DESIGN OF TRAFFIC SIGNAL AT UN-SIGNALIZED INTERSECTIONS USING WEBSTER'S AND MICRO SIMULATION TECHNIQUE

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Abstract: In India, the increase in population has caused a lot of traffic problems at intersections. More people are using their own vehicles; the increasing of traffic volume at the un-signalized intersections has been on the rise which has resulted in many problems like road accidents, conflicts, and congestions. At present condition in Mahabubnagar town there will have the same problems like accidents, conflicts and congestion. The aim of this study is to determine the optimum signal timings at an un-signalized intersection during both peak and off-peak hours in Mahabubnagar town, specifically at one town, Ashok Talkies and Newtown junctions. This effort aims to minimize conflicts, accidents, and congestion in these areas, ultimately improving the overall traffic flow and safety.

A literature review is a text of previous scholarly papers, which includes the current knowledge including substantive findings, as well as theoretical and methodological contribution to a particular topic. Dr. Manish dutta (Assistant professor) and Prachi Agrawal (student), 2021 had focused their paper on designing and simulation of traffic signal at an un-signalized intersection at Nagpur. Data was collected from secondary sources and site visit. The peak and off-peak hour Traffic volume were collected through video graphic survey. Analysis and simulation was carried out using microscopic simulation technique that is PTV Vissim. Optimum signal timings were determined using Webster's method. The results were observed at selected un-signalized intersections and it was found that 118 sec, 92 sec & 72 seconds at Newton, Ashok talkies & one town junction respectively during peak hour traffic, and 84 sec, 60 sec & 58 seconds at Newton, Ashok talkies & one town junction respectively during off-peak hour traffic. This study can be further extended Signal coordination can be performed at study area, and also It can be further extended for performance evaluation with increasing geometric features at study area.

IndexTerms: **Traffic volume, Conflict points, Cycle length, Webster's, Microscopic simulation, PTV Vissim.**

1. INTRODUCTION

Traffic engineering is a specialized field within transportation engineering that utilizes engineering methods to ensure the secure and efficient flow of people and goods. Its primary focus lies in designing and constructing the infrastructure required for transportation, such as roads, railways, bridges, traffic signals, and signs. Additionally, traffic engineering involves the planning and geometric design of streets, highways, and adjacent areas, with the objective of facilitating safe, convenient, and cost-effective transportation for both individuals and goods. This scientific discipline encompasses the measurement and analysis of traffic and travel patterns, as well as the application of this knowledge to the practical aspects of urban planning and transportation management. Traffic signals, commonly known as traffic lights, are widely employed to manage traffic operations at urban intersections. The efficiency of an urban road network is heavily reliant on the effectiveness of these traffic signals. These signaling devices, found at road junctions, pedestrian

crossings, and other strategic locations, are designed to regulate the flow of conflicting traffic streams. As a crucial element of traffic control devices, traffic signals play a central role in assessing potential traffic hazards at intersections, which tend to be points of congestion and conflicts within the road network. Transportation has been a pivotal aspect of civil engineering since its inception. The construction of roads, bridges, tunnels, pipelines, canals, railways, ports, and harbors has been integral to the evolution of this profession. Civil engineers are actively involved in the development, construction, and operation of various transportation facilities, including street railways and underground transit systems, among others.

Need of the Study

Due to the rise in population and vehicle ownership, un-signalized intersections face challenges like accidents, conflicts, and congestion. In 2022, India recorded 4,61,312 in that 76,566 accidents occurred at un-signalized intersections only, which resulting in 27,308 deaths and around 50,000 injuries at un-signalized intersections. Traffic signals, often overlooked, aim to enhance safety, control traffic, and guide drivers. This study's primary objective is to minimize conflict points, ensure safe and smooth vehicle flow, and reduce the frequency and severity of accidents.

Objectives of the study

The objectives of this Study are as follows:

- To identify the traffic conflict points in major and minor streams in a particular study area.
- To identify the peak and off-peak hour traffic and estimate the traffic volume.
- To calculate the optimum cycle length of signal using Webster's method.
- To Analyze and simulate the traffic signal by using PTV Vissim micro simulation Technique.

2. LITERATURE REVIEW

The literature review is basically discussed about what work has already been done by other researches from the review of earlier investigations. The following some research article are discussed as follows;

Prof. Apeksha Choudhary, Saurabh Bora (2023) this paper focuses on the redesigning of existing traffic signals in Amravati city to minimize delay and accommodate heterogeneous traffic conditions. The traffic volume study was conducted using videography method and manual counting of vehicles. Webster's method is used for optimum cycle length and compared the results with existing traffic signal.

Prachi Agrawal et.al, (2021) The main aim of this Paper is designing proper traffic signal at un-signalized intersection in Nagpur city for continuous and smooth movement of vehicles, traffic volume study was conducted through video graphic survey at 11:00AM only, using Webster's method optimum cycle length is determined, from this obtained values are used to simulate the junction using Python software.

S. Pradeep Reddy, P. R. Bhanu murthy (2021) in this paper the author heterogeneous traffic is considered and analyzed by simulation tool that is PTV Vissim. And in this did not considered PCU factors, considered only traffic volume data for analysis.

D. Swetha et.al, (2020) in this paper the author discusses in urban areas, multiple road intersections in series can lead to conflicts and accidents. To address this, traffic signals are used to control flows, but fixed timings may cause delays and congestion. This study utilized PTV VISSIM micro-simulation software to assess and coordinate traffic signals, resulting in reduced delays and travel times along the street. The findings offer valuable insights for similar traffic coordination studies in other locations with comparable intersection intervals and traffic flow characteristics.

3. RESEARCH METHODOLOGY

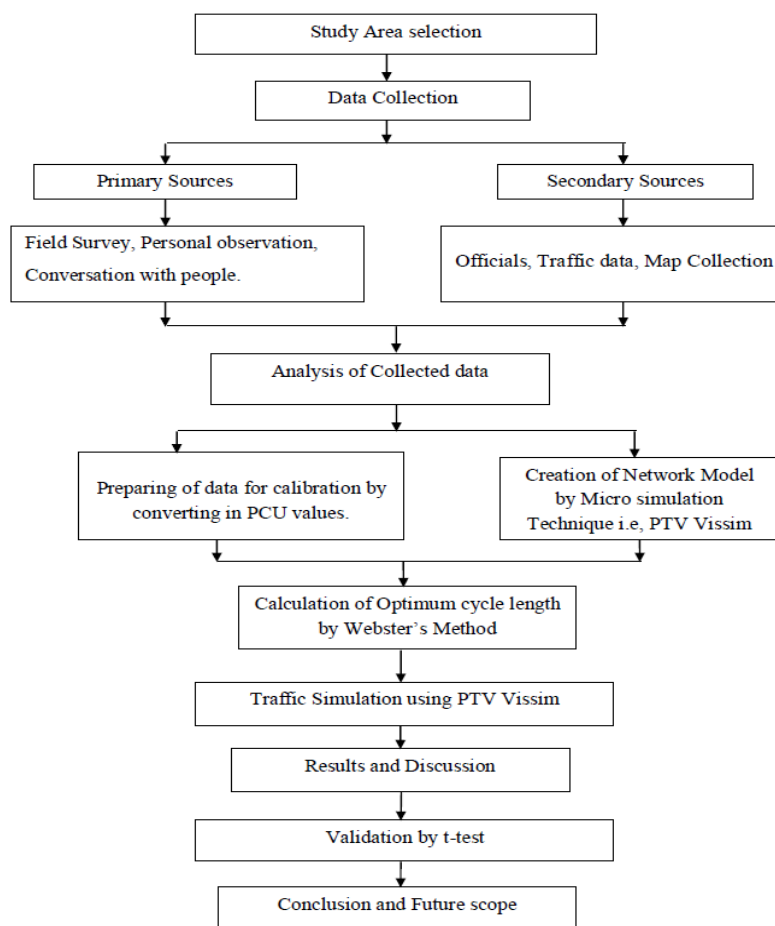The steps and methodology employed for this study are illustrated in Figure 1.

