"Traffic Assessment of an Intersection and its signal design using Webster's Model: A case study of *Ghatia Azam Khan Intersection* in Agra city"

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Abstract -*Agra is dense populated city situated in Uttar Pradesh state India. The Tajmahal is one of the seven wonder of world also situated in Agra which is getting more popular day by day. Agra is the biggest national and international tourist place in India. Agra is old city covered by narrow roads and traffic situation has become worse than worst because of lots of tourist vehicles. Nowadays, Agra is facing congested roads and large queues of vehicle at intersection. As we've observed the Agra town, there is a lot of inconvenience for traffic flow in Agra city. The lack of traffic signal conspicuity is continually mentioned as a contributing factor through motorists which are concerned in accidents at junction. Therefore, we need to design a traffic signal for clean go with the flow of visitors. The advantage of traffic signal includes an orderly movement of traffic, an increase capacity of intersection and requires only simple analytic design. In this project we have study traffic at Ghatiya Azam khan intersection. We choose this location because there are lots of school and different types of shops at this place and there is great rush all over the intersection. After studying the records we conclude that there is a need of traffic signal at that intersection. In order that we designed the traffic signal with two phase system within IRC suggestions. Signal timing includes determining how an awful lot green time the traffic lighting fixtures shall provide at an intersection approach. Traffic volume studies are carried out to determine the variety, movements, and groups of drive motors at a given area. This information can assist to discover critical flow time durations, determine the impact of huge vehicles or pedestrians on vehicle traffic flow, or document traffic volume traits. The length of the sampling duration depends in the type of be counted being taken and the intended use of the information recorded. Webster method is a rational technique for signal design.*

***Keywords*: Passenger car unit (PCU), traffic system, Webster's Models, Indian Road Congress (IRC)**

I. INTRODUCTION

India is a country with the second largest road network in the world. Out of the total stretch of 5.4 million km of road network, nearly 97991 km is covered by national roadways. Transport is an all exploitable sedulity. In the product stage, transportation is needed for carrying raw material and in the distribution stages; transportation is needed from ranch and manufactories to the marketing canters for distribution to the retailers and consumers. Transportation enhancement has increased particular mobility, reduce travel time, permit lesser freedom to elect the people their work and in the carrying of goods. Still the unprecedented growth of vehicles command especially the small automobiles and scooters in recent periods, our metropolises are beset with serious traffic problems like traffic and antecedents particularly at road crossway due to land constraints. The urban transportations problems are well known not just for traffic engineers but to people. Overcrowded and congested with vehicles of all type creating lots of traffic problems and profanations making the cities a veritable jungle. In fact jam-ups in the urban transportation system have risen because the cities aren't planned and erected for supporting the volume of population they're given harbor today. Travel has turn innately unsafe exercise in cities.

As human population grows quick in urban areas, vehicular traffic volume has also increased proportionally following increased mobility and the geometric increase in the rate of motor vehicle control. This accounts for the violent traffic jam-up that's associated with urban areas which affects their livability in terms of jam-up, pollution, high travel cost, detention, etc. Traffic jam-ups are generally caused by extreme detainments at junctions in supreme cases.

In earlier time traffic is controlled by traffic police by showing sign to the traffic but as the traffic volume is growing large and large it isn't possible to handle the traffic by one traffic police so as to under come this problem traffic signals has been designed to control the traffic with delicacy and timely. Road signal design is a must-have demand for traffic present which enables smooth inflow of traffic, prevents accidents and controls traffic movement at an junction. Due to the growing population in India, there's a rapid-fire growth in employment and accordingly transportation, these days have turn a authentically important. In order to get a grip on traffic movement and to shut out problems, these signals are much more useful.

