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EVALUATION OF LEVEL OF SERVICE AT SIGNALIZED INTERSECTIONS USING MICROSCOPIC SIMULATION TECHNIQUE

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Abstract
Mixed traffic in cities of many developing countries is mainly characterized by the lack of lane discipline on the roads. The rapid evolution in the sophistication of micro simulation models has encouraged their use in transportation engineering and planning. Traffic simulation models are useful in analyzing the traffic operations. Traffic simulation models allow visualizing existing and future traffic conditions, test strategies that would be difficult or impossible to test in roadway conditions. The main objective of this study is to evaluate the present condition of the existing intersection. The present study aims to evaluate the present traffic conditions in the study area considered by using the microscopic simulation tool VISSIM. Two signalized intersections namely hindu college junction and chandana bros junction located in the Guntur city of Andhra Pradesh are considered as study area for the present work. The study area is evaluated based on the present condition of the two junctions and evaluation is done in terms of delay at intersection. The validation of the developed model for both the junctions is made by comparing the delay obtained from the VISSIM model and that from the formula. Improvements are made in the existing intersections in the form of channelization for left moving vehicles for all the directions of two junctions. For the improved condition of intersection, evaluation is done and the delay at intersection is determined for the same. A typical comparison of improved condition of the intersection is made with the existing condition of intersection. The results showed improvement in the delay for both the intersections after channelization over the existing condition. Also, to verify the hypothesis the Chi-squared test is conducted on the results in terms of delay for both the junctions. From the Chi-squared test it is concluded that the improvement for the two junctions in terms of left channelization is accepted and verified.

Key Words: Traffic simulation models, VISSIM Software, Delay time, Channelization.

1.0 Introduction

Intersections play an important role in the road network, where traffic flows in different directions converge. Because of their influence on each other, disturbance of pedestrians and bicycle to vehicles, and the loss of green time for beginning and clearance and so on, the capacity of intersections is much lower than that of their approach links. Signalized urban intersections are amongst the most complex locations in urban networks. The operational conditions of such intersections affect the wellbeing of the surface transportation of goods and passengers in the cities, whose social, economic, recreational and other activities depends on efficient road system. As a result, simulation-based models are being recommended to aid transportation planners, designers, and policy-makers in assessing future needs and mobility options. Microscopic and Mesoscopic simulation models overcome the inherent limitations of traditional four-step models through their ability to model detailed system operations and management strategies [1].
A large amount of work has been done in studying and trying to improve traffic intersections. Originally, much traffic intersection research focused on analytically describing vehicles delay in terms of the intersection characteristics. One of the most prominent early works is Webster [2] explain the signal time setting. For more recent analytical delay models and queuing theory approaches Hurdle [3] and Hagen and Courage [4] made a Comparison of Macroscopic Models for Signalized Intersection Analysis and also delay models on a primer for the Uninitiated. A discussion of more complex intersection models Combining Traffic Assignment and Signal Control can be found in Meneguzzer [5]. There are several studies for evaluating the trade-offs between comfort and safety of road users in signalized intersections by using LOS concept. For example, Landis et al. [6] described an intersection LOS model for bicycle through movement. Steinma and Hines [7] developed a methodology to assess features affecting pedestrians and bicyclists crossing signalized intersections. This evaluation is based on the influence of comfort and safety on non-motorized road users and includes: crossing distance, roadway space allocation for crosswalks/bike lanes, corner radius dimension and characteristics of traffic signal. Dowling et al. [8] presented a method for multimodal assessment of the quality of service for four different types of users: auto drivers, transit passengers, bicycle riders and pedestrians. They developed four level-of-service models for each mode based on the street cross section, intersection controls and traffic characteristics.

Ishaque and Noland [9] used a micro-simulation model to study the effects of signal cycle timings on delay and travel time costs for both vehicles and pedestrians in various pedestrian phasing scenarios

Delay is defined in HCM [10] as *"the additional travel time experienced by a driver, passenger, or pedestrian"*. The control delay equation comprises three elements: uniform delay, incremental delay, and initial queue delay. The primary factors that affect control delay are lane group volume, lane group capacity, cycle length, and effective green time. Factors are provided that account for various conditions and elements, including signal controller type, upstream metering, and delay and queue effects from oversaturated conditions. Control delay is used as the basis for determining LOS. Intersection control delay is generally computed as a weighted average of the average control delay for all lane groups based on the amount of volume within each lane group. The other factors that affect LOS are lane width, lateral obstruction, traffic and composition, grade. Level of service ranges from level A to F, where 'A' representing the free flow conditions and 'F' representing the worst traffic conditions like less speed, high density etc where A ≤10 Free Flow, B >10 – 20 Stable Flow (slight delays), C >20 – 35 Stable flow (acceptable delays), D >35 – 55 Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding), E >55 – 80 Unstable flow (intolerable delay), F >80 Forced flow (jammed).

The average delay experienced by the vehicle can be directly related to the level of service (LOS). The equation for the average vehicle delay [3] is given below [Eq. 1].

$$d = \frac{0.5C\left(1-\frac{g}{C}\right)^2}{1-\left(\min(1,\ X)\left(\frac{g}{C}\right)\right)} \qquad \text{[Eq. 1]}$$

Where:

d = Average stopped delay per vehicle for the lane or lane group of interest (s/veh)
C = cycle length (s)
g/C = green ratio for the lane or lane group
g = the effective green time for the lane or lane group (s)
X = v/c ratio for the lane group
v = the actual or design flow rate for the lane or lane group (pcu/h)
c = capacity of the lane group (pcu/hour)

The chi-squared (χ^2) test is a useful statistical tool for testing the goodness-of-fit test. Under this test, measure of the discrepancy between a set of observed data and the values that are to be expected if the results follow a hypothesis distribution is evaluated. The chi-squared (χ^2) value is estimated from the following equation [Eq. 2]

$$\chi^2 \text{ (observed)} = \sum_{j=1}^{c} \frac{(O_j - E_j)^2}{E_j} \qquad \text{[Eq. 2]}$$

Where:

O_j = observed frequency of the jth class or event as per hypothesised distribution.
E_j = expected frequency of the jth class or event as per hypothesised distribution.
c = number of classes or events

The degree of freedom, v, for a goodness-of-fit test depends upon the particular distribution being tested and given by [Eq. 3]

$$v = (m-1)(n-1) \qquad \text{[Eq. 3]}$$

Where,

m = number of columns
n = number of rows

1.1 Need for the study

Signalized Intersection is typically needed to process traffic efficiently through an intersection. This is an attempt to utilize the existing roadway infrastructure by ensuring optimum travel speeds while reducing delay. Signalized intersection may delay or even eliminate the need for roadway widening. Since signalized intersection attempts to reduce the number of stops and slow down of traffic, there is a reduction in accident potential. In addition to traffic and safety concerns, the need for signalized intersection may be justified by high levels of vehicle emissions and poor air quality.