Figure 1: Research Methodology Flowchart

a) Study Area:-The study area selected in Mahabubnagar town it is located on National Highway 167, this corridor connecting Hagari (Karnataka) and Kodad (Telangana). There are three intersections, namely One town Junction, Ashok Talkies junction and Newtown junction. This town is located at 16.7488° N, 78.0035° E and MSL is 498m.

Fig. 2: Study Area Google Map Showing 3 Junctions

Fig. 3: Camera setup for traffic flow recording

b) Data Collection and Analysis:- In the present study traffic volume studies are studied at a intersections for a period of 4 months, and one week traffic volume data is collected during the morning peak hour traffic between 8:00Am to 10:00Am, Evening peak hour traffic 5:00Pm to 7:00Pm and off-peak hour traffic during Afternoon session 2:00Pm to 4:00Pm is collected using video graphic Survey by setting a camera at all the Three intersection during peak and off-peak hour traffic and taken the average of traffic volume data for signal design. The traffic volume study has started on 24th July, 2023 and the weather condition on this period is sunny during the day.

i) One town junction:- the below tables shows the traffic volume data in Veh/hr and it is converted into PCU/hr.

Table 1: Peak hour traffic volume data at one town junction in PCU/hr

Type of vehicle	Number of vehicles (Veh/hr)			PCU Value (Pcu/hr)		
	Phase-1	Phase-2	Phase-3	Phase-1	Phase-2	Phase-3
Two wheelers	1203	1550	960	601	775	480
Three wheelers	333	475	324	400	570	389
Car	304	246	153	304	246	153
LCV	41	47	35	57	66	49
Bus	46	34	19	101	75	41
Trucks	27	19	25	59	41	55
Tractor	22	16	12	88	64	48
Total	**1976**	**2387**	**1528**	**1610**	**1837**	**1215**

Table 2: Off-Peak hour traffic volume data at one town junction in PCU/hr

Type of vehicle	Number of vehicles (Veh/hr)			PCU Value (Pcu/hr)		
	Phase-1	Phase-2	Phase-3	Phase-1	Phase-2	Phase-3
Two wheelers	1129	1286	876	565	643	438
Three wheelers	287	423	298	344	508	358
Car	267	281	117	267	281	117
LCV	50	59	41	70	83	58
Bus	20	29	24	45	64	53
Trucks	35	19	22	77	42	48
Tractor	21	15	12	84	60	48
Total	**1809**	**2112**	**1390**	**1452**	**1681**	**1120**
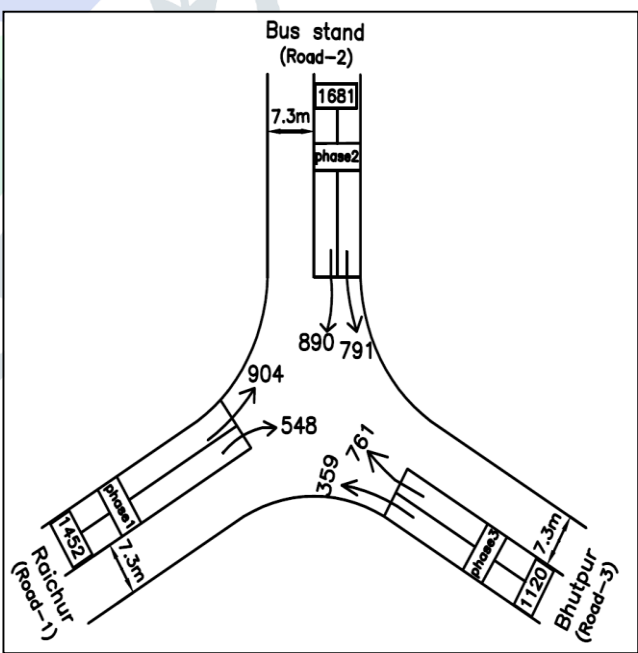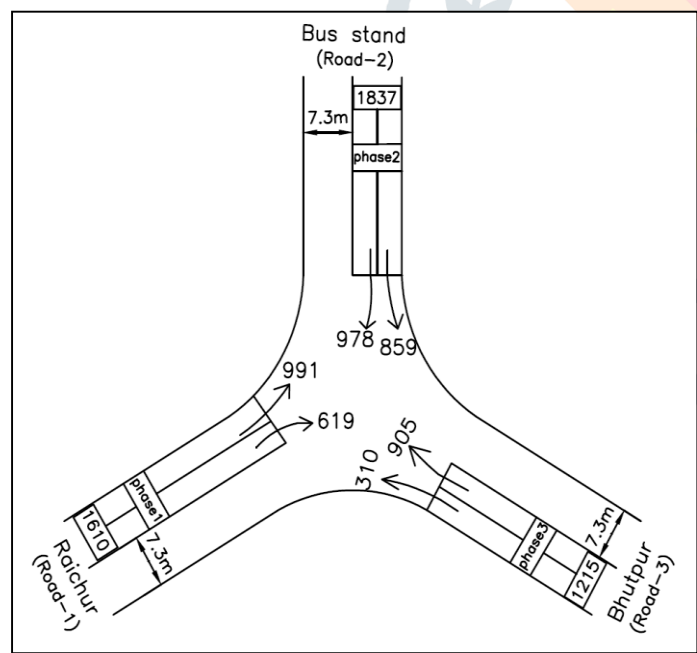
Fig 4: Phase diagram of peak hr. traffic At one town junction

Fig 5: Phase diagram of off- peak hr. traffic At one town junction

Steps for Simulation Analysis in PTV Vissim:

Step-1: Creating Road Network
Step-2: Vehicle inputs
Step-3: Creating vehicular composition
Step-4: Vehicle Routing Decision
Step-5: Signal controllers
Step-6: Creating Signal Heads