II. LITERATURE REVIEW

There are number of similar findings which helped us in a direct or indirect way. They are as follows-
College of Engineering, University of Agriculture Makurdi, Benue State, Nigeria. ***(2018)*** publish a paper involved the designing of fixed-timed signal- controlled traffic system for 4-leg at-grade intersections, namely "SMS" and "B-Division" intersections in Makurdi town

using Webster's traffic signal models, and performance assessed. Geometric layouts of the intersections were measured and manual traffic count carried out to obtain average travel demand (pcu/h) for base year (2017) and projected year (2027) using traffic growth rate of 3%. This study is very similar to our study where authors precisely evaluates the required data and design traffic signal using Webster method. It helps us to understand Webster method more clearly and assess us to collect all the data manually at the selected location.

Department of Civil Engineering, College of Engineering, Osmania University, Hyderabad. ***(2018)*** publish a paper which deal with the designing of traffic control system at Narsingi Junction, Hyderabad, using Webster method. It aimed at minimising total delay, building short queues, and providing a high probability of passing through the intersection on the first given period for most users.This study is useful in a way that the authors evaluated total cycle time and green time for each road at intersection. The bar graphs depicting traffic volume at each hour on different sections of road which further helps us to support our study.

International journal of scientific and Engineering research ***(2018)***
paper involved the designing of Traffic Signal at Kundalahalli Junction, Bengaluru, Karnataka. The Design of traffic signal is done according to the Indian Road congress (IRC 93) method of signal design by adopting maximum average Passenger count unit (PCU) on the intersection in each direction. The traffic signal is already provided at the intersection which is to be upgraded as the cycle length provided is more than the optimum cycle length.
It clearly shows traffic signal time diagram for each road at intersection which in return helps us to incorporate in our study.

Civil Engineering Department, PEC University of Technology, India. ***(2015)*** publish a study in which author has proposed an automatic traffic signal at Madhya Marg, Chandigarh in which pre timed signals were designed by making use of Webster's method and I.R.C method of signal design. Webster's method gives the optimum cycle length whereas the IRC method gives minimum green time on basis of time taken by pedestrians to cross the approach lane. The count was taken by slow playback of video on laptop. In this paper, He has compared pre timed signal with automated signal in which automated signals were proven to be more efficient as these signals save the wasted time and increase the capacity.

Department of Computer and Communication System Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia. ***(2007)*** also publish a research paper in which author has presented a combination of electromagnetic sensors and fuzzy logic technology in which electromagnetic sensors where responsible for counting the number of cars and fuzzy logic technology was responsible for allotment green time to the traffic to clear off the intersection efficiently. This method was proven to be very effective in handling the traffic and helps us to understand other ways for counting traffic vehicles.

In a Paper by International Journal of Innovative Research in Science, Engineering and Technology ***(2014)*** the author has designed a project to develop a density based dynamic traffic signal system. The project consisted processing of image captured in the traffic signal and then it was converted to grey scale image and after that to calculate the number of vehicles contours were drawn to have its threshold. Calculation of number of vehicles gave the density which was further used for allocating green time to the traffic on the approach lane by using the Raspberry pi as a microcontroller.

Civil Engineering Department, F.E.T.R, Bardoli, Surat. ***(2018)*** presented a paper related to improvement of intersection at Simada Naka Junction, Surat. It aimed to to investigate traffic related problem and to provide necessary solutions. The analysis is based on video graphic method, data has been collected of peak hours at the selected intersection. Volume conversion is carried out by adopting PCU values from IRC recommendations. Various other traffic flow characteristics are calculated from empirical formula proposed by Transportation Road Research Lab (TRL). Various alternatives has been referred for the solution and out of various alternatives rotary design is taken into account which will be helpful in managing traffic flow on intersection.

LITERATURE GAP

India is developing country with population of about 125 crores and with that ranking 2nd in world. As traffic flow in India is heterogeneous, so to carry out analysis of traffic is difficult. Consequently, there are very few papers available which deals and collects on-site data incorporating traffic congestion problems in India.
In this study, one intersection of Agra city is selected as the study area because Agra is an important world heritage site. For a city with 1.7 million population that has grown at more than 25% in the last thirty years, the infrastructure development has failed to keep pace with population growth. Recent data show that Agra has recorded an increase in road fatalities from 89 in 2001 to 653 in 2011. Agra had a fatality rate of 41 persons per 100,000 persons in 2011. This compares with rates of 11 in Delhi, 10 in Vadodara, and 24 in Visakhapatnam. Agra has among the highest fatality rates in Indian cities. Therefore this paper is unique in a way that it only design traffic control system at selected intersection but also provides other preventive measures to avoid the problem of traffic congestion as well as increased fatalities.