2.0 Data Collection

In the present study, two intersections were chosen, namely, Hindu college junction and Chandana bros junction of Guntur city. Guntur is one of the fast developing cities in the Indian state of Andhra Pradesh (AP) and also, the administrative headquarters of the Guntur district. The city is also a part of Andhra Pradesh Capital Region. The terrain view of both the intersections hindu college junction and chandana bros junction are shown in Figures 1 and 2 respectively. The junction characteristics of both the intersections are given in Tables 1 and 2 respectively.

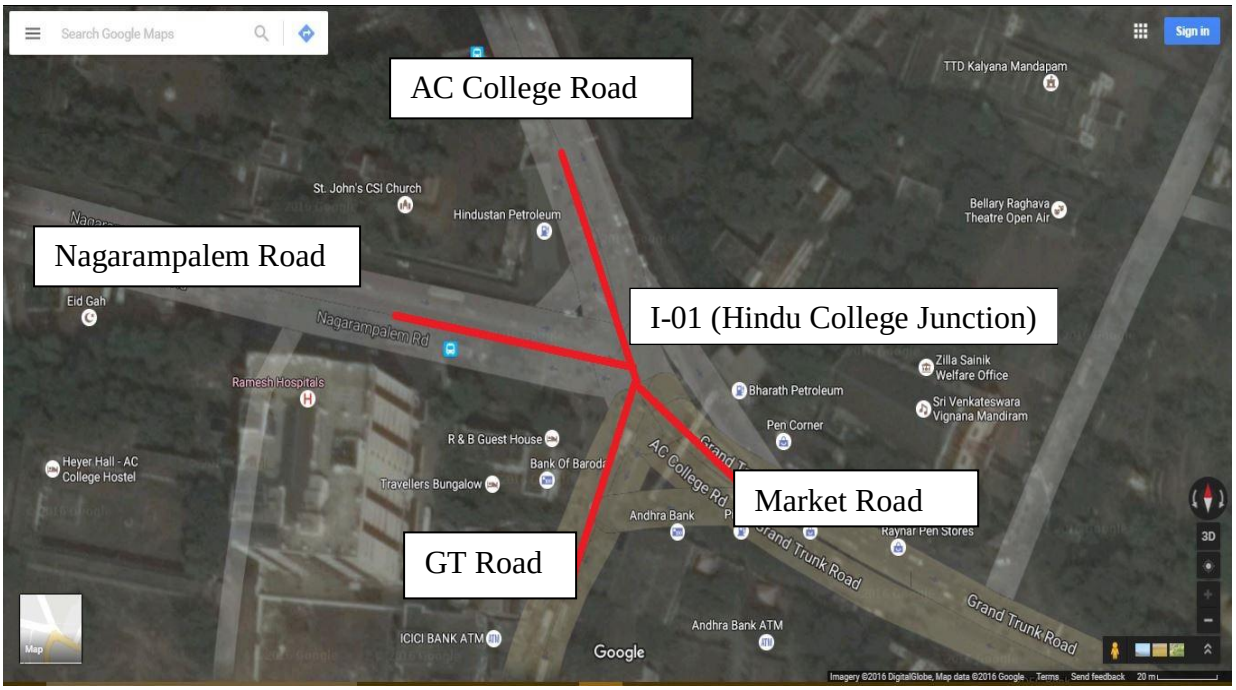

Figure 1 Hindu college junction (terrain view)

