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Performance Analysis of Signalized Intersection at Metropolitan Area

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Abstract – *The aim of this paper is to measure the performance level of signalized intersections, based on traffic and geometric characteristics. The required field data were collected in Retteri signalized intersection, Chennai, India for 12 hours duration on weekdays. Traffic volume were analysed and peak hours volumes were estimated at morning and evening. Volume/Capacity (V/C) ratio was calculated by using IRC 106-1990. Vehicle delay was estimated by applying classical Webster's formula and level of service (LOS). Traffic volumes were projected for next 10years. V/C ratio and delay values were 0.801 and 39sec respectively. The performance results at Retteri junction was LOS D based on V/C ratio and delay values. The projected volume was exceeding than maximum capacity in next four years from base year data. The performance analysis results were shown the over saturated conditions at Retteri junctions and the study was proposed flyover to reduce the congestion level and huge vehicle delay. The flyover was designed by using MX ROAD software. This study has shown that it is easy to describe the current performance conditions of particular signalized intersections and is expected to help traffic engineers, planners and policy makers understand the evaluation of particular signalized intersections under mixed traffic conditions.*

Keywords: Signalized intersection, vehicle, delay, LOS, V/C ratio, Traffic Volume, MX ROAD

1.0 INTRODUCTION

Signalized intersections are one of the complex locations in urban networks. The operational qualities of urban networks were decreased and affected due to increase of traffic volume. The evaluation of present status and performance of signalized intersections is one of the important tasks in management and improvement of urban networks. Based on evaluation results, traffic planners can provide required solutions and improvements. A number of methods to analyse the performance of signalized intersections were proposed by various researchers [1]–[8]. In the layout of roadways, considerable attention is needed for the design of intersections. In India, vehicle and pedestrian behaviours along with Level of Service (LOS) are very complex and unpredictable at signalized intersections. Planning and implementation of the facilities require an understanding of the characteristics of pedestrian and vehicle traffic. Thus there is a need to study about vehicle and pedestrian traffic characteristics at signalized intersections. The objective of this paper is to provide various suitable solutions and performance stages for a particular signalized intersection problem, based on vehicle flow characteristics.

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2.0 METHODOLOGY

The required qualitative data were collected from selected signalized intersections. Field data of vehicle flow were collected in Retteri signalized intersection, Chennai, India. Morning and evening peak hour volume have been identified and compositions of vehicles have been studied. V/C ratios are calculated based on IRC 106-1990 manual. Vehicle delay is estimated by applying Webster's classical formula and LOS have been identified at Retteri junction. Traffic volume growth is calculated for next 10years and impacts are studied. Finally, Flyover has been designed by using MX ROAD software.

3.0 DATA COLLECTION AND EXTRACTION

To cover typical traffic and roadway conditions in India, trap length of two kilometre urban road was selected in Chennai, India. Chennai is the fifth largest city and fourth most populous metropolitan city in India. It is the biggest industrial and commercial center in south India with 4.34million population. The trap length covered one major signalized intersections and study area covered residential, industrial, commercial and institutional area.

The selected Retteri junction was four arm signalized intersection connecting Jawahalal Nehru road and Red hills high road. The junction seems to be highly congested and delay occurs as the traffic flows exceeds 10,000PCUs/hr and hence it warrants for a grade separator. The conditions of traffic and geometric details at signalized intersection were collected with a field survey. The traffic volume in each direction of the intersection was noted by trained investigator using a 5min time interval. The crosswalk length, width of median, number of lanes, free left turning and sidewalk connection were also measured. The cycle length, green time, flashing green time and red time of the intersections were also recorded. The selected signalized intersection is shown in Figure 1.

Figure 1: Study Location in Road View and Satellite View

The selected Retteri junction was four arm signalized intersection with fixed single time. The details of four arms with directions are shown in Table 1. The observed signal phase plan is shown in Figure 2 and signal times are explained in Table 2.