Step-7: Creation of Nodes
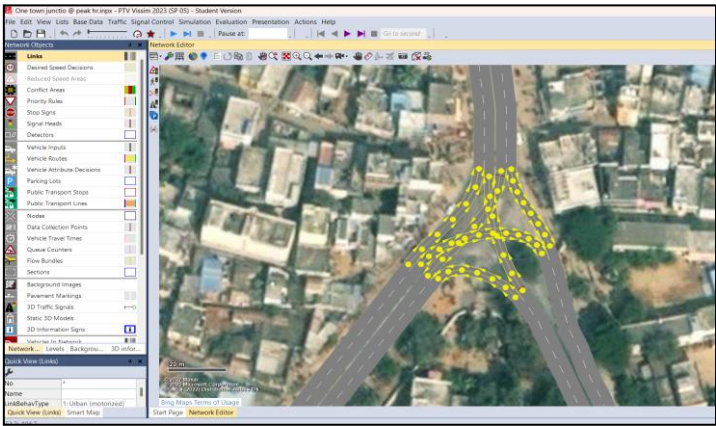Step-8: Network Check
Step-9: Simulation Results
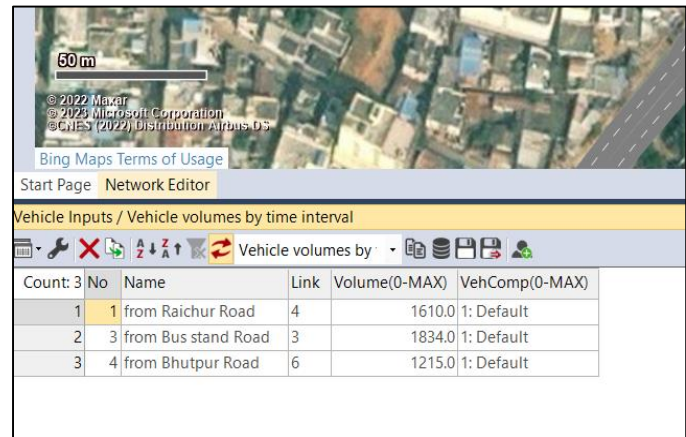

Fig 6: Connecting links
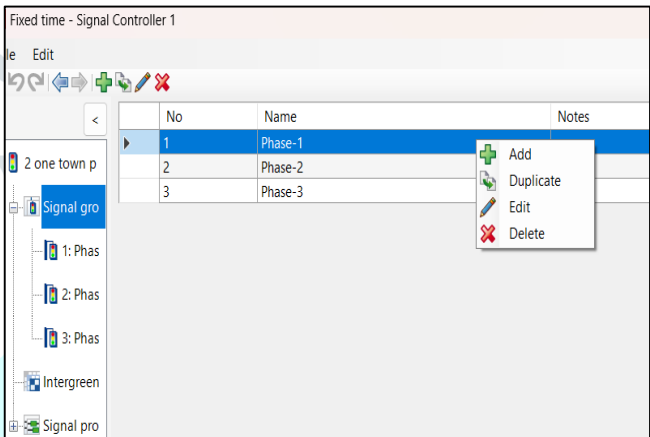

Fig 7: Vehicular volume inputs

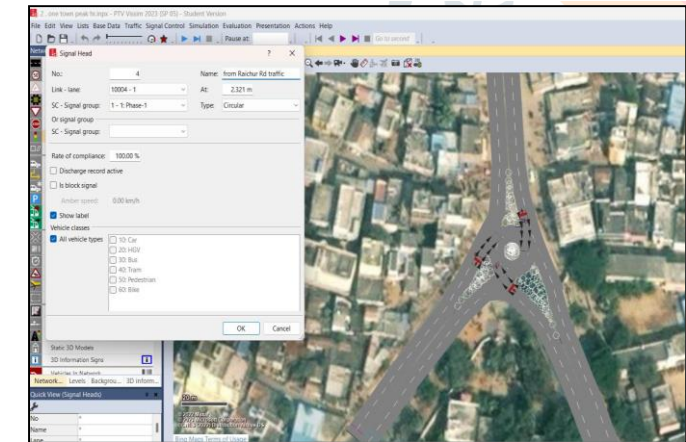**Fig 8: Creating Signal Phases**

Fig 9: Creation of Signal Head

Fig 10: Node Selection

Fig 11: 2D Simulation at one town junction

Fig 12: 3D Simulation at one town junction

ii) Ashok Talkies junction:- the below tables shows the traffic volume data in Veh/hr and it is converted into PCU/hr.

Table 3: Peak hour traffic volume data at Ashok Talkies junction in PCU/hr

Type of vehicle	Number of vehicles (Veh/hr)			PCU Value (Pcu/hr)		
	Phase-1	Phase-2	Phase-3	Phase-1	Phase-2	Phase-3
Two wheelers	1831	1772	1152	916	886	576
Three wheelers	571	743	470	685	892	564
Car	236	265	79	236	265	79
LCV	83	149	29	116	209	35
Bus	35	29	7	77	64	16
Trucks	16	17	7	36	37	15
Tractor	8	13	3	32	52	12
Total	**2938**	**3188**	**1849**	**2098**	**2405**	**1297**

Table 4: off-Peak hour traffic volume data at Ashok Talkies junction in pcu/hr

Type of vehicle	Number of vehicles (Veh/hr)			PCU Value (Pcu/hr)		
	Phase-1	Phase-2	Phase-3	Phase-1	Phase-2	Phase-3
Two wheelers	1322	1439	988	661	719	494
Three wheelers	358	572	218	430	686	262
Car	178	239	98	178	239	98
LCV	36	30	27	51	42	38
Bus	16	11	0	35	25	0
Trucks	19	14	7	41	31	15
Tractor	7	14	8	28	56	32
Total	**1936**	**2319**	**1346**	**1424**	**1798**	**939**

Fig 13: Phase diagram of peak hr. traffic At Ashok Talkies junction
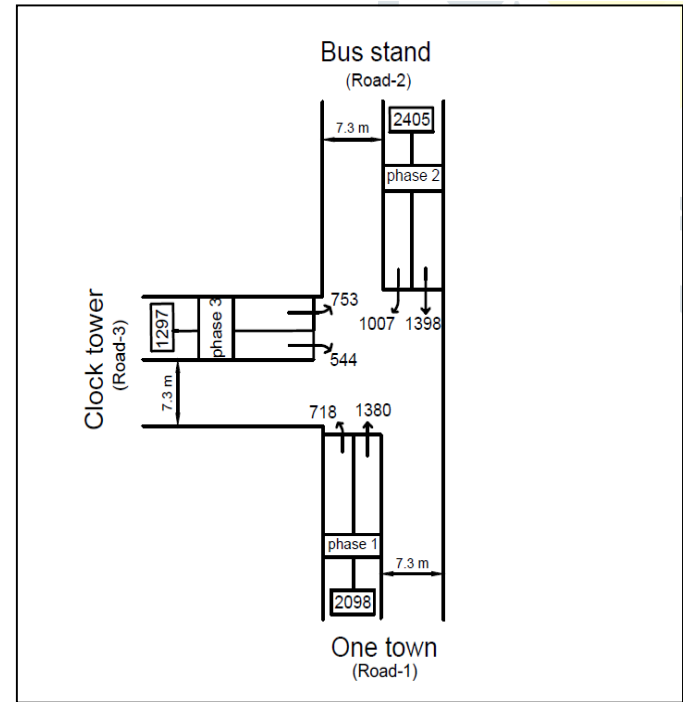

Fig 14: Phase diagram of off- peak hr. traffic At Ashok Talkies junction

Steps for Simulation Analysis in PTV Vissim:

Step-1: Creating Road Network
Step-2: Vehicle inputs
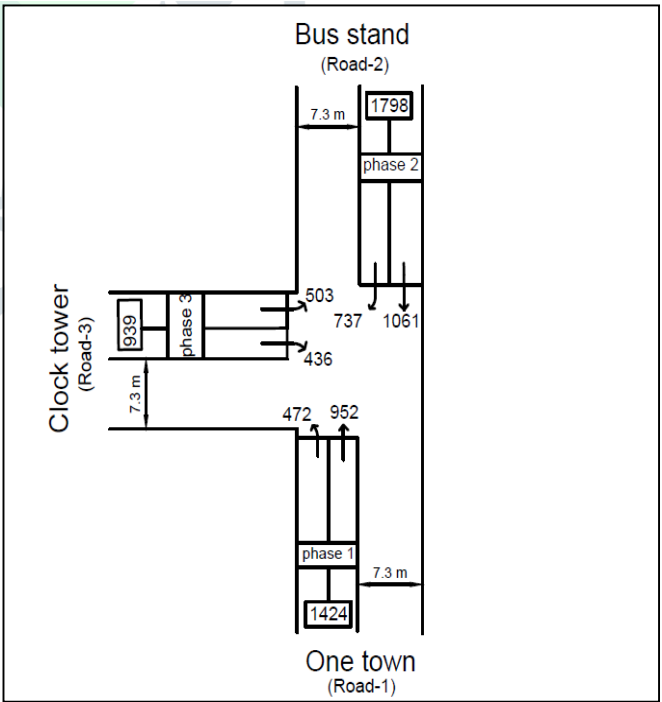Step-3: Creating vehicular composition

Step-4: Vehicle Routing Decision
Step-5: Signal controllers
Step-6: Creating Signal Heads
Step-7: Creation of Nodes
Step-8: Network Check
Step-9: Simulation Results

Fig 15: Connecting links

Fig 16: Vehicular volume inputs
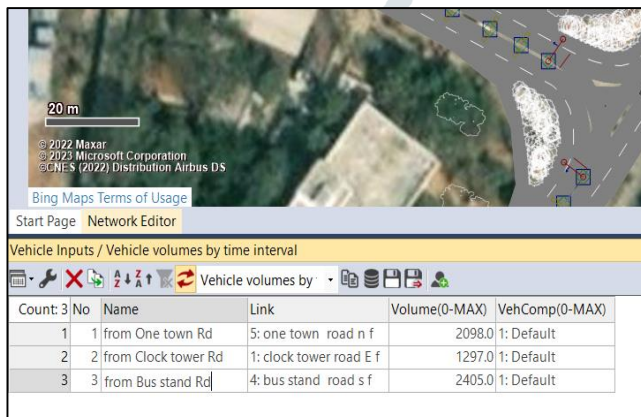
Fig 17: Creation of signal phases

Fig 18: Creating Signal Heads

Fig 19: Node Selection

Fig 20: 2D Simulation at Ashok Talkies junction   **Fig 21: 3D Simulation at Ashok Talkies junction**

iii) Newtown junction:- the below tables shows the traffic volume data in Veh/hr and it is converted into PCU/hr.

Table 5: Peak hour traffic volume data at Newtown junction in PCU/hr

Type of vehicle	Number of vehicles (Veh/hr)			PCU Value (Pcu/hr)		
	Phase-1	Phase-2	Phase-3	Phase-1	Phase-2	Phase-3
Two wheelers	2164	2339	1106	1082	1169	553
Three wheelers	765	852	302	918	1022	362
Car	294	365	130	294	365	130
LCV	22	40	17	31	56	24
Bus	22	46	12	49	101	27
Trucks	4	27	5	10	59	12
Tractor	16	7	5	64	28	20
Total	**3287**	**3676**	**1577**	**2448**	**2800**	**1128**

Table 6: Off-Peak hour traffic volume data at Newtown junction in PCU/hr

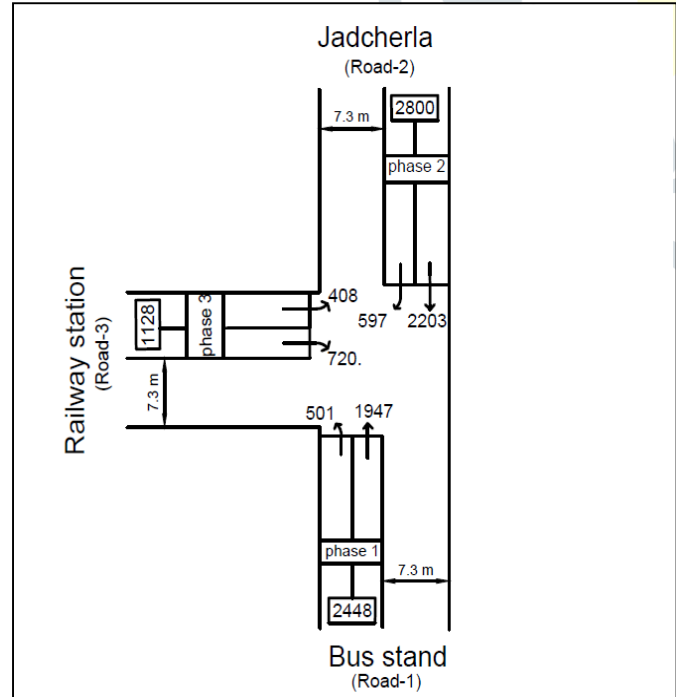| Type of vehicle	Number of vehicles (Veh/hr)			PCU Value (Pcu/hr)		
	Phase-1	Phase-2	Phase-3	Phase-1	Phase-2	Phase-3
Two wheelers	1604	2208	750	802	1104	375
Three wheelers	618	832	273	741	999	328
Car	240	336	60	240	336	60
LCV	16	57	7	23	80	10
Bus	15	19	0	34	42	0
Trucks	4	24	1	8	53	3
Tractor	8	5	3	32	20	12
Total	**2505**	**3481**	**1094**	**1880**	**2634**	**788**

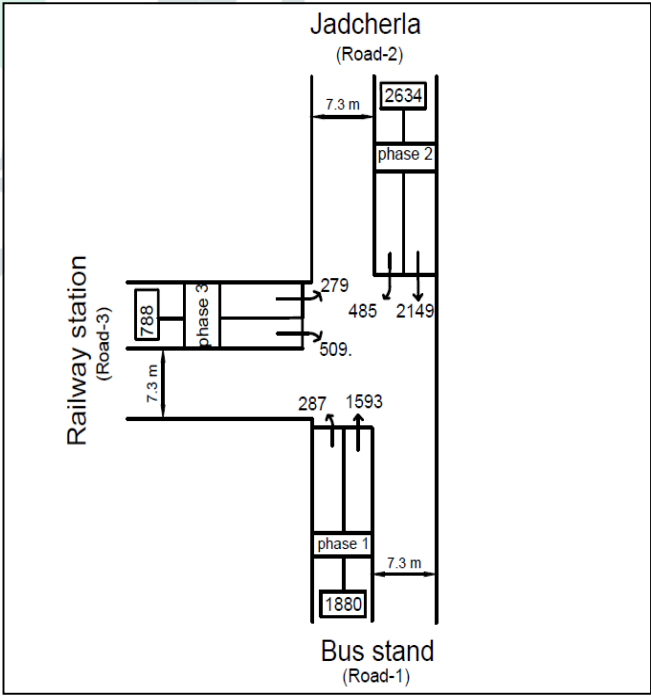**Fig 22: Phase diagram of peak hr. traffic At Newtown junction**   **Fig 23: Phase diagram of off- peak hr. traffic At Newtown junction**

Steps for Simulation Analysis in PTV Vissim:

Step-1: Creating Road Network

Step-2: Vehicle inputs

Step-3: Creating vehicular composition
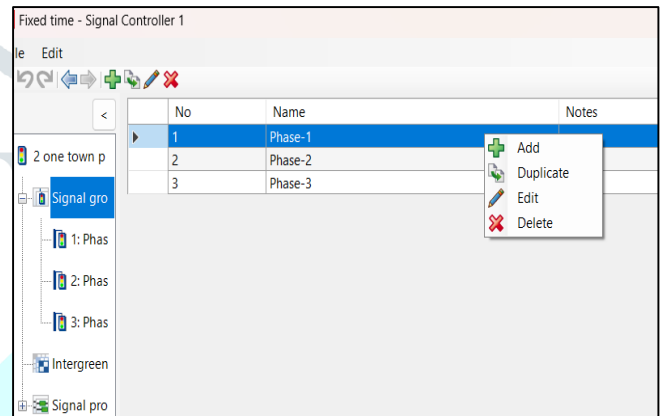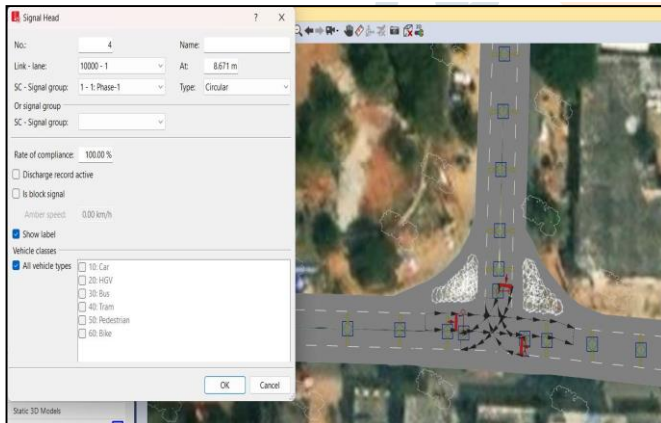Step-4: Vehicle Routing Decision
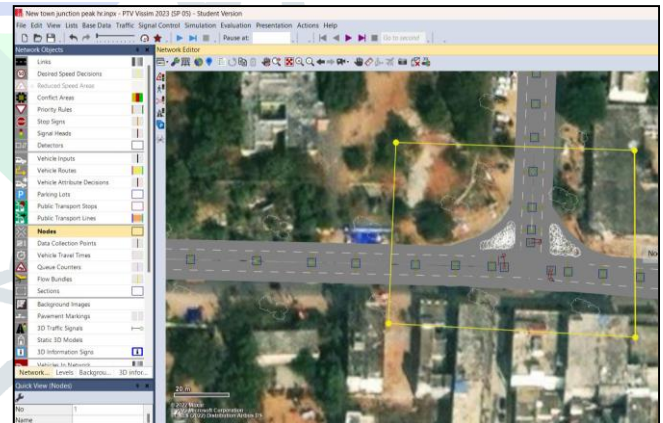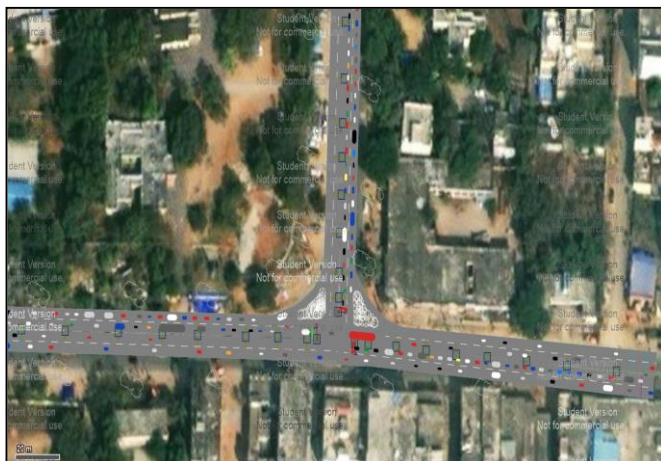Step-5: Signal controllers
Step-6: Creating Signal Heads
Step-7: Creation of Nodes
Step-8: Network Check
Step-9: Simulation Results

Fig 24: Connecting links

Fig 25: Vehicular volume inputs

Fig 26: Creating Signal Phases

Fig 27: Creating Signal Heads

Fig 28: Node Selection

Fig 29: 2D Simulation at Newtown junction

Fig 30: 3D Simulation at Newtown junction

4. DESIGN OF SIGNAL USING WEBSTR'S METHOD

The signal design procedure is outlined specifically focusing on peak hour traffic. The same approach applies to the signal design for off-peak hour of remaining junctions, as detailed below.

(a) Design of Signal for One town junction during Peak hour traffic

The following steps outline the process for designing a traffic signal at One Town Junction.

Step -1 Phase plan

The phase arrangement for one town junction during peak traffic hours is illustrated in Figure 4.

Step -2 Optimum Cycle Length (C_0)

$$C0 = \frac{1.5xL+5}{(1-Y)}$$ ……………………….……………Equation (1)

Where,

L = Lost time=2n+R

n = Number of phases = 3

R = All red time = 2 sec per each phase = 6 sec

Y = Summation of critical flow ratio = $y_1+y_2+y_3 = q_1/s_1 + q_2/s_2 + q_3/s_3$

L = 2x3+6 = 12 seconds

Table 7: Calculation of peak hour Critical flow ratio at one town junction

From	Raichur Road		Bus stand Road		Bhutpur Road	
To	Bhutpur	Bus stand	Raichur	Bhutpur	Bus stand	Raichur
Traffic Volume (PCU/hr)	619	991	978	859	905	310
Normal flow (q) in PCU/hr	619		978		905	
Width of Approach Road (W) in m	7.3		7.3		7.3	
Saturation flow (S) = 525xW	3830		3830		3830	
Critical flow ratio (Y) = q/s	0.17		0.26		0.24	

- Critical flow ratio (Y) = 0.17+0.26+0.24 = 0.67
- C_0 = 1.5x12+5/(1-0.67) = **72 seconds**

Step -3 Effective Green Time

Phase-1
- $G1 = \frac{y1}{Y}$x (C_0-L) = 0.17/0.67 x (72-12) = 16 seconds.

Phase-2
- $G2 = \frac{y2}{Y}$x (C_0-L) = 0.26/0.67 x (72-12) = 23 seconds.

Phase-3
- $G3 = \frac{y3}{Y}$x (C_0-L) = 0.24/0.67 x (72-12) = 21 seconds.
- Provide 2 seconds Amber time and 2 seconds All Red time per each phase