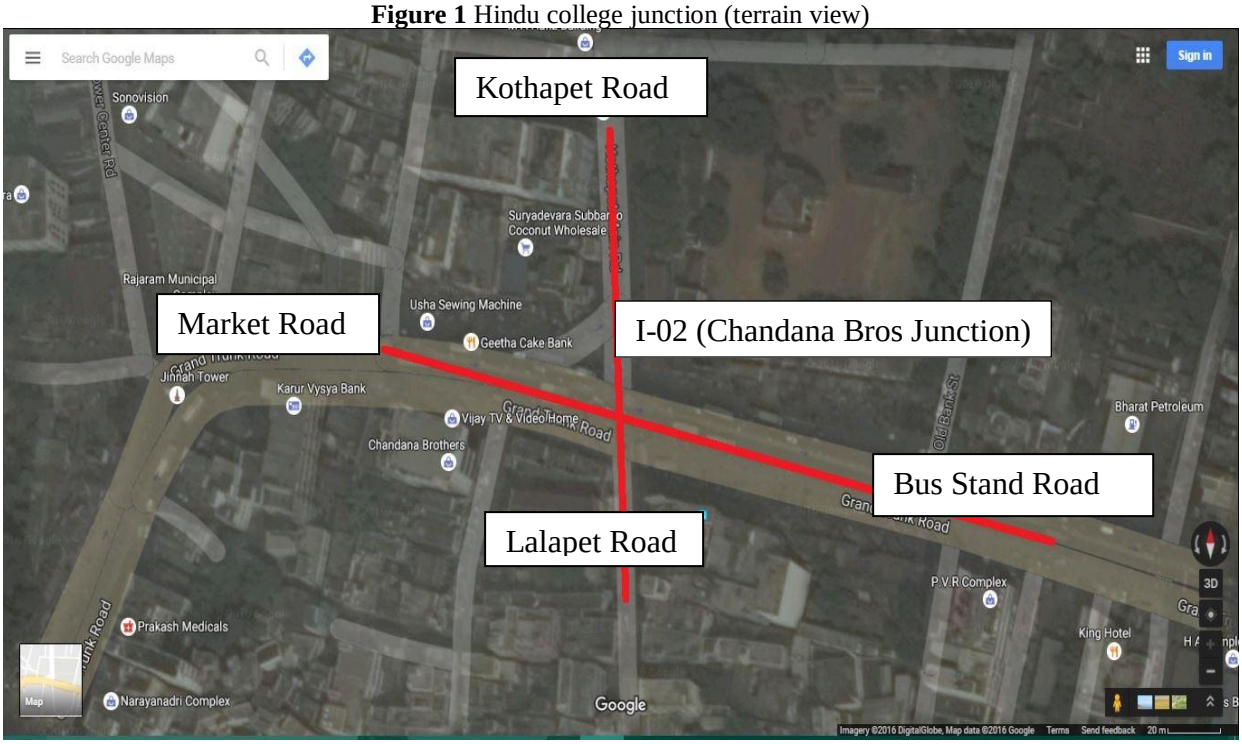

Figure 2 Chandana bros junction (terrain view)

Table 1 Hindu college junction characteristics

S.No.	From	To	Type
1	AC College	Market	Free Movement
2	AC College	GT Road	Signalized Movement
3	AC College	Nagarampalem	Signalized Movement
4	Market	GT Road	Free Movement
5	Market	Nagarampalem	Signalized Movement
6	Market	AC College	Signalized Movement
7	GT Road	Nagarampalem	Free Movement
8	GT Road	AC College	Signalized Movement
9	GT Road	Market	Signalized Movement
10	Nagarampalem	AC College	Free Movement
11	Nagarampalem	Market	Signalized Movement
12	Nagarampalem	GT Road	Signalized Movement

Table 2 Chandana bros junction characteristics

S.No.	From	To	Type
1	Market	Kothapet	Free Movement
2	Market	Bus Stand	Signalized Movement
3	Market	Lalapet	Signalized Movement
4	Kothapet	Bus Stand	Free Movement
5	Kothapet	Lalapet	Signalized Movement
6	Kothapet	Market	Signalized Movement
7	Bus Stand	Lalapet	Free Movement
8	Bus Stand	Market	Signalized Movement
9	Bus Stand	Kothapet	Signalized Movement
10	Lalapet	Market	Free Movement
11	Lalapet	Kothapet	Signalized Movement
12	Lalapet	Bus Stand	Signalized Movement

2.1 Traffic volume count

Classified traffic volume count is conducted to know the present trend of traffic in the specified stretch. It is conducted to assess the traffic characteristics in terms of traffic volume, its composition, peak hour and directional split. Traffic data is collected for one week i.e. from sunday to saturday. The peak hour traffic is determined from the data and is presented in Tables 3 and 4 respectively for hindu college junction and chandan bros junction. The traffic composition at hindu college junction and chandana bros junction are given in Figures 3 and 4 respectively. From the Figures 3 and 4, it can be noted that the bike has major share of the traffic composition at 44% and 43% at hindu college junction and chandana bros junction respectively.

Table 3 Traffic flow at hindu college junction

S.No.	From	To	Bike	Auto	Car	Bus	Total
1	AC College	Market	356	212	102	64	**734**
2	AC College	GT Road	203	74	86	0	**363**
3	AC College	Nagarampalem	217	84	102	0	**403**
4	Market	GT Road	175	102	106	57	**440**
5	Market	Nagarampalem	153	95	114	0	**362**
6	Market	AC College	312	227	131	41	**711**
7	GT Road	Nagarampalem	122	86	64	0	**272**
8	GT Road	AC College	113	92	92	0	**297**
9	GT Road	Market	231	155	104	75	**565**
10	Nagarampalem	AC College	122	77	96	0	**295**
11	Nagarampalem	Market	188	147	84	0	**419**
12	Nagarampalem	GT Road	72	88	66	0	**226**
Total number of vehicles in the junction			**2264**	**1439**	**1147**	**237**	**5087**

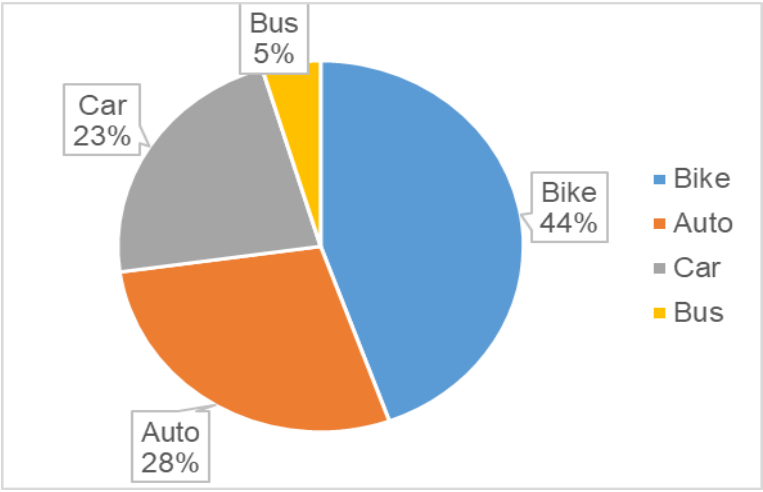

Figure 3 Traffic composition at hindu college junction

Table 4 Traffic flow at chandana bros junction

S.No.	From	To	2W	3W	Car	Bus	Total
1	Market	Kothapet	234	95	55	0	**384**
2	Market	Bus Stand	574	517	425	149	**1665**
3	Market	Lalapet	70	46	20	0	**136**
4	Kothapet	Bus Stand	146	94	40	0	**280**
5	Kothapet	Lalapet	131	75	25	0	**231**
6	Kothapet	Market	118	70	45	0	**233**
7	Bus Stand	Lalapet	75	38	18	0	**131**
8	Bus Stand	Market	670	616	457	181	**1924**
9	Bus Stand	Kothapet	257	120	62	0	**439**
10	Lalapet	Market	85	48	15	0	**148**
11	Lalapet	Kothapet	101	61	20	0	**182**
12	Lalapet	Bus Stand	97	47	22	0	**166**
Total number of vehicles in the junction			**2558**	**1827**	**1204**	**330**	**5919**