Figure 1-Screenshot of Agra plan view from google map.

III. OBJECTIVES AND SCOPE

To study the existing traffic situation for the selected 2 km road, proposed research project aims to investigate the features of mixed traffic flows in order to determine correct conjectural distributions for key traffic variables that influence traffic stream characteristics, as well as to investigate flow characteristics and vehicular interactions. The broad objectives of research work are listed below follows:

A. To design the appropriate signal timings for Ghatiya Azam khan. Intersection.
B. To achieve optimal performance of intersections and reduce traffic congestion.
C. To calculate the basic traffic flow parameters for the intersection.
D. To provide suggestion for improvement of intersection.
E. Reduce the frequency of delays and accidents occur at intersection.

The study's scope includes an understanding of how to identify road sections in order to conduct necessary traffic studies and quantify problems in order to provide solutions. The traffic studies in research work's include :

- Design of signal timings at Ghatiya Azam Khan. Intersection.
- Spot Speed Study on the roads approaching to the intersection.
- Traffic Volume Count Study at Ghatiya Azam Khan Intersection.

The major purpose of the project is to review and redesign intersections in light of the city's current traffic concerns and as part of a continuing programme of examining and redesigning intersections. The goal of this analysis is to look into road intersections in depth. Using their traffic control tactics as an example performance and other key characteristics, and then redesign them in accordance with the current needs and future traffic, as well as suggest improvements to their current situation layout. The findings and recommendations from these research will aid in a better understanding of the issues and the development of effective solutions all of the issues.

Figure2-Passing vehicles on intersection

IV. FIELD SURVEY OF PROJECTED AREA

In this report, LOS levels were determined primarily using An existing at-grade 4-leg un-signalised road intersection in Agra city U.P. were considered for this study. The intersection is namely Ghatiya Azam khan Chauraha situated near St. Johns school. This junction connects Chilli Int road in north direction to St. Peter's road in south direction and Ghatiya road in west direction to City Station road in east direction. The St. Peter's road leads to many schools and street side vendors on the way which creates great rush at the intersection. It has been observed over the years that these intersections experience high traffic demand on daily basis, with delays and crashes becoming prolonged and increasingly frequent.

The screen shot from Google maps is as shown below. As it has cross section, there are merges and diverges in the crossing of these three roads. And there will be no orderly movement of traffic. In this connection, there is possibility for the traffic jams as well as accidents to occur. So there is a very heavy requirement for regulation of traffic, as well as orderly movement. To achieve this, there is a need of signalized cross-section.

Figure 3-Screenshot of intersection from google map.

V. PROBLEM STATEMENT

A. Absence of pedestrian pathway: The roads are mostly devoid of any safe infrastructure like footpaths or refuge space. Mostly in rural and urban areas roads have only been paved to allow for movement of motorized vehicles

B. Parking encroachments: Pedestrian paths are encroached by two wheelers car parking and especially local vendors making it unusable; forcing the pedestrian to walk on the carriageway alongside motorized traffic.

C. Insufficient widths: if footpaths are available, they are not wide enough to ensure smooth and comfortable walking.

D. Lack of designated parking spaces: Most road stretches do not have designated parking for TSR, rickshaws and cars. Most of the on-street parking is free of charge.

E. Missing traffic signals: Intersections are unsafe since traffic signals are absent or are not in a working condition.

F. Design of integrated spaces for hawkers/ vendors: A great deal of informal activity exists on the roads. Street vendors stand along the road providing service to bus commuters, cyclists and pedestrians. Though they are seen as encroachments by authorities, they provide security and essential services on our roads. The need to integrate them
For the road design is critical.