4.0 ANALYSIS

Based on the collected 12hours quantitative data, Retteri junction was analysed in four categories. First category, traffic volume were counted and calculated morning and evening peak hour. Second categories, the proposition of vehicle categories were analysed with

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impacts. Third category, volume/capacity ratio, delay and level of service were analysed. Fourth category, the traffic volume were projected for next 10years.

Table 1: Details of four arm and direction at Retteri junction

LOCATION	DIRECTION
NH 5 Road to CMBT	NS
NH 5 Road to Perambur	NE
NH 5 Road to Redhills	NW
CMBT to NH 5	SN
CMBT to Perambur	SE
CMBT to Redhills	SW
Redhills to NH 5	WN
Redhills to CMBT	WS
Redhills to Perambur	WE
Perambur to NH 5 Road	EN
Perambur to CMBT	ES
Perambur to Redhills	EW

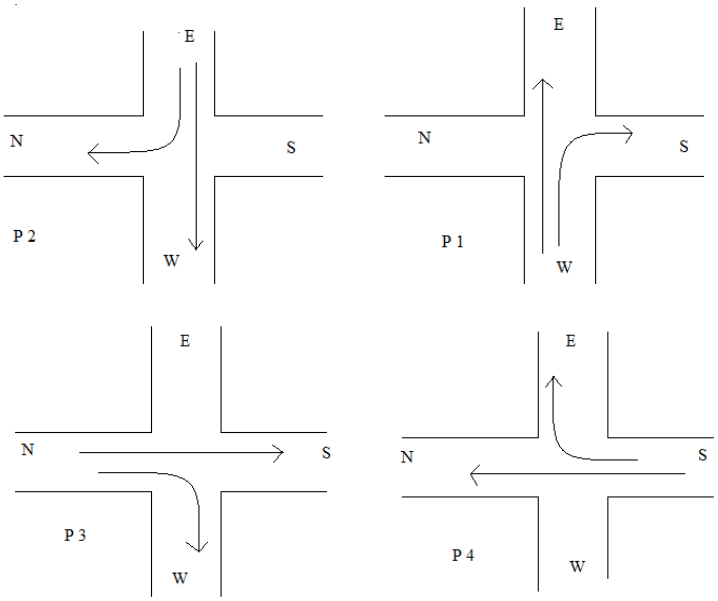

Figure 2: Phase plan at Retteri Junction

Table 2: Signal time at Retteri junction

PHASE	DIRECTION	SIGNALTIME
Phase 1	WN, WS, WE	24 sec
Phase 2	EN, EW, ES	24 sec
Phase 3	NE, NS, NW	48 sec
Phase 4	SN, SE, SW	62 sec

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4.1 Volume Count Analysis

Traffic volume count survey was conducted for 12 hours (7 am – 7 pm) in the month of December. The category wise traffic count for each direction for 5minutes interval was recorded. In order to convert different categories of vehicle into a common scale, the passenger car units (PCU) as per IRC 106-1990 been adopted.

The hourly volumes in PCUs/hr were calculated and the survey data was analysed to obtain the morning and evening peak hour flow of vehicles in each direction. It was found out that the morning peak hour for the study intersection was 8.45AM – 9.45AM and observed volume was 12218 PCUs and the evening peak hour was 5.00PM – 6.00PM with an observed volume of 11092PCUs. The graphical representation of hourly volume is shown in Figure 3.