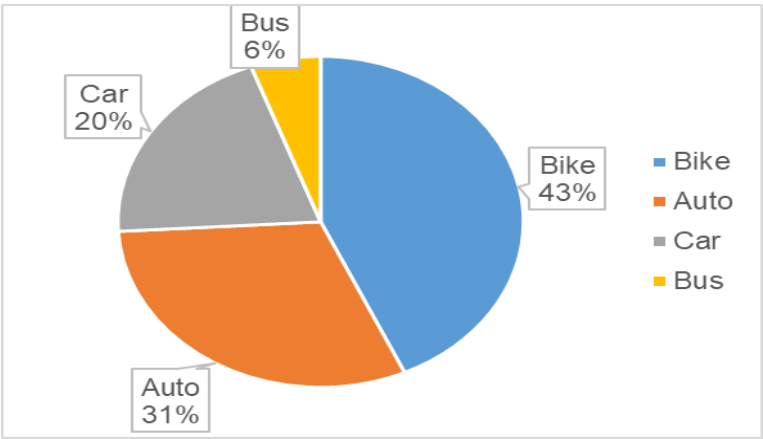

Figure 4 Traffic composition at chandana bros junction

2.2 Signal controls

Signal timing for both the intersections are collected during the peak and non-peak hours. Both the junctions are signalized. The cycle time with green, red and amber is collected for using in VISSIM in place of signal control. The signal timings of hindu college junction and chandana bros junction are given in Tables 5 and 6.

Table 5 Signal timings of hindu college junction

S.No.	From	To	Green	Red	Amber
1	AC College	Nagarampalem, GT Road	25	119	3
2	Nagarampalem	Market, GT Road	25	119	3
3	GT Road	Market, AC College	45	99	3
4	Market	Nagarampalem, AC College	40	104	3

Table 6 Signal timings of chandana bros junction

S.No.	From	To	Green	Red	Amber
1	Market	Bus Stand, Lalapet	32	77	3
2	Kothapet	Market, Lalapet	15	94	3
3	Bus Stand	Market, Kothapet	38	71	3
4	Lalapet	Kothapet, Bus Stand	15	94	3

3.0 Modelling

VISSIM, a microscopic simulation tool is used for modelling of the two intersections. Wiedemann–99 model is used for the present study. In the first stage, a model is developed to determine the delay at the intersection for the present condition of the two intersections i.e hindu college junction and chandana bros junction. The model is validated by comparing the delays obtained from the model and that obtained from the delay formula. In the second stage, improvements are made for the present condition of the two intersections by providing channelization and the delay is determined. The level of service of the two intersections are determined for both the conditions i.e. before and after improvement.

4.0 Analysis of Data and Results

4.1 Evaluation of existing intersections

In analysis the first step is to evaluate the existing field conditions, here analysis for the two intersections i.e. hindu college junction and chandana bros junction are done in VISSIM. The analysis is done in terms of delays.

4.1.1 Hindu college junction

The hindu college junction is modelled in VISSIM for the existing field conditions. This model is evaluated for the existing signal timings and the delay is found. The data obtained from the VISSIM model is presented in Table 7.

Table 7 Output from VISSIM for hindu college junction

From Link	To Link	Link Description	Average Delay per Vehicle (All), s	Average Queue Length, m	Maximum Queue Length, m	Average Stopped Delay per vehicle (All), s	Average Number of Stops per Vehicles (All)
1	3	AC College to Market	**56.5**	17.5	72.3	45.9	1.50
1	6	AC College to GT Road	**73.4**	50.3	114.7	60.2	2.00
1	8	AC College to Nagarampalem	**69.4**	50.3	114.7	58.7	1.33
4	2	Market to AC College	**54.2**	51.6	103.2	45.4	0.84
4	6	Market to GT Road	**57.1**	53.5	108.2	49.6	1.08
4	8	Market to Nagarampalem	**67.3**	51.6	103.2	57.2	1.22
5	2	GT Road to AC College	**43.4**	25.2	94.8	35.3	0.90
5	3	GT Road to Market	**39.7**	25.2	94.8	33.5	0.87
5	8	GT Road to Nagarampalem	**35.7**	25.2	94.8	26.8	0.90
7	2	Nagarampalem to AC College	**21.2**	0.0	0.0	16.9	0.51
7	3	Nagarampalem to Market	**49.9**	22.0	72.7	43.8	0.89
7	6	Nagarampalem to GT Road	**51.3**	22.0	72.7	46.0	0.91

4.1.2 Chandana bros junction

The chandana bros junction is modelled in VISSIM for the existing field conditions. This model is evaluated for the existing signal timings and the delay is found. The data obtained from the VISSIM model is presented in Table 8.

Table 8 Output from VISSIM for chandana bros junction

From Link	To Link	Link Description	Average Delay per Vehicle (All), s	Average Queue Length, m	Maximum Queue Length, m	Average Stopped Delay per vehicle (All), s	Average Number of Stops per Vehicles (All)
1	1	Market to Bus stand	**30.7**	18.5	61.5	23.5	0.89
1	4	Market to Kothapet	**39.7**	10.1	36.4	5.4	0.78
1	6	Market to Lalapet	**32.9**	18.5	61.5	23.6	1.09
2	2	Bus stand to Market	**39.5**	37.4	124.1	25.1	1.62
2	4	Bus stand to Kothapet	**42.7**	37.4	124.1	25.2	1.66
2	6	Bus stand to Lalapet	**34.4**	17.0	91.3	19.3	1.34
3	1	Kothapet to Bus stand	**3.6**	12.8	38.8	0.6	0.16
3	2	Kothapet to Market	**40.3**	12.8	38.8	34.3	0.80
3	6	Kothapet to Lalapet	**45.0**	12.8	38.8	38.3	0.93
5	1	Lalapet to Bus stand	**95.1**	26.8	41.7	84.7	1.57
5	2	Lalapet to Market	**96.9**	26.8	41.7	83.9	1.96
5	4	Lalapet to Kothapet	**109.1**	26.8	41.7	97.0	1.79

4.1.3 Validation of the VISSIM model

The validation of the VISSIM model developed is done by comparing the delays obtained from the model and that with the manually calculated delays. The comparison is done for both the hindu college junction and chandana bros junction. The delay time obtained from the VISSIM model and the manually calculated delay are given in Table 9 for hindu college junction and Table 10 for chandana bros junction. From Tables 9 and 10 it can be noted that the difference between the manual calculated delay and that obtained the VISSIM is 0.1% and -10.7% respectively.

