger car equivalent PCE is used instead of PCU. Based on IRC signification, the mathematical model is developed by the regression analysis which is performed for the capacity. Capacity effecting zones are found by finding the relation between capacity and cross-section elements. This helps to study the variations in capacity with respect to different road elements which are considered in the PCE. Impact on the capacity of roads is considered due to the geometric and road elements. The results are the realistic and most efficient capacity of roads. [3]

The PCU values are dynamic which are affected by the traffic volume of the road. The traffic volume and composition, the simulation equation was derived to find their speed. An equation was used to find the changes in PCU values with traffic volume. The variation in PCU values is explained on the interaction of vehicles types with different volume levels. The vehicles were characterized into five types 2-Wheeler, 3-Wheeler, small cars, big cars and heavy vehicles with the PCU ranges of 0.20-0.23, 0.99-1.01, 1.47-1.65 and 5.51-6.54 respectively. The simulation equation was checked with the actual data. The testing shows that the PCU prediction data of model and field data doesn’t very much. But the capacity values with the different PCU values have a difference less than 2%. [4]

The capacity is estimated of this midblock section influenced by their operating speed. The lane capacity of this midblock is found to be from 1482 to 2105 PCU/hr. This variation is due to the size of the city and driver’s behaviour which affects the free flow speed. From the above data is used to find the 85\(^{th}\) percentile operating speed. The lane capacity is depending on the operating speed. The model is developed to validate the collected speed flow data at two sections and their capacity is estimated from the field data and the model developed. The error occurred in the study is 0.1 \(\%\) between field data and the model. The operating speed of roads can vary due to its road surface condition, side friction of roads. The model of capacity is very useful for determining the capacity of urban roads by the operating speed. [5]

### 3. OBJECTIVES

The objectives for the project are:

(a) To study the effect of roads capacity by vehicles characteristics.

(b) To determine the capacity of roads by road geometric conditions.

(c) To determine the overall capacity of roads.

### 4. METHODOLOGY

The data required for the study is collected from Nagpur city. The data collected are from the section which has different road geometric characteristics. The selected roads are Arterial roads, Sub-arterial Roads and Collector Roads.

#### Table 1: Selected sites for the study

<table>
<thead>
<tr>
<th>Sr. no</th>
<th>Name of the Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Orange city hospital to Chhatrapati chowk</td>
</tr>
<tr>
<td>2</td>
<td>Ajini police station to medical</td>
</tr>
<tr>
<td>3</td>
<td>Chhatrapati chowk to Orange city hospital</td>
</tr>
<tr>
<td>4</td>
<td>Mangalmurti chowk to jaitala</td>
</tr>
<tr>
<td>5</td>
<td>Medical to Ajini Police Station</td>
</tr>
<tr>
<td>6</td>
<td>Jaitala to Mangalmurti chowk</td>
</tr>
</tbody>
</table>

The traffic volume is calculated on the selected site which is mentioned above. For the volume count, the vehicles considered are a hatchback, S.U.V, sedan, 2-wheeler, 3-wheeler auto, 3-wheeler electric auto, city bus, travel bus, mini truck, container truck, trailer, L.C.V and bicycles. The collected data is of peak hours. To find the capacity of the sections of roads. To find the PCU values the area of vehicles is given as follows.