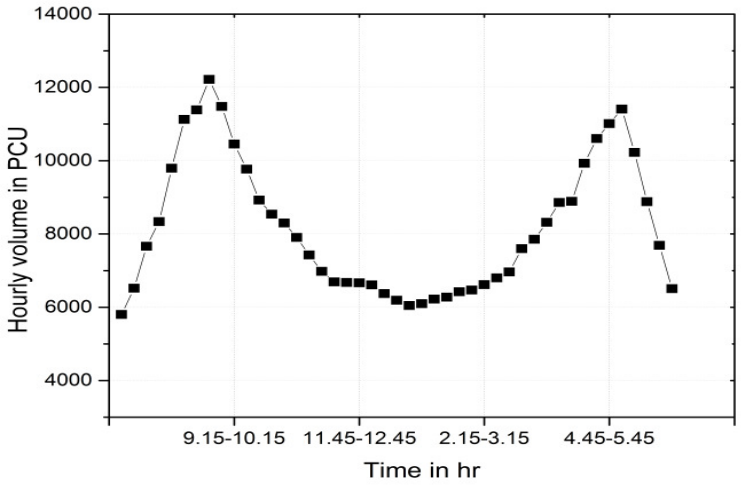

Figure 3: Total Hourly Volumes in PCU for the Retteri Intersection

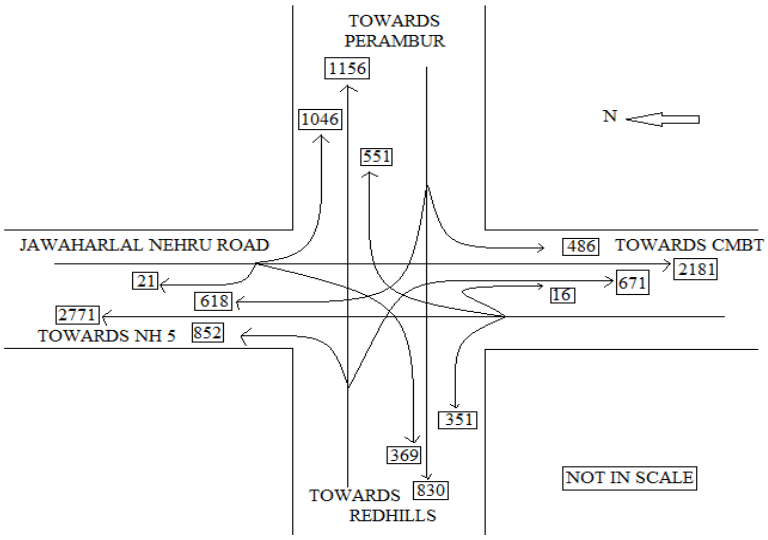

Figure 4: Direction Wise Morning Peak Hour Volume at the Study Intersection

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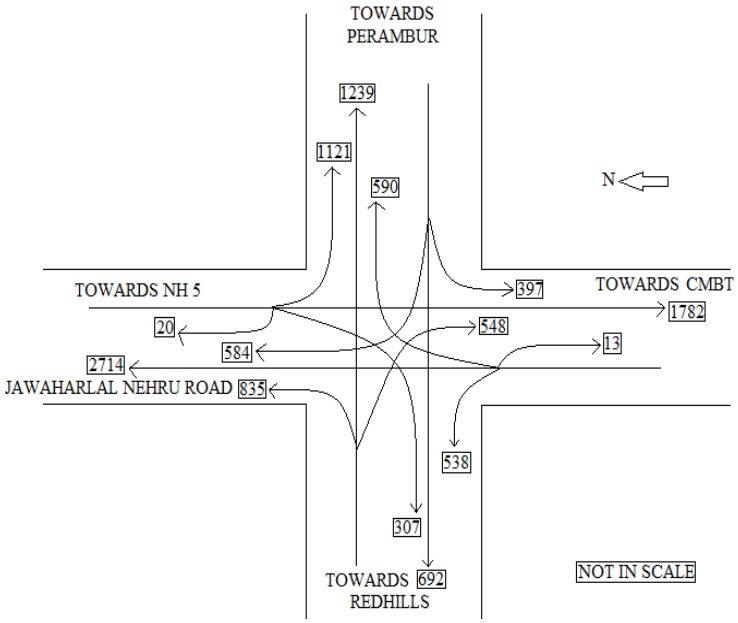

Figure 5: Direction Wise Evening Peak Hour Volume at the Study Intersection

Direction wise volume was done during morning peak hour and evening peak hour and the results are shown in Figure 4 and 5.