G. Lack of planning to integrate services and utilities: Light and electricity poles intrude abruptly along the pedestrian path and road edges. These obstructions indicate a lack of planning to integrate the utility in the road design so that they can be easily maintained in future without disturbing pedestrians and cyclists. Proper drainage has been not provided. This leads to waterlogging, adding to the inconvenience to people on the sidewalks and road edges.

VI. METHODOLOGY

Level of Service, signal design procedure involves six major steps. They include the-

- Phase design
- Determination of amber time and clearance time
- Determination of cycle length
- Apportioning of green time
- The performance evaluation of the above design.

A. The objective of phase design is to separate the conflicting movements in an intersection into various phases, so that movements in a phase should have no conflicts. If all the movements are to be separated with no conflicts, then a large number of phases are required.

B. To illustrate various phase plan options, consider a four legged intersection with through traffic and right turns. Left turn is ignored.

CYCLE TIME

Cycle time is the time taken by a signal to complete one full cycle of iterations, i.e. one complete rotation through all signal indications. It is denoted by C. In Webster Method corresponding to least total delay to the vehicles at signalised intersection has been worked out. This is rational approach. The field work consists of finding (i) Saturation flow Sa per unit time on each approach of the intersection and (ii) the normal flow "$q_{,,}$ on each approach during the design approach. The standard values for saturation flow, Sa according to Webster are given as in the below table1.

Width (m)	3.0	3.5	4.0	4.5	5.0	5.5
PCU/hr	1850	1890	1950	2250	2250	2900

Table 1- Saturation flow for widths 3 to 5.5 meter

Based on the higher value of normal flow, the ratio

Y1 = q1/ Sa and

Y2 = q2/Sa---------- (I)

are determined on the approach roads 1 and 2. In the case of mixed traffic, it is necessary to convert all the values in terms of PCU values which should be determined separately. The Saturation flow is to be obtained from careful field studies by noting the number of vehicles in the stream of compact flow during the green phases and the corresponding time intervals precisely. In the absence of the data

approximately value of saturation flow is estimated assuming 160 PCU per 0.3 meter width of the approach. The normal flow of the traffic is also determined on the approach roads from the field studies from the design period (during the peak or off peak hours, as the case may be).

The optimum signal cycle is given by

$$C_0 = (1.5L+5)/(1- Y) \text{---------- (II)}$$

Where L = total lost time per cycle, seconds

L = 2n+R ---------- (III)

n = number of phases, R = all red time.

Y =Y1+Y2 +Y3---------- (IV)

Then G1= Y1/ Y (C0−L) and

G2= Y2/ Y (C0−L) ----- (V)

- **Traffic count**

Traffic counts are carried out by different groups consisting of

Similarly the procedure is followed when there are more number of signal phases.

four students in each group. On the site, the students are directed to record the video from their mobile phones of 10 minutes interval, starting each video at the same time, having a clear view of though traffic and turning traffic. The readings are taken in a three sessions of a working day i.e. morning, afternoon and evening session. The traffic count comes out maximum in afternoon session due to schools leaves at the same time in the nearby areas.

CALCULATION

- Traffic design using the present condition of road during peak hours

Final Data after Observing Traffic Volume in P.C.U.

The PCU values for peak hour session for the corresponding routes are as the below figure.

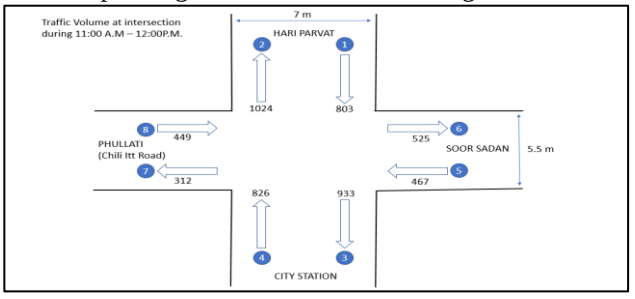

Figure 4- Layout of *Ghatiya Azam khan* intersection with PCU values

From the above PCU values, the maximum PCU value from each phase is considered for the calculation of cycle length. Since the there is good value of right turning traffic on the minor road, therefore there is need to increase phase for the turning traffic. The most appropriate signalling system for this road would be three phase signalling system.