#### Table 2: Area of vehicles

<table>
<thead>
<tr>
<th>Sr. no</th>
<th>Vehicle Categories</th>
<th>Length in m</th>
<th>Breadth in m</th>
<th>Total Area in m(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hatchback</td>
<td>3.6</td>
<td>1.6</td>
<td>5.76</td>
</tr>
<tr>
<td>2</td>
<td>S.U.V</td>
<td>4.4</td>
<td>1.8</td>
<td>7.92</td>
</tr>
<tr>
<td>3</td>
<td>Sedan</td>
<td>4.5</td>
<td>1.8</td>
<td>8.1</td>
</tr>
<tr>
<td>4</td>
<td>2-Wheeler</td>
<td>1.8</td>
<td>0.6</td>
<td>1.2</td>
</tr>
<tr>
<td>5</td>
<td>3-Wheeler auto</td>
<td>2.6</td>
<td>1.3</td>
<td>3.38</td>
</tr>
<tr>
<td>6</td>
<td>3-wheeler electric auto</td>
<td>2.8</td>
<td>0.95</td>
<td>2.68</td>
</tr>
<tr>
<td>7</td>
<td>City Buses</td>
<td>12</td>
<td>2.51</td>
<td>30.12</td>
</tr>
<tr>
<td>8</td>
<td>Travel buses</td>
<td>10.65</td>
<td>2.56</td>
<td>27.264</td>
</tr>
<tr>
<td>9</td>
<td>Mini truck</td>
<td>6.4</td>
<td>2.136</td>
<td>13.67</td>
</tr>
<tr>
<td>10</td>
<td>Container truck</td>
<td>9.7</td>
<td>2.5</td>
<td>24.25</td>
</tr>
<tr>
<td>11</td>
<td>trailer</td>
<td>12.19</td>
<td>2.43</td>
<td>29.62</td>
</tr>
<tr>
<td>12</td>
<td>L.C. V</td>
<td>6</td>
<td>1.9</td>
<td>11.4</td>
</tr>
<tr>
<td>13</td>
<td>Bicycle</td>
<td>1.9</td>
<td>0.45</td>
<td>0.85</td>
</tr>
</tbody>
</table>

The traffic volume of the vehicles is calculated for these types of vehicles for all the six sections for the peak hours.
4.1 Regression regarding the proportion of Vehicles
The regression analysis is the statistical model. The Regression analysis is done to find the relationship between the selected variables. It is used to find the relationship between the 1 dependent variable and many independent variables. Here the dependent variable is the volume of the vehicles on site condition and the independent variable are the proportion of vehicles on the field. This regression is done with the help of Minitab software.

4.2 Speed of vehicles
Speed of the vehicles is calculated of the collected data. For finding the speed of each vehicle the distance of 30m is taken. The time of each vehicle is count by the help of stopwatch. As the vehicle enters the starting point of the 30 m the stopwatch is started and closed when the vehicles leave the end point of the 30m. By this manual way, the time taken by each vehicle is calculated and noted in the Excel sheet for the easy handling of data. After collecting the time duration of each vehicle, their speed was calculated with the help of

\[
\text{Speed} = \frac{\text{Distance}}{\text{Time}}
\]

4.3 Regression regarding vehicle/speed
The regression done in this phase of the project is taken of vehicle/speed with the volume of vehicles the independent variable considers in this relationship are the vehicles/speed. And the dependent variable in this regression is the volume. The regression done here is done while considering the constant as it was giving more accuracy in the result.

4.4 Root-mean-square-error
Root-Mean-Square-Error (RMSE) is used to find the difference of two samples it is done with the help of model or by the estimator. The result obtained from this is always positive value the closer the value toward zero better the value. Mostly the value should be positive it becomes easy for comparison of the data. The formula used over here for the RMSE is

\[
\text{RMSE} = \sqrt{\frac{\sum (y^\cdot - y)^2}{n}}
\]

Where,
\( y^\cdot = \) Predicted values for RMSE
\( y = \) Depending variable till n times
\( n = \) numbers of values

4.5 PCU Calculation
The passenger car unit is the ‘standard unit’ for heterogeneous traffic condition to calculate the capacity of the roads. The PCU is calculated with the formula

\[
\text{PCU} = \frac{V_c}{V_i} \times \frac{A_c}{A_i}
\]

Where,
\( V_c = \) Speed of hatchback car (km/h)
\( V_i = \) Speed of i th type vehicle (km/h)
\( A_c = \) area of a hatchback car (m2)
\( A_i = \) area of i th type of vehicle (m2)

4.6 Greenshields model
The Greenshields model gives the relation between the volume, speed and density. The Greenshields model uses a linear equation to find the value of \( R^2 \) the value of this should be near to the value of 1. The closer the value towards 1 the more the accuracy level of the model. The linear equation used for the Greenshields model is derived from the collected data. The graph created for the Greenshields model is created with the help of speed and density the density is plotted on Y-axis and speed on X-axis. By this data, the linear equation is generated. This equation is used to find the speed of the Greenshields model. In Greenshields model, the density is constant which is increasing with the value of 10 unit in every minute. After that, the volume is calculated by the product of speed and density.