From Figure 4, the morning peak hour high volume at intersection arm were towards NH 5 and observed volume was 2771 PCUs/hr and towards CMBT road and volume is 2181 PCUs/hr. From Figure 5, the evening peak hour volume at intersection arm were towards NH 5 and observed volume was 2714 PCUs/hr and towards CMBT road and observed volume was 1782 PCUs/Hr.

4.2 Vehicle Composition Analysis

Six types of vehicles, namely, two wheelers, cars, auto, buses, trucks and others (cycles, bull carts etc.) were selected to obtain the distribution of vehicles at signalized intersections and the result is presented in Figure 6.

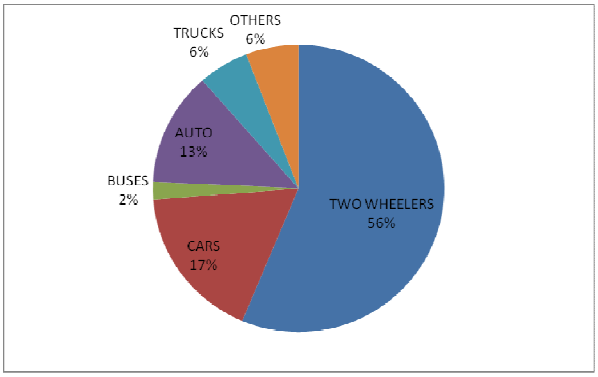

Figure 6: Composition of Vehicles at Retteri Junction

From Figure 6, the composition of vehicular traffic is dominated by two wheelers, cars and auto and it is inferred that the two wheelers population constitutes a higher percentage 56% followed by Cars, Auto, Trucks and Others with 17 %, 13%, 6% and 6% each. The buses constitute a minimum of 2%.

4.3 Volume and Capacity ratio, Delay and LOS Analysis

The saturation value is one of the significant parameters that indicate the operational performance of signalized intersection, and it is calculated as the ratio of volume/capacity (V/C ratio). Volume refers to the number of vehicles that are used a particular arm during a peak hour or evaluation period. Right turning and left turning correction were applied and the calculated volumes are discussed in Table 3. Capacity refers to the maximum number of vehicles that can be obtained from IRC 106 -1990.

Table 3: Observed traffic volume with correction factor

RETTERI JUNCTION FLOW						
DIRECTION	**W**			**E**		
	WN	WS	WE	EN	EW	ES
PCUs/Hr	1065	1174	1156	1081	830	607
RIGHT TURN CORRECTION	-	880.5	-	810.75	-	-
LEFT TURN CORRECTION	266.25	-	-	-	-	151.75
TOTAL	1331.25	2054.5	1156	1891.75	830	758.75
DIRECTION	**N**			**S**		
	NE	NS	NW	SN	SE	SW
PCUs/Hr	1307	2180	648	2771	964	807
RIGHT TURN CORRECTION	-	-	486	-	723	-
LEFT TURN CORRECTION	326.75	-	-	-	-	201.75
TOTAL	1633.75	2180	1134	2771	1687	1008.8

Table 4: V/C ratio for each phase

PHASE 1			
FLOW	217	221	200
SAT FLOW	1968	5355	4042.5
Y 1	0.11	0.04	0.05
PHASE 2			
FLOW	369	203	134
SAT FLOW	1968	4042.5	5355
Y 2	0.19	0.05	0.03
PHASE 3			
FLOW	818	491	76
SAT FLOW	5355	1968	1968
Y 3	0.15	0.25	0.04
PHASE 4			
FLOW	1343	391	211
SAT FLOW	5355	1968	1968
Y 4	0.251	0.21	0.11

The V/C ratio calculations were discussed in Table 4. The V/C ratio ranges from 0 to1. When the value of V/C is 1, the observed volume is equal to maximum capacity. When the V/C ratio is 0, there is zero observed value. If the value of V/C ratio is greater than 1, then the observed flow is over saturated conditions. The calculated V/C ratio at Retteri junction was 0.801 and the results indicates that vehicle were facing more delay due to shorter cycle length.