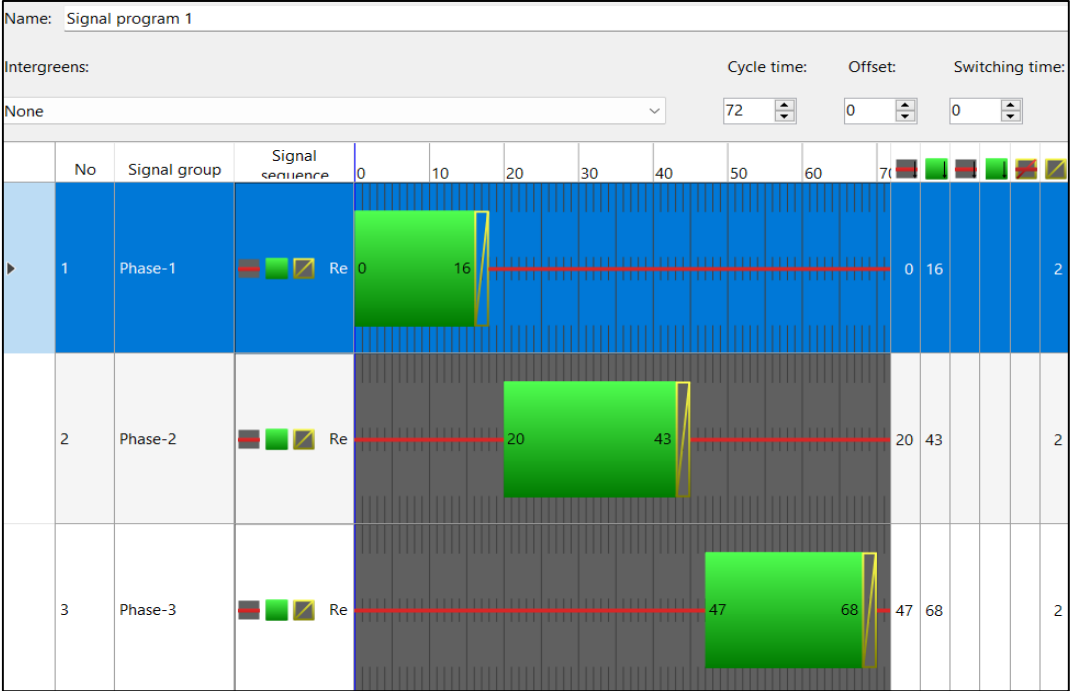∴ Total Cycle Length = 16+23+21+6+6 = **72 seconds.**

Fig. 31: Peak hour Signal program at one town junction

The above figure 31 shows the peak hour traffic signal timings for one town junction. Based on the calculation done on the PCU values obtained from the traffic survey, the optimum signal cycle length was found to be 72 seconds.

Fig. 32: Off-Peak hour Signal program at one town junction

The above figure 32 shows the off-peak hour traffic signal timings for one town junction. Based on the calculation done on the PCU values obtained from the traffic survey, the optimum signal cycle length was found to be 58 seconds.
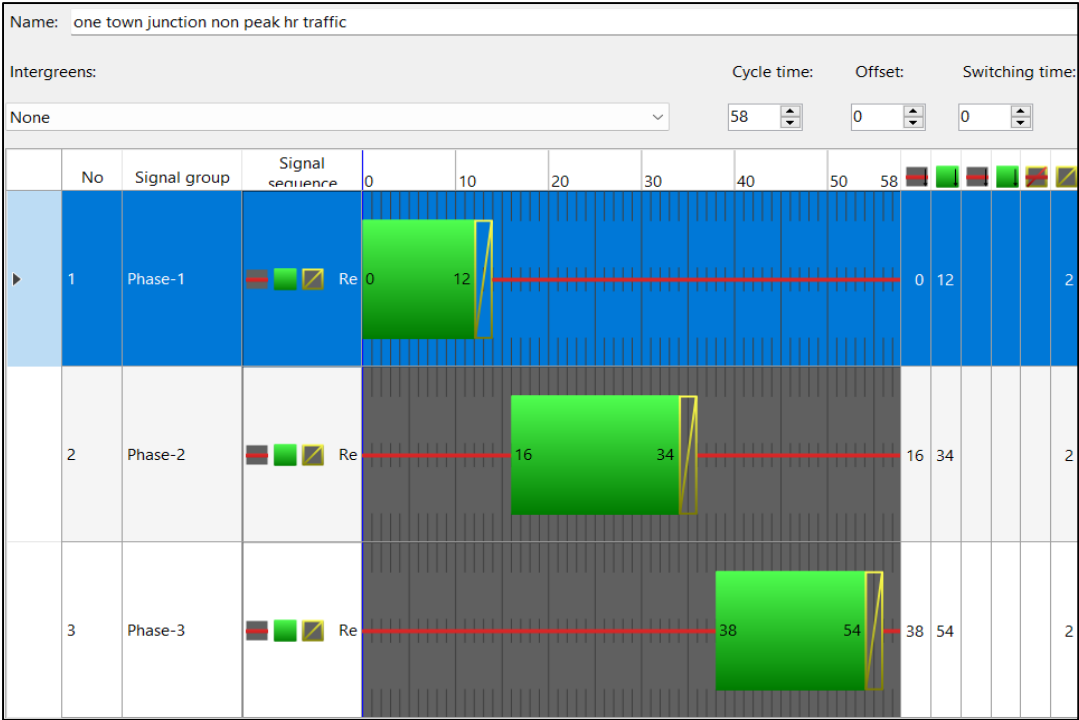
(b) Design of Signal for Ashok Talkies junction during Peak hour traffic

The following steps outline the process for designing a traffic signal at Ashok Talkies Junction.

Step -1 Phase plan

The phase arrangement for Ashok talkies junction during peak traffic hours is illustrated in Figure 13.

Step -2 Optimum Cycle Length (C₀)

$$C0 = \frac{1.5xL+5}{(1-Y)}$$ …………………….……… Equation (2)

Where,

> L = Lost time=2n+R
> n = Number of phases = 3
> R = All red time = 2 sec per each phase = 6 sec
> Y = Summation of critical flow ratio = $y_1+y_2+y_3$ = q_1/s_1 +q_2/s_2+ q_3/s_3

L = 2x3+6 = 12 seconds

Table 8: Calculation of peak hour Critical flow ratio at Ashok Talkies junction

From	One town Road		Bus stand Road		Clock tower Road	
To	Bus stand	Clock tower	One town	Clock tower	One town	Bus stand
Traffic Volume (PCU/hr)	1380	718	1398	1007	544	753
Normal flow (q) in PCU/hr	1380		1007		544	
Width of Approach Road (W) in m	7.3		7.3		7.3	
Saturation flow (S) = 525xW	3830		3830		3830	
Critical flow ratio (Y) = q/s	0.36		0.26		0.14	

- Critical flow ratio (Y) = 0.36+0.26+0.14 = 0.75
- C₀ = 1.5x12+5/(1-0.75) = **92 seconds**

Step -3 Effective Green Time

Phase-1

- $G1 = \frac{y1}{Y}$x (C₀-L) = 0.36/0.75 x (92-12) = 38 seconds.

Phase-2

- $G2 = \frac{y2}{Y}$x (C₀-L) = 0.26/0.75 x (92-12) = 27 seconds.

Phase-3

- $G3 = \frac{y3}{Y}$x (C₀-L) = 0.14/0.75 x (92-12) = 15 seconds.