4.7 Capacity of roads
The capacity is found with the help of this Greenshields model data and collected data. The capacity is calculated in both manners veh/hr as well as PCU/hr. The maximum value on the curve is noted as the capacity of the road. The curve is plotted of the positive values from the Greenshields model data. The values taken from the collected data are their volume and their speed of complete one hour. And from Greenshields model, only the positive values are taken of volume and speed. Both the data are feed in the two different series and both the series are combined to find out the result.

5. RESULTS
5.1 Results
5.1.1 Capacity of Geometric Condition: The geometric condition of the roads plays a very important role in the capacity of roads. The road parameter width of lanes, gradient, condition of the shoulder, slow-moving vehicles splitting of direction and unevenness of the surface this are required for finding the capacity of the roads.
Where,

\[ C_a = c_b \cdot f_g \cdot f_w \cdot f_{ds} \cdot f_{smv} \cdot f_s \cdot f_{ui} \]

- \( C_a \): actual capacity under prevailing roadway and traffic condition
- \( c_b \): basic capacity (3100 PCU/hr)
- \( f_g, f_w, f_{ds}, f_{smv}, f_s \) and \( f_{ui} \): are the adjustment factors for gradient, the width of the lane, directional split, slow-moving vehicles, shoulder condition and unevenness of the surface.

(a) Gradient adjustment factor = When there is no gradient the factor is 1.00 there is no upgradation or downgradation. If the gradient increase by 1% then the capacity degrades by 2.60% (\( f_g = 0.940 \)) and if the gradient decreases by 1% then the capacity increases by 3% (\( f_g = 1.03 \)).

(b) Adjustment for the width of lane = the standard width will affect the capacity by the following way as per HCM 2000

### Table 3: Adjustment factor of lane width

<table>
<thead>
<tr>
<th>Lane width (m)</th>
<th>3.6</th>
<th>3.3</th>
<th>3.0</th>
<th>2.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor (( f_w ))</td>
<td>1.0</td>
<td>0.88</td>
<td>0.76</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Direction Split= When the volume on two ways are not the same then it affects the capacity of the road in such a way

### Table 4: Adjustment factor for flow of direction

<table>
<thead>
<tr>
<th>Flow in main direction (%)</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjustment factor (( f_{ds} ))</td>
<td>1.00</td>
<td>0.97</td>
<td>0.94</td>
<td>0.90</td>
<td>0.87</td>
</tr>
</tbody>
</table>

(a) Slow moving vehicles= The slow-moving vehicles in the traffic volume of the roads are considered in this parameter while considering all lanes the slow-moving vehicles are less than 10% so the effect on capacity is not there so the factor will be 1.

(b) Condition of shoulder = The shoulders are very important to increase the capacity of roads. If the good quality shoulders are present then it can be utilised during the emergency. But the maintenance is very difficult of the shoulder so it breaks down. Therefore, it is categorized into 4 parts.

### Table 5: Adjustment factor for condition of the shoulder

<table>
<thead>
<tr>
<th>Condition of shoulder</th>
<th>Adjustment factor (( f_s ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td>Average</td>
<td>0.85</td>
</tr>
<tr>
<td>Poor</td>
<td>0.77</td>
</tr>
<tr>
<td>Bad</td>
<td>0.58</td>
</tr>
</tbody>
</table>

An unevenness of surface= The uneven surface affects the speed of the vehicles and on the capacity of roads. According to IRC 30-1993, the capacity is reduced by 300PCU/hr if the surface roughness is below 1000mm/km.