Delay is a significant factor that is used in the performance evaluation of signalized intersections. Webster's classical formula is the most popular and oldest one to estimate average delay per vehicle at signalized intersections. Webster's formula applied to calculate delay at Retteri junction and the calculations are show in Table 5 and 6. The value of total delay at Retteri junction is 39 sec.

Table 5: Green Time Calculation based on Webster's formula

Total Lost Time	16 sec
Optimum Cycle Time	146 sec
Effective Green Time	130 sec
Green Time	
Phase 1	18 sec
Phase 2	31 sec
Phase 3	40 sec
Phase 4	41 sec

Table 6: Delay Calculation

PHASE	P 1	P 2	P 3	P 4
C	130	130	130	130
G	18	31	40	41
Q	0.18	0.196	0.385	0.54
Y	0.138	0.238	0.307	0.315
X	1.304	0.824	1.254	1.714
Delay	25 sec	50 sec	32 sec	45 sec

The value of V/C ratio and delay values at Retteri junction are 0.801 and 39sec/veh respectively. The level of service at Retteri junction is D based on V/C ratio and vehicle delay.

4.4 Traffic Growth Analysis

Chennai Metropolitan Development Authority (CMDA) in consultation with World Bank has suggested the following growth rates for Tamilnadu Urban Development Projects. Table 7 is shown the mode wise traffic growth rates up to 2020 for Tamilnadu.

The study stretch has been classified as "Arterial- Road" as per the IRC 106 -1990 [9]. The total design service volume of three lanes one way is 3600PCUs/Hr as per IRC. The traffic in the direction towards NH 5 in the year 2011 is 2771PCUs/Hr. On projection it exceeds the design service volume of three lane in the year 2014. The traffic value projected for next 10 years and the results are shown in Table 8.

Table 7: Mode Wise Traffic Growth Rates

Sl No	Vehicle Type	Annual traffic growth rate (%)	
		2010 – 2015	2016 - 2021
Motorised Vehicles			
1	Two Wheelers	4.0	3.0
2	Auto	4.0	3.0
3	Car	7.0	6.5
4	Minibus	10.0	10.0
5	Bus	10.0	10.0
Non- Motorised Vehicles			
1	Cycles	2.5	2.0
2	Bullock carts	1.0	1.0

Table 8: Projected Traffic

Year	Total Traffic (PCUs/Hr)
2011 (Base Year)	2771
2012	3004
2013	3256
2014	3530
2015	3826
2016	4148
2017	4496
2018	4874
2019	5283
2020	5727
2021	6208

4.5 Discussions

From the volume count analysis, the traffic on toward NH 5 is more than other roads and exceeds service volume. The vehicle delay around 39Sec and LOS D indicates the queuing and approaching unstable flow condition at study intersection. Then the projected traffic growth also exceeds the limit. Finally all the above inference indicates to propose flyover for reduce delay and queuing at intersection

5.0 DESIGN OF GRADE SEPERATOR USING MXROAD

Bentley MX ROAD is an advanced, string based modelling tool that enables the rapid and accurate design of all road types. MX ROAD automates much of the design detailing process, saving the user time and money. The MX command language uses simple, repeatable commands that can be recorded and replayed using wizards. This powerful, unique MXROAD features saves time on reiterating designs. New designs can be quickly created through the use of inputs files. MXROAD requires ground data in which the input is generally given in Genio format.

Basic input data for MX ROAD was X, Y and Z coordinates data, which is used to create ground data model. Ground model is the working model which depicts the real world ground conditions. Total station is widely used instrument to obtain the ground coordinates. Total station survey data was secondary data and the ground has to be checked in AUTOCAD and the center line of the grade separator has to be marked in AUTOCAD itself. After checking the ground details and marking the center line the drawing file were saved in .DXF format

which is the input format for MX ROAD. Surface checker option was used to check ground coordinates. There were different options available such as, Null Levels, Zero Levels, Single Point, High Point, Low Point, Coincident Point and Intersection Point.