Table 9 Comparison of delay time from VISSIM and manual calculation for hindu college junction

From Link	To Link	Link Description	Average Delay per Vehicle (All), s (VISSIM)	Average Delay per Vehicle (All), s (Manual Calculation)	% Variation
1	3	AC College to Market	56.5	69.7	+18.9
1	6	AC College to GT Road	73.4	57.1	-28.5
1	8	AC College to Nagarampalem	69.4	57.8	-20.1
4	2	Market to AC College	54.2	47.5	-14.1
4	6	Market to GT Road	57.1	44.4	-28.6
4	8	Market to Nagarampalem	67.3	52.7	-27.7
5	2	GT Road to AC College	43.4	39.4	-10.2
5	3	GT Road to Market	39.7	39.7	0.0
5	8	GT Road to Nagarampalem	35.7	46.2	+22.7
7	2	Nagarampalem to AC College	21.2	56.3	+62.3
7	3	Nagarampalem to Market	49.9	59.3	+15.9
7	6	Nagarampalem to GT Road	51.3	55.6	+7.7
Average percentage difference of delay from VISSIM and Manual Calculation for the Hindu College junction					**-0.1**

Table 10 Comparison of delay time from VISSIM and manual calculation for chandana bros junction

From Link	To Link	Link Description	Average Delay per Vehicle (All), s (VISSIM)	Average Delay per Vehicle (All), s (Manual Calculation)	% Variation
1	1	Market to Bus stand	30.7	33.1	+7.3
1	4	Market to Kothapet	39.7	87.2	+54.5
1	6	Market to Lalapet	32.9	30.7	-7.2
2	2	Bus stand to Market	39.5	47.2	+16.3
2	4	Bus stand to Kothapet	42.7	46.3	+7.8
2	6	Bus stand to Lalapet	34.4	46.3	+25.7
3	1	Kothapet to Bus stand	3.6	26.2	+86.3
3	2	Kothapet to Market	40.3	113.4	+64.5
3	6	Kothapet to Lalapet	45.0	29.0	-55.2
5	1	Lalapet to Bus stand	95.1	47.4	-100.6
5	2	Lalapet to Market	96.9	48.6	-99.4
5	4	Lalapet to Kothapet	109.1	47.8	-128.2
Average percentage difference of delay from VISSIM and Manual Calculation for the Hindu College junction					**-10.7**

5.0 Proposed Improvements

5.1 Evaluation of improved condition of the intersections

The delays in the hindu college junction and chandana bros junction are determined from VISSIM model. Based on the delay time at intersection, improvements are made in the form of providing channelization for the left vehicles to move freely so that congestion at intersection can be reduced.

5.1.1 Hindu college junction

The improvements for hindu college junction are modelled in VISSIM. This model is evaluated for the existing signal timings and the delay is found. The data obtained from the VISSIM model is presented in Table 11. From Table 11 it is clear that the delay for various routes was reduced indicating the effectiveness of the improved condition of the intersection. For better understanding, a comparison of the existing delays and delays of the improved condition is presented in Figure 5. The Figure 6 shows the schematic view of hindu college junction after the proposed left channelization.

Table 11 Output from VISSIM for improved condition of hindu college junction

From Link	To Link	Link Description	Average Delay per Vehicle (All), s	Average Queue Length, m	Maximum Queue Length, m	Average Stopped Delay per vehicle (All), s	Average Number of Stops per Vehicles (All)	% Reduction in Delay
1	3	AC College to Market	**6.0**	8.8	72.3	2.8	0.18	89.38
1	6	AC College to GT Road	**66.4**	37.2	114.7	55.5	1.78	9.54
1	8	AC College to Nagarampalem	**63.0**	37.2	114.7	54.7	1.07	9.22
4	2	Market to AC College	**43.5**	39.6	95.8	35.0	0.89	19.74
4	6	Market to GT Road	**47.4**	37.9	96.2	35.8	1.06	16.99
4	8	Market to Nagarampalem	**56.4**	39.6	95.8	47.4	0.99	16.20
5	2	GT Road to AC College	**41.2**	20.1	75.2	33.8	0.78	5.07
5	3	GT Road to Market	**37.5**	20.1	75.2	31.4	0.80	5.54
5	8	GT Road to Nagarampalem	**15.4**	0.1	11.8	9.8	0.55	56.86
7	2	Nagarampalem to AC College	**7.5**	0.0	0.0	5.2	0.26	64.62
7	3	Nagarampalem to Market	**57.7**	20.3	72.6	51.1	1.04	15.63
7	6	Nagarampalem to GT Road	**49.5**	20.3	72.6	44.2	0.86	3.51