### Table 6: Capacity of roads based on road geometry condition

<table>
<thead>
<tr>
<th>S no.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lanes</td>
<td>Chhatrapati chowk to Orange city</td>
<td>Orange city to Chhatrapati chowk</td>
<td>Mangalmurti to Jaitala</td>
<td>Jaialta to Mangalmurti</td>
<td>Medical Square to Ajini police station</td>
<td>Ajini Police station to Medical Square</td>
</tr>
<tr>
<td>Base Capacity</td>
<td>3100</td>
<td>3100</td>
<td>3100</td>
<td>3100</td>
<td>3100</td>
<td>3100</td>
</tr>
<tr>
<td>Gradient</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Lanes width</td>
<td>3.6</td>
<td>3.6</td>
<td>3</td>
<td>3</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Shoulder condition</td>
<td>GOOD</td>
<td>GOOD</td>
<td>POOR</td>
<td>AVG</td>
<td>AVG</td>
<td>POOR</td>
</tr>
<tr>
<td>Slow moving vehicles</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Direction split</td>
<td>50</td>
<td>50</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Surface unevenness</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>( f_g )</td>
<td>1</td>
<td>0.97</td>
<td>1</td>
<td>0.97</td>
<td>1</td>
<td>1.03</td>
</tr>
<tr>
<td>( f_w )</td>
<td>1</td>
<td>1</td>
<td>0.76</td>
<td>0.76</td>
<td>0.88</td>
<td>0.88</td>
</tr>
<tr>
<td>( f_{ds} )</td>
<td>1</td>
<td>1</td>
<td>0.97</td>
<td>1</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>( f_{smv} )</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>( f_s )</td>
<td>1</td>
<td>1</td>
<td>0.77</td>
<td>0.85</td>
<td>0.85</td>
<td>0.77</td>
</tr>
<tr>
<td>( f_{ui} )</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Capacity</td>
<td>3100</td>
<td>3007</td>
<td>1759.7</td>
<td>1942.52</td>
<td>2249.24</td>
<td>2098.67</td>
</tr>
</tbody>
</table>

### 5.1.2 Proportional Equation made on Minitab

The capacity of roads depends upon the traffic volume of the field data. The traffic has various types of roads. The 13 types of roads are considered in the study. The data of vehicles are differentiated according to the percentage of the vehicles.

The data collected from the selected site are represented below
The capacity of each lane will also differ as per their proportion. Therefore, to find the capacity as per the proportions of vehicles the Minitab software is used. In Minitab, the regression analysis of the proportion is done with the dependent variable as the volume of the vehicles. The regression done in the Minitab is done with removing the errors and increasing the accuracy with 95%+. The equation generated to find the capacity are as follows:

**Chhatrapati Chowk to the Orange City Hospital**

\[ C = 19.195 \times 2 \text{ Wheelers} + 22.11 \times \text{Hatchback} + 16.40 \times \text{S.U.V} + 21.18 \times \text{Sedan} + 21.87 \times \text{3-Wheeler} + 19.55 \times \text{3-Wheeler Electric Auto} + 24.16 \times \text{City Bus} + 9.54 \times \text{Travel Buses} + 10.74 \times \text{Mini Truck} + 17.97 \times \text{3-Wheeler Auto} + 19.72 \times \text{Continer Truck} + 21.51 \times \text{Trailer} + 16.65 \times \text{L.C.V} + 15.76 \times \text{Bicycle} \]

\[ C = 1911.166 \]

**Orange City Hospital to Chhatrapati Chowk**

\[ C = 22.779 \times 2 \text{ Wheelers} + 21.42 \times \text{Hatchbacks} + 23.62 \times \text{S.U.V} + 26.21 \times \text{Sedan} + 26.21 \times \text{3-Wheeler} + 20.87 \times \text{3-Wheeler Electric Auto} + 14.70 \times \text{City Bus} + 11.18 \times \text{Travel Buses} + 30.76 \times \text{Mini Truck} + 24.93 \times \text{Container Truck} + 21.03 \times \text{Trailer} + 18.05 \times \text{L.C.V} + 8.83 \times \text{Bicycle} \]

\[ C = 2227.797 \]