Surface checker was used to find out the null levels (Point having no value for level), zero level (Point having zero value of level), High Points (Eg: Buildings), Low points, Coincident points and Intersection points. If any point is expected to be having error that particular point can be viewed and modified. There are many methods that can be used to create horizontal alignments in MX. The Horizontal Element Method and Quick Horizontal Alignment are the common methods that are generally used for designing the horizontal alignments. The Horizontal Element Method is the most commonly used horizontal alignment tool, and allows the designer to place individual tangents and curves of an alignment, and link these elements together to form an alignment. The Quick Horizontal Alignment Method is a PI method that allows you to quickly and interactively place PI's on the drawing by simply clicking on points on the screen. The tangents of your alignment were automatically defined by the placement of the PI's. A default curve was automatically placed between each of pair of adjacent tangents that must be edited to suit your design. In case of Vertical Alignment design the Quick Vertical Alignment allows to interactively and dynamically place Vertical geometry on an alignment.

MX will now calculate the existing ground profile, and show it in MX viewpoint. A toolbar will also appear. The procedures for utilizing Vertical Quick alignment are nearly identical to the methods with Quick Alignment. The start off by adding vertical PI's on the graphics display, lock the end PI's down to the existing ground profile, and adjust your vertical PI locations and curve data as described. All of the tools needed to accomplish this are located on the toolbar.

Two other features to notice on the Quick Vertical Design are the Horizontal Curve annotation, and the High and Low Point indicators. The Horizontal Curves for an alignment were shown as vertical bars in the display. The light blue or cyan coloured line indicates a horizontal PC for alignment, and the yellow vertical line indicates the horizontal PT for that alignment. Carriage way design can be done by giving appropriate width and then super elevation design is done by choosing appropriate design rules and design speed.

5.1 Proposed Flyover Details

The details of Geometric elements of the Grade separator designed as given in the drawing are summarized as

- Design speed 100Kmph
- Length of the grade separator 1043m
- Carriageway width of the grade separator 7m
- Width of shoulder (paved) 1m
- Width of shoulder (unpaved) 1m
- Horizontal Curvature 200m
- Transition Length 130m
- Superelevation 7%
- Cross slope 2.5%
- Sight Distance 180m
- Length of Vertical Curve 1 485.760m
- Length of Vertical Curve 2 143.028m
- Length of Vertical Curve 3 120.000m

- Ramp speed 100Kmph
- Ramp gradient 3.3%

5.2 Improvement of Signalized Intersection Performance Level

The existing through movement vehicle volumes at Jawaharlal Road can be reduced by proposed flyover at retteri signalized intersection. The performance evaluation of before and after flyover at retteri signalized intersection were analysed theoretically and the comparisons of results are shown in Table 9.

Table 9: Performance Evaluation Results for before and after flyover

Variables	Before flyover	After flyover
Peak hour traffic volume in pcu	12218	7266
V/C ratio	0.801	0.481
Delay in sec	39	18
LOS	D	B

From Table 9, it is inferred that the proposed fly over can reduce 40% of traffic congestion by reducing traffic volumes and delay values. The level of service was improved D to B and it shows the less congestion and reduction of 60% queue length at signalized intersection.

6.0 CONCLUSIONS

We have presented the evaluation of signalized intersections under mixed traffic conditions. 12hours data were collected from selected signalized intersections in Chennai, India. The traffic volumes were counted and peak hours were identified. The directions wise vehicle movement and impacts were analysed and compositions of vehicles were calculated at Retteri junctions during peak hours. We have also calculated V/C ratio at each arm by using IRC manual and value is 0.801. By using Webster's formula, vehicle delay at Retteri junction was calculated and the value is 39sec. The LOS value at study location is D and it indicates the saturation level at particular junction. The volumes were projected for next 10years. Finally the results suggested that the flow and delay at Retteri junction is over saturated and it needs immediate remedial measures. The flyover were proposed and designed by using MX ROAD.

The application of this study has shown that it is easy to describe the current performance conditions of particular signalized intersections. The study is expected to help traffic engineers, planners and policy makers understand the evaluation of particular signalized intersections under mixed traffic conditions.

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