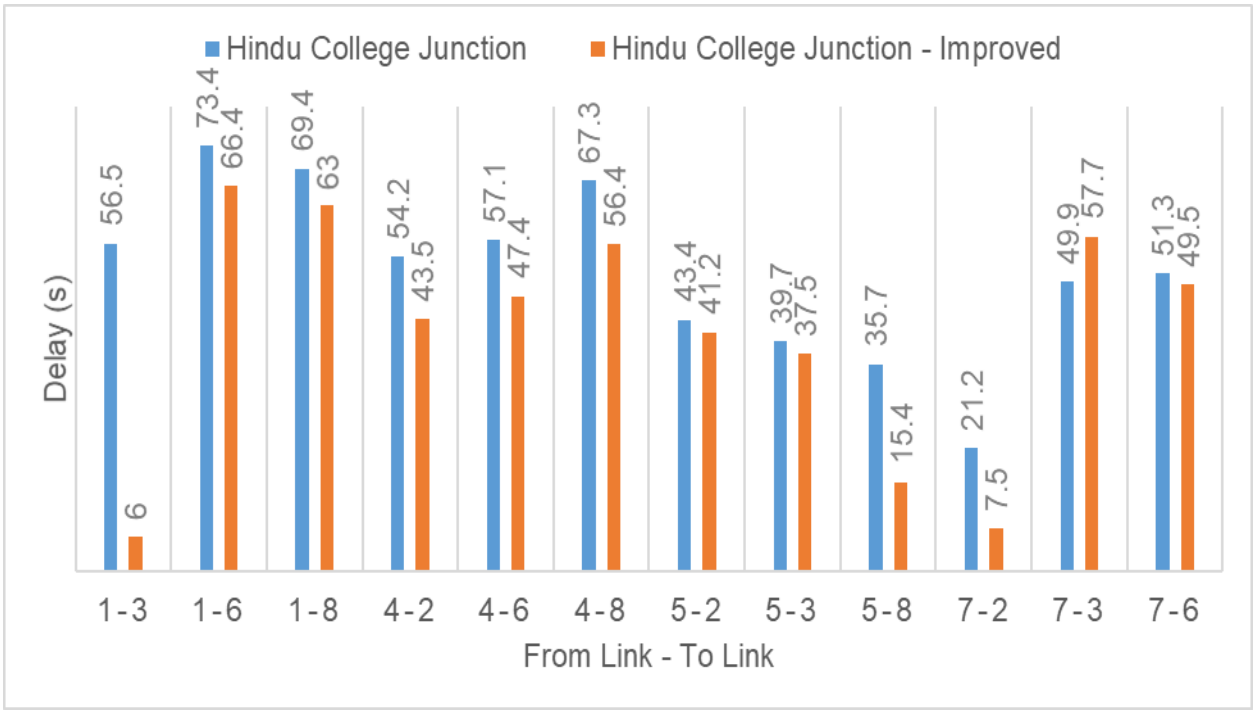

Figure 5 Comparison of existing and improved delay for hindu college junction

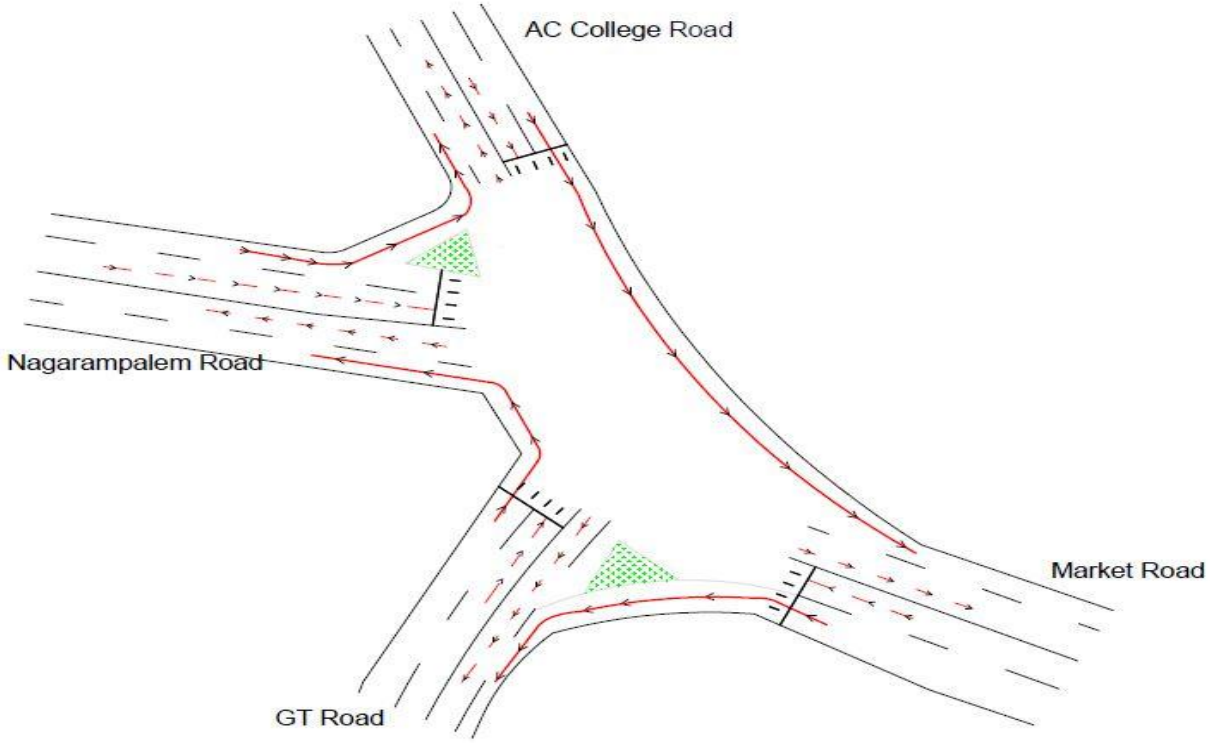

Figure 6 Schematic view of hindu college junction after proposed left channelization

5.1.2 Chandana bros junction

The improvements for Chandana Bros Junction are modelled in VISSIM. This model is evaluated for the existing signal timings and the delay is found. The data obtained from the VISSIM model is presented in Table 12. From Table 12 it is clear that the delay for various routes was reduced indicating the effectiveness of the improved condition of the intersection. For better understanding, a comparison of the existing delays and delays of the improved condition is presented in Figure 7. The Figure 8 shows the schematic view of chandana bros junction after the proposed left channelization.