**Jaitala to Mangalmurti**

\[ C = 14.374 \times 2 \text{ Wheelers} + 21.42 \times \text{Hatchbacks} + 16.26 \times \text{S.U.V} + 8.34 \times \text{Sedan} + 11.5 \times \text{3-Wheeler} + 13.69 \times \text{3-Wheeler Electric Auto} + 10.30 \times \text{City Bus} + 5.64 \text{Travel Buses} + 19.88 \times \text{Mini Truck} + 19.02 \times \text{Container Truck} + 20.80 \times \text{Trailer} + 10.97 \times \text{L.C.V} + 15.16 \times \text{Bicycle} \]

\[ C = 1770.657 \]

**Medical Square to Ajini police station**

\[ C = 1770.063 \]

**Ajini Police station to Medical Square**

\[ C = 1343.303 \]

**Fig. 1: Capacity of Road Geometry**

- **Chhatrapati Chowk to the Orange City Hospital**
- **Orange City Hospital to Chhatrapati Chowk**
- **Jaitala to Mangalmurti**
• Mangalumarti to Jaitala
C = 13.708 2 Wheelers % + 12.57 Hatchbacks % + 11.11 S.U.V % + 13.44 Sedan %+ 15.41 3-wheeler auto % + 10.18 3- Wheeler electric auto % + 13.43 City bus % + 15.53 Travel buses % + 15.35 Mini truck % + 13.21 Container Truck % + 12.45 Trailer % + 9.69 L.C.V % + 12.23 Bicycle % =1343.303

• Medical Square to Ajini police station
C = 17.880 2 Wheelers % + 16.27 Hatchbacks % + 17.23 S.U.V % + 16.09 Sedan %+ 23.59 3-wheeler auto% + 11.42 3-Wheeler electric auto % + 10.95 City bus % + 14.79 Travel buses % + 14.34 Mini truck % + 23.66 Container Truck % + 20.96 Trailer % + 18.45 L.C.V % + 21.09 Bicycle % =1770.3.

• Ajini Police station to Medical Square
C = 17.647 2 Wheelers % + 14.92 Hatchbacks % + 18.87 S.U.V % + 19.00 Sedan %+ 22.64 3-wheeler auto % + 19.15 3- Wheeler electric auto % + 17.78 City bus % + 16.51 Travel buses % + 17.16 Mini truck % + 20.88 Container Truck % + 19.19 Trailer %+ 19.16 L.C.V % + 17.92 Bicycle % =1770.063

5.1.3 Regression analysis based on the vehicle/speed ratio on Minitab: The vehicle characteristics that affects the road capacity include the speed of the vehicles. The speed affects the capacity. The regression analysis is done of the relation between the vehicle/speed with the volume of the vehicles. In this phase the regression analysis is done with help of taking the constant vehicle/speed ratio. This shows the relation between the volume, speed and the number of vehicles.

The equations as per the area:
• Chhatrapati Chowk to Orange City Hospital
C= 1720.1 + 65.1 2 Wheelers + 108.9 Hatch backs - 24 S.U.V - 49 Sedan - 35.0 3-wheeler auto+ 38.0 3- Wheeler electric auto + 81.7 City bus - 58 Travel buses - 168.1 Mini truck+ 74.8 Container Truck + 41.2 Trailer + 74 L.C.V - 10.2 Bicycle

• Orange City Hospital to Chhatrapati Chowk
C= 1554 + 149.6 2 Wheelers + 150 Hatch backs + 491 S.U.V + 371 Sedan + 143.4 3-wheeler auto+ 81.5 3- Wheeler electric auto + 2 City bus - 109 Travel buses + 284 Mini truck + 132 Container Truck + 26 Trailer + 237 L.C.V + 1.5 Bicycle

• Jaitala to Mangalumarti
C = 1086 + 73.3 2 Wheelers - 146 Hatch backs + 216 S.U.V + 682 Sedan + 145 3-wheeler auto + 121 3- Wheeler electric auto + 45 City bus - 14 Travel buses + 274 Mini truck + 183 Container Truck + 108 Trailer - 134 L.C.V + 58.3 Bicycle