● Provide 2 seconds Amber time and 2 seconds All Red time per each phase

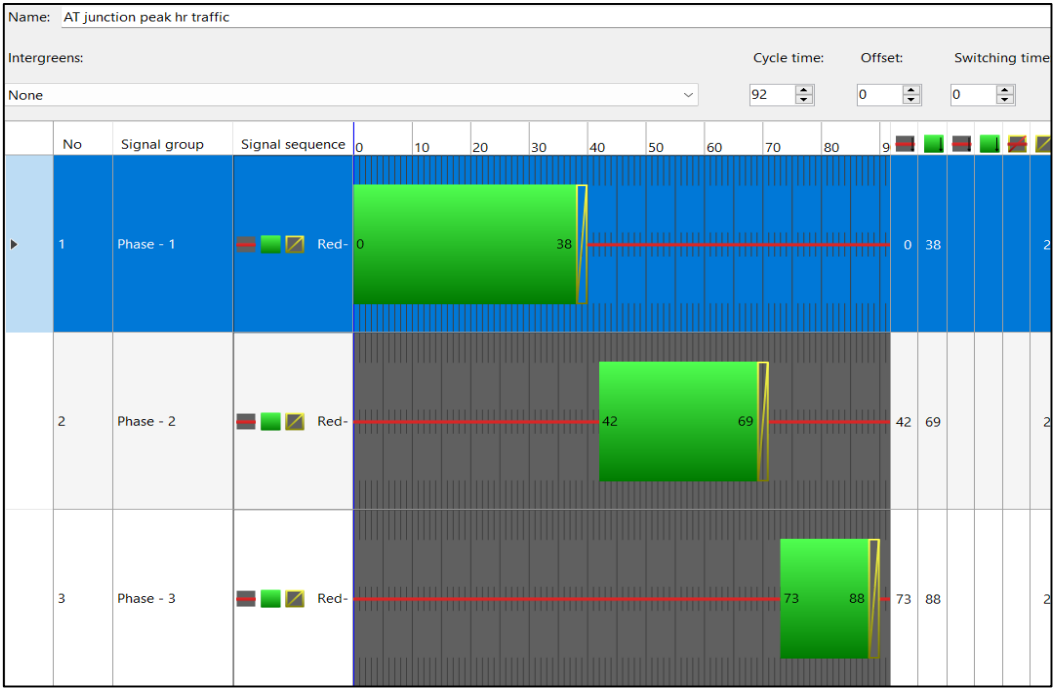∴ Total Cycle Length = 38+27+15+6+6 = **92 seconds.**

Fig. 33: Peak hour Signal program at Ashok Talkies junction

The above figure 33 shows the peak hour traffic signal timings for Ashok Talkies junction. Based on the calculation done on the PCU values obtained from the traffic survey, the optimum signal cycle length was found to be 92 seconds.
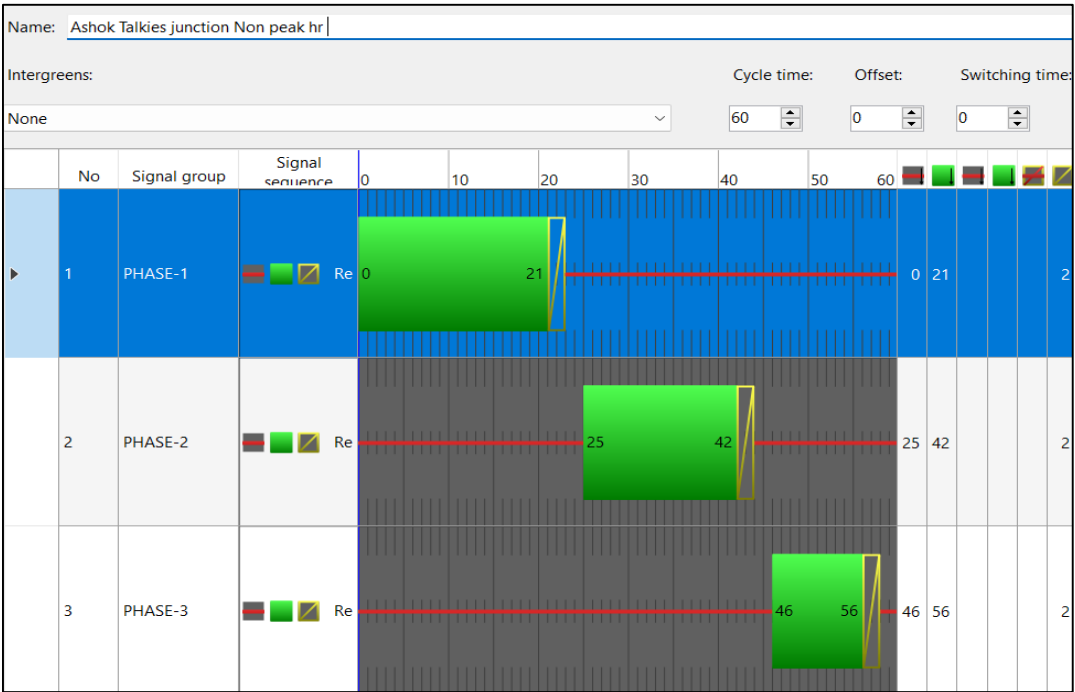

Fig. 34: Off-Peak hour Signal program at Ashok Talkies junction

The above figure 34 shows the off-peak hour traffic signal timings for Ashok Talkies junction. Based on the calculation done on the PCU values obtained from the traffic survey, the optimum signal cycle length was found to be 60 seconds.

(c) Design of Signal for Newtown junction during Peak hour traffic

The following steps outline the process for designing a traffic signal at Newtown Junction.

Step -1 Phase plan

The phase arrangement for Newtown junction during peak traffic hours is illustrated in Figure 3.20.

Step -2 Optimum Cycle Length (C$_0$)

$$C0 = \frac{1.5xL+5}{(1-Y)}$$ ……………………….…Equation (3)

Where,

L = Lost time=2n+R
n = Number of phases = 3
R = All red time = 2 sec per each phase = 6 sec
Y = Summation of critical flow ratio = $y_1+y_2+y_3 = q_1/s_1 +q_2/s_2+ q_3/s_3$

L = 2x3+6 = 12 seconds

Table 3.18: Calculation of peak hour Critical flow ratio at Newtown junction

From	Bus stand Road		Jadcherla Road		Railway station Rd	
To	Jadcherla	Station Rd	Bus stand	Station Rd	Bus stand	Jadcherla
Traffic Volume (PCU/hr)	1947	501	2203	597	720	408
Normal flow (q) in PCU/hr	1947		597		720	
Width of Approach Road (W) in m	7.3		7.3		7.3	
Saturation flow (S) = 525xW	3830		3830		3830	
Critical flow ratio (Y) = q/s	0.46		0.157		0.190	

- Critical flow ratio (Y) = 0.460+0.157+0.190 = 0.80
- C$_0$ = 1.5x12+5/(1-0.80) = **118 seconds**

Step -3 Effective Green Time

Phase-1
- $G1 = \frac{y1}{Y}$x (C$_0$-L) = 0.460/0.80 x (118-12) = 60 seconds.

Phase-2
- $G2 = \frac{y2}{Y}$x (C$_0$-L) = 0.157/0.80 x (118-12) = 21 seconds.

Phase-3
- $G3 = \frac{y3}{Y}$x (C$_0$-L) = 0.190/0.80 x (118-12) = 25 seconds.