Table 12 Output from VISSIM for Improved condition of Chandana Bros Junction

From Link	To Link	Link Description	Average Delay per Vehicle (All), s	Average Queue Length, m	Maximum Queue Length, m	Average Stopped Delay per vehicle (All), s	Average Number of Stops per Vehicles (All)	% Reduction in Delay
1	1	Market to Bus stand	**27.8**	18.6	64.4	19.5	1.07	9.45
1	4	Market to Kothapet	**32.4**	9.6	28.7	3.8	0.54	18.39
1	6	Market to Lalapet	**34.4**	18.6	64.4	22.8	1.18	4.56
2	2	Bus stand to Market	**33.7**	26.7	92.3	21.4	1.13	14.68
2	4	Bus stand to Kothapet	**32.1**	26.7	92.3	18.3	1.55	24.82
2	6	Bus stand to Lalapet	**15.5**	8.8	59.5	6.3	0.52	54.94
3	1	Kothapet to Bus stand	**3.3**	1	13.2	0.8	0.16	8.33
3	2	Kothapet to Market	**40.2**	13.2	37.8	34.2	0.82	0.25
3	6	Kothapet to Lalapet	**39.5**	13.2	37.8	33.5	0.93	12.22
5	1	Lalapet to Bus stand	**61.3**	18.2	41.7	54.4	0.97	35.54
5	2	Lalapet to Market	**38.7**	3.6	19.9	33.3	0.7	60.06
5	4	Lalapet to Kothapet	**70.1**	18.2	41.7	62.5	1.09	35.75