• Mangalumarti to Jaitala
C = 1028.0 + 137.9 2 Wheelers + 294.2 Hatchbacks + 114.2 S.U.V + 90 Sedan + 23.8 3-wheeler auto + 6.0 3- Wheeler electric auto + 181.3 City bus + 72.1 Travel buses + 231.9 Mini truck - 32.2 Container Truck - 12.9 Trailer - 259.0 L.C.V - 28.2 Bicycle

• Medical Square to Ajini police station
C = 1772.9 + 1.7 2 Wheelers - 24.4 Hatchbacks + 27.1 S.U.V - 110.5 Sedan + 131.3 3-wheeler auto - 90.1 3- Wheeler electric auto - 214.0 City bus- 24.3 Travel buses - 128.2 Mini truck + 86.5 Container Truck + 71.0 Trailer + 20.9 L.C.V + 12.2 Bicycle

• Ajini Police Station to Medical Square
C = 1853.0 - 34.9 2 Wheelers - 114.5 Hatchbacks + 201 S.U.V - 181 Sedan + 179.6 3-wheeler auto + 64.3 3- Wheeler electric auto + 77.4 City bus - 113.8 Travel buses - 17.6 Mini truck - 0.9 Container Truck + 18.9 Trailer + 40.0 L.C.V + 11.2 Bicycle

The results obtained from this equation were compared with the volume of the field data. The comparison was done with the help of root mean square error. The formula used for the root-mean-square-error.

\[
RMSE = \sqrt{\frac{\sum(y^2 - y)^2}{n}}
\]

Where,
\(y^2 = \) Predicted values for RMSE
\(y = \) Depending variable till n times
5.1.4 Passenger car unit (PCU): The PCU is derived in the study with the help of the speed of the vehicles and Dimensions of the vehicles. The ratio of the speed of vehicles is taken as the speed of the required vehicles with the speed of hatchback. The ratio of the dimensions is taken as the dimensions of the required vehicle with the base of the hatchback. The PCU is calculated for each site separately.

Table 8: PCU of vehicles according to roads

<table>
<thead>
<tr>
<th>S no.</th>
<th>PCU for Chhatrapati chowk to the orange city hospital</th>
<th>PCU for Orange city hospital to Chhatrapati chowk</th>
<th>PCU for Jaitala to Mangalmurti</th>
<th>PCU for Mangalmurti to Jaitala</th>
<th>PCU for Medical Square to Ajini police station</th>
<th>PCU for Ajini Police station to Medical Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.22</td>
<td>0.22</td>
<td>0.24</td>
<td>0.23</td>
<td>0.23</td>
<td>0.21</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
<td>1</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>1.15</td>
<td>1.12</td>
<td>1.14</td>
<td>1.10</td>
<td>1.17</td>
<td>1.01</td>
</tr>
<tr>
<td>4</td>
<td>1.00</td>
<td>1.01</td>
<td>1.03</td>
<td>1.01</td>
<td>1.07</td>
<td>1.01</td>
</tr>
<tr>
<td>5</td>
<td>0.87</td>
<td>0.83</td>
<td>0.85</td>
<td>0.67</td>
<td>0.86</td>
<td>0.83</td>
</tr>
<tr>
<td>6</td>
<td>0.91</td>
<td>0.91</td>
<td>0.97</td>
<td>0.95</td>
<td>0.99</td>
<td>0.94</td>
</tr>
<tr>
<td>7</td>
<td>6.72</td>
<td>5.88</td>
<td>6.13</td>
<td>5.54</td>
<td>5.95</td>
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<tr>
<td>9</td>
<td>3.40</td>
<td>3.35</td>
<td>3.66</td>
<td>3.58</td>
<td>3.61</td>
<td>3.35</td>
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<tr>
<td>10</td>
<td>6.16</td>
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<td>6.58</td>
<td>6.37</td>
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<tr>
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<td>2.30</td>
<td>2.31</td>
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<tr>
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<td>0.46</td>
<td>0.44</td>
<td>0.44</td>
<td>0.41</td>
</tr>
</tbody>
</table>