- Provide 2 seconds Amber time and 2 seconds All Red time per each phase

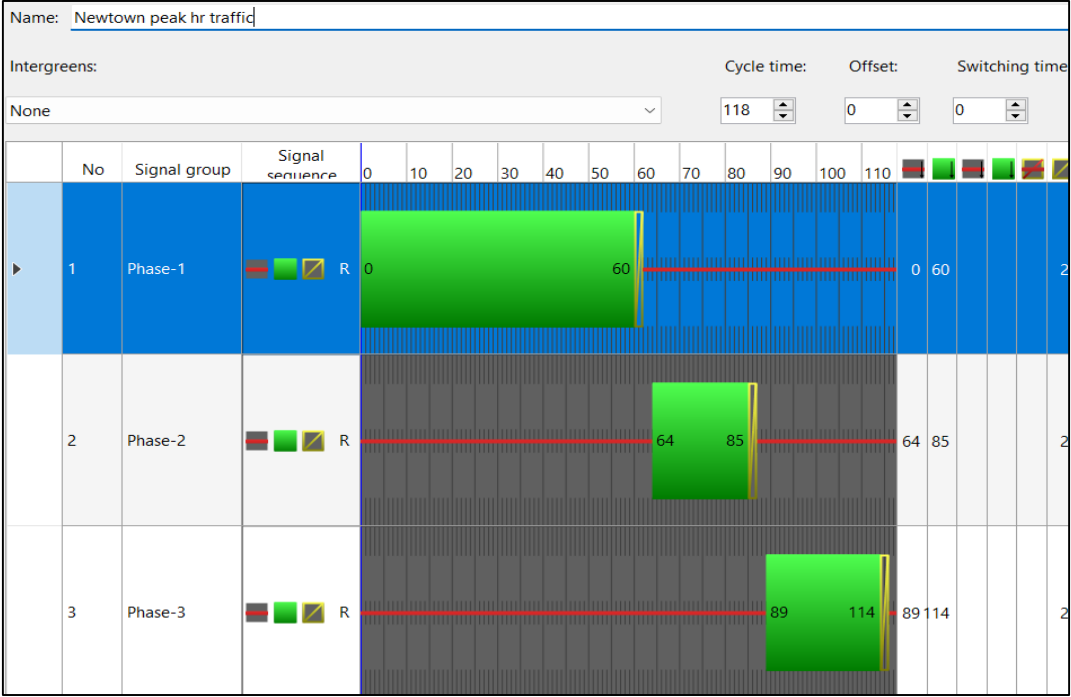∴ Total Cycle Length = 60+21+25+6+6 = **118 seconds.**

Fig. 35: Peak hour Signal program at Newtown junction

The above figure 35 shows the peak hour traffic signal timings for Newtown junction. Based on the calculation done on the PCU values obtained from the traffic survey, the optimum signal cycle length was found to be 118 seconds.
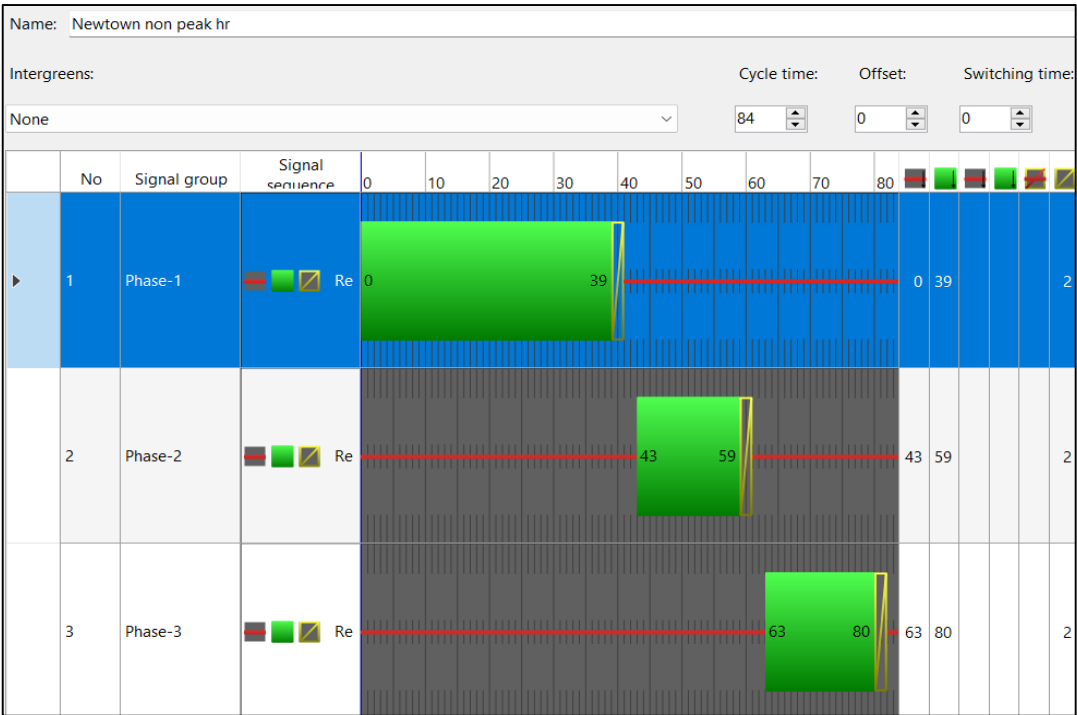
Fig. 36: Off-Peak hour Signal program at Newtown junction

The above figure 36 shows the off-peak hour traffic signal timings for Newtown junction. Based on the calculation done on the PCU values obtained from the traffic survey, the optimum signal cycle length was found to be 84 seconds.

5. RESULTS AND DISCUSSION

The main purpose of this study was to minimize conflict points at three un-signalized intersections by Webster's method and Microscopic simulation technique. The three intersections namely, one town junction, Ashok talkies junction and Newtown junction were studied on the basis of their traffic volume, Conflict points and geometric data. After analysis of traffic volume data and conflict points at the

intersections it was found that all the 3 intersection consisting of Traffic congestion, Conflict points, which is total 9 conflict points observed at each intersection and there is no proper control of traffic flow at three intersections. Therefore, the traffic signals are designed for controlling traffic flow and minimizing conflict points at the junctions. After the design of traffic signal the conflict points are minimized at three intersections, traffic signal timings are calculated on the basis of peak hour and off-peak hour traffic condition. The optimum cycle length for peak hour traffic at one town junction, Ashok talkies junction, & Newtown junctions is 72 sec, 92 sec & 118 seconds respectively and optimum cycle length for off-peak hour traffic at one town junction, Ashok talkies junction, & Newtown junctions is 58 sec, 60 sec & 84 seconds. The phase timings displayed in the figures above are all presented and illustrate the duration and sequence of signal phases at the intersection.

6. CONCLUSION

- The total 9 conflict points are observed at each 3 un-signalized intersections namely one town junction, Ashok talkies junction and Newtown junction.
- The peak hours are identified as 8:00-10:00 in the morning time where as 17:00-19:00 in the evening time and off-peak hours are identified as 14:00-16:00 in the afternoon time, during this period traffic volume data were collected successfully.
- Based on the estimated traffic volume data and PCU values the optimum cycle length was found for peak and off-peak hour traffic, for peak hour traffic the optimum cycle length at one town junction, Ashok talkies junction and Newtown junction is 72 sec, 92 sec, and 118 sec respectively, for off-peak hour traffic the optimum cycle length at one town junction, Ashok talkies junction and Newtown junction is 58 sec, 60sec and 84 seconds respectively.
- The traffic Simulation has done successfully at 3 intersections. By providing signals, there will be minimizing the conflict points, Smooth and orderly movement of vehicles at three junctions.

7. FUTURE SCOPE OF THE STUDY

- This study can be further extended Signal coordination can be performed at the study area using PTV Vissim.
- It can be further extended for performance evaluation with increasing geometric features at the study area.
- The signals can be further extended in such a way as to control automatically the signals depending on the traffic density on the roads using sensors like IR detector and receiver module extended with automatic turn off when no vehicles are running on any side of the road which helps reducing the Queuing length, Delay and power consumption saving.

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