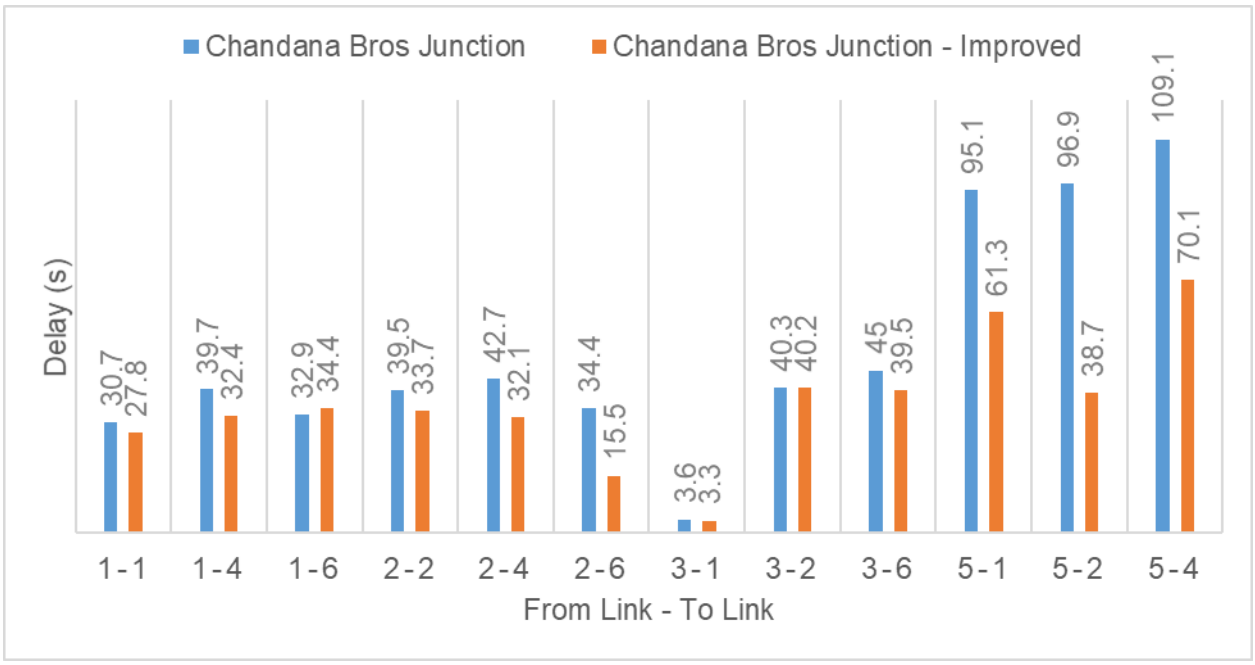

Figure 7 Comparison of existing and improved delay for Chandana Bros Junction

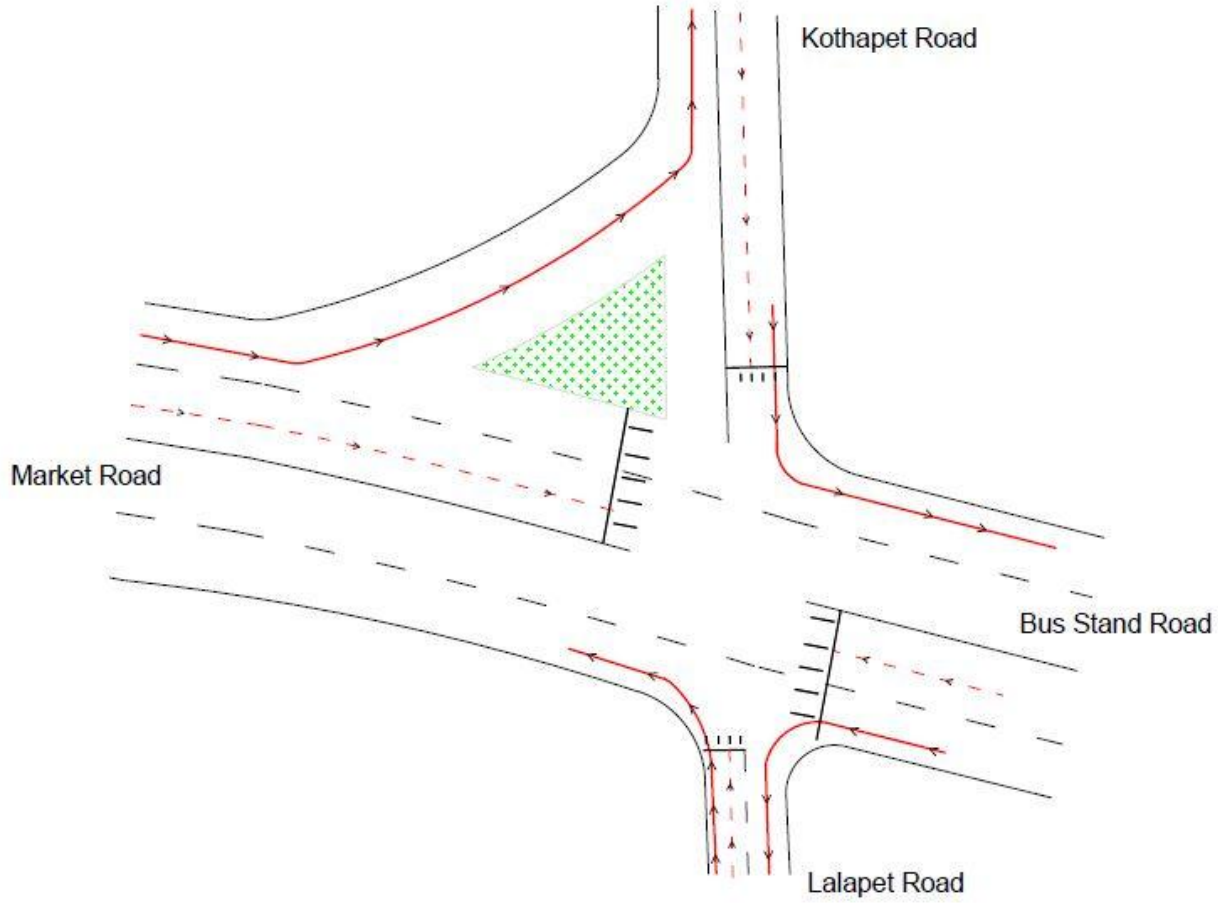

Figure 8 Schematic view of chandana bros **j**unction after proposed left channelization

5.2 Chi-squared Test

The chi-squared (χ^2) test is used for measuring the discrepancy between the average delay per vehicle (s) obtained from VISSIM model for the improved condition of junction and that of the present (actual) condition of the junction. The results of the chi-square are presented in the Table 13 for hindu college junction and for the chandana bros junction are presented in Table 14 below. From the Tables 13 and 14 it can be noted that the chi-square values for hindu college junction and chandana bros junction are 33.13 and 76.28 respectively.

Table 13 Chi-squared test values for hindu college junction

From Link – To Link	Delay obtained from VISSIM for existing condition (s)	Delay obtained from VISSIM for improved condition (s)
AC College to Market	56.5	6
AC College to GT Road	73.4	66.4
AC College to Nagarampalem	69.4	63
Market to AC College	54.2	43.5
Market to GT Road	57.1	47.4
Market to Nagarampalem	67.3	56.4
GT Road to AC College	43.4	41.2
GT Road to Market	39.7	37.5
GT Road to Nagarampalem	35.7	15.4
Nagarampalem to AC College	21.2	7.5
Nagarampalem to Market	49.9	57.7
Nagarampalem to GT Road	51.3	49.5
Total Delay at the Intersection	**619.1**	**491.5**
Chi-square value = 33.13		

Table 14 Chi-squared test values for chandana bros junction

From Link – To Link	Delay obtained from VISSIM for existing condition (s)	Delay obtained from VISSIM for improved condition (s)
Market to Bus stand	30.7	27.8
Market to Kothapet	39.7	32.4
Market to Lalapet	32.9	34.4
Bus stand to Market	39.5	33.7
Bus stand to Kothapet	42.7	32.1
Bus stand to Lalapet	34.4	15.5
Kothapet to Bus stand	3.6	3.3
Kothapet to Market	40.3	40.2
Kothapet to Lalapet	45	39.5
Lalapet to Bus stand	95.1	61.3
Lalapet to Market	96.9	38.7
Lalapet to Kothapet	109.1	70.1
Total Delay at the Intersection	**609.9**	**429.0**
Chi-square value = 76.28		

The degree of freedom for both the junctions is 6. For a degree of freedom of 6 and for a significance level of 0.05, the χ^2 critical is 12.59. In the present case for the hindu college junction the χ^2 (observed) is 33.13 which is greater than χ^2 (critical) of 12.59. For the chandana bros junction, the χ^2 (observed) is 76.28 and is greater than χ^2 (critical) = 12.59. Hence, the hypothesis of improved conditions for the junction hindu college and chandana bros are verified and accepted.

5.3 Evaluation of Level of Service (LOS)

Level of Service (LOS) as defined by the Highway Capacity Manual (HCM) (2010) is evaluated for the existing condition of hindu college junction and chandana bros junction and also for the improved condition for the same. The LOS of the hindu college junction and chandana bros junction are presented in Table 15 and 16 respectively.

Table 15 LOS for hindu college junction

From Link	To Link	Link Description	Actual Level Of Service (LOS)	New Level Of Service (LOS)
1	3	AC College to Market	**E**	**A**
1	6	AC College to GT Road	E	E
1	8	AC College to Nagarampalem	E	E
4	2	Market to AC College	D	D
4	6	Market to GT Road	**E**	**D**
4	8	Market to Nagarampalem	E	E
5	2	GT Road to AC College	D	D
5	3	GT Road to Market	D	D
5	8	GT Road to Nagarampalem	**D**	**B**
7	2	Nagarampalem to AC College	**C**	**A**
7	3	Nagarampalem to Market	D	E
7	6	Nagarampalem to GT Road	D	D

Table 16 LOS for chandana bros junction

From Link	To Link	Link Description	Actual Level Of Service (LOS)	New Level Of Service (LOS)
1	1	Market to Bus stand	C	C
1	4	Market to Kothapet	**D**	**C**
1	6	Market to Lalapet	C	C
2	2	Bus stand to Market	**D**	**C**
2	4	Bus stand to Kothapet	**D**	**C**
2	6	Bus stand to Lalapet	**C**	**B**
3	1	Kothapet to Bus stand	A	A
3	2	Kothapet to Market	D	D
3	6	Kothapet to Lalapet	D	D
5	1	Lalapet to Bus stand	**F**	**E**
5	2	Lalapet to Market	**F**	**D**
5	4	Lalapet to Kothapet	**F**	**E**

6.0 Conclusions

The following are the conclusions from the simulated results.

1. The delay for various routes of hindu college junction ranged from 21.2 – 73.4 seconds which has improved to 7.5 – 66.4 seconds. This improvement i.e. percentage reduction in delay is observed to be around 90% to 3.5% for various routes of hindu college junction.
2. Similarly, for chandana bros junction, the delay after improvements for various routes was determined to be 3.3 – 70.1 seconds over the existing 12.5 – 77.8 seconds. The percentage reduction in delay time was 73.6% - 4.3%.
3. From the Chi-square test, it is concluded that the hypothesis of improved conditions for the junctions hindu college and chandana bros are verified and accepted
4. Level Of Service (LOS) as defined by the Highway Capacity Manual (HCM) was also determined from the delays. For various rotes of two junctions, the LOS has improved with the improvements made to the intersections.

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