5.1.5 Greenshields model: The Greenshields Model is used for the estimation of the capacity of roads. The Greenshields model is generated by the linear equation, and the linear equation is generated from the relation of Speed (V), Volume (Q) and Density(K). that is, Q=K*V. For generating the linear Equation and coefficient of determination ($R^2$) graphs are formed for the relation of Speed -Density both types of gthe raph are plotted (veh/hr and PCU/hr).
Fig. 4: speed-density relation for Chhatrapati chowk to orange city (a) Veh/Hr and (b) PCU/Hr

Fig. 5: Speed-density relation for Jaitala to Mangalmurti (a) Veh/Hr and (b) PCU/Hr

Fig. 6: speed-density relation for Mangalmurti to Jaitala (a) Veh/Hr and (b) PCU/Hr

Fig. 7: speed-density relation for Ajini Police station to Medical Square (a) Veh/Hr and (b) PCU/Hr
5.1.6 Capacity of Roads : The Capacity of Roads is estimated for all roads with the help of linear equation generated with the help of Greenshields model. The capacity estimation for all six roads are done. The graphs show the capacity of the graph.

(a) Fig. 8: speed-density relation for Medical Square to Ajini Police station (a) Veh/Hr and (b) PCU/Hr

The coefficient of determination ($R^2$) values for all roads are determined, the ($R^2$) values represents the proportion of the input values. The closer values of ($R^2$) towards 1 more the accuracy of the linear equation.

(a) Fig. 9: Capacity for Orange city to Chhatrapati chowk (a) Veh/Hr and (b) PCU/Hr

(b) Fig. 10: Capacity for Chhatrapati chowk to orange city (a) Veh/Hr and (b) PCU/Hr

(a) Fig. 11: Capacity for Jaitala to Mangalmurti (a) Veh/Hr and (b) PCU/Hr
The capacity of all the section is estimated here. It was done with the help of Greenshields model. For calculating the capacity, the graph is plotted with the help of volume and speed of the field data and the data obtained by the Greenshields model.

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**Fig. 12:** Capacity for Mangalmurti to Jaitala (a) Veh./Hr and (b) PCU/Hr

**Fig. 13:** Capacity for Ajini Police station to Medical Square (a) Veh/Hr and (b) PCU/Hr

**Fig. 14:** Capacity for Medical Square to Ajini Police station (a) Veh/Hr and (b) PCU/Hr

---

The capacity of all the section is estimated here. It was done with the help of Greenshields model. For calculating the capacity, the graph is plotted with the help of volume and speed of the field data and the data obtained by the Greenshields model.
6. CONCLUSIONS
This study helps us to conclude the effects of road geometric characteristics and Vehicle Characteristics on the capacity of the roads. The study was done on both parameters. The effects on capacity based on road Geometry are as follows.
- The capacity of the road is maximum when all the road characteristics of roads are in good condition.
- As the width of the lane reduces the capacity of the road reduces.
- The gradient of roads acts inversely on the capacity of roads.
- If the slow-moving vehicle increases the capacity of the roads reduces as it increases the congestion on the road. The effects on the capacity of roads by vehicular characteristic are as follows.
- The RMSE values are less than 10. Which shows the difference between the volume of roads and the number of vehicles/ speed of vehicles.
- The capacity based on the percentage of vehicles and Greenshields model. There is a maximum 8.5 percentage variation on Mangalmurti to Jaitala. Otherwise, all the results were having the difference less than 1 per cent. So, capacity can also be estimated with the regression method also.
- The regression model for the proportion of vehicles shows how much each type of vehicles effects. The multiplication factors before the percentage show how each type of vehicles is required for the capacity of the roads.

7. FUTURE SCOPE
The research ends here but there are some places for future studies or scope for improvement on the study of effects of road geometry and vehicle effects on the capacity of roads. A place for improvement is described below.
- The detailed study on the geometry of the road can be done for more effective results.
- Detail analysis of the vehicle’s characteristic can be done. More characteristic can be considered.
- The more study can be done on the capacity of a road with the same methodology.
- Combine effects of vehicles and road geometry can be considered on the capacity of roads.

8. REFERENCES