Normal flows.

q_1=1024 PCU/hr

q_2=449 PCU/hr

q_3=467 PCU/hr

For the calculation of cycle length, saturation value, Sa is required, and it is taken as 1890 for the length of lane 7m and 1850 for the length of lane 5.5m.

$Y_1=q_1/S_{a1}=1024/1890=0.54$ PCU/hr

$Y_2=q_2/S_{a2}=449/1850=0.24$ PCU/hr

$Y_3=q_3/S_{a3}=467/1850=0.25$ PCU/hr

$Y=Y_1 + Y_2+ Y_3$

$=0.54+0.24+0.25$

$=1.03>1$, which is **not a safe condition**.

Therefore, there is a need to redesign the traffic system by increasing the lane width of both roads. For accommodating good saturation traffic volume, increase the lane width of both roads to 9m.

Redesign the traffic by increasing the lane width (w_A=9m & w_B=9m).

1) The PCU values for **afternoon session** (peak hour) for the corresponding routes are as the below figure.

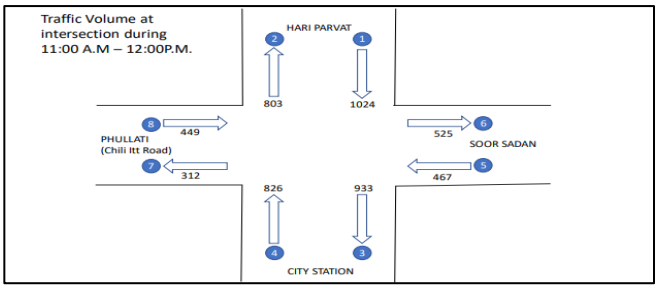

Figure 5- Layout of *Ghatiya Azam khan*. Intersection with PCU values for afternoon

Again, from the above PCU values, the maximum PCU value from each phase is considered for the calculation of cycle length. Since the there is good value of right turning traffic on the minor road, therefore there is need to increase phase for the turning traffic. The most appropriate signalling system for this road would be three phase signalling system.

Normal flows.

q_1=1024 PCU/hr
q_2=449 PCU/hr
q_3=467 PCU/hr

For the calculation of cycle length, saturation value, Sa is required, and it is taken as 2250 for the length of lane 9m.

$Y_1=q_1/S_{a1}=1024/2250=0.45$ PCU/hr
$Y_2=q_2/S_{a2}=449/2250=0.19$ PCU/hr
$Y_3=q_3/S_{a3}=467/2250=0.20$ PCU/hr

$Y=Y_1 + Y_2+ Y_3$
$=0.45+0.19+0.20$
$=0.84<1$, which is a safe condition.

Cycle length according to ***Webster method*** is calculated using the formula

$$C_0 = (1.5L+5)/(1- Y)$$

where L= 2n+R

Considering all red time = 9 seconds (time for pedestrian crossing),
Amber time = 2 seconds for each phase = 6 seconds for three phases.

L=lost time per cycle
n= number of phases=3
L=2(3)+9=15 sec

C_0= (1.5(15)+5)/(1-0.84)=172 sec

Calculation of Green time

(a) Phase 1

$G_1=Y_1/Y\ (C_0—L)$
$=0.45/0.84\ (172—15)$
$=84$ secs

(b) Phase 2

$G_2= Y_2/Y\ (C_0—L)$
$=0.19/0.84\ (172—15)$
$=36$ secs

(c) Phase 3

$G_3= Y_3/Y\ (C_0—L)$

$=0.20/0.84\ (172—15)$
$=37$ secs

CYCLE LENGTH=172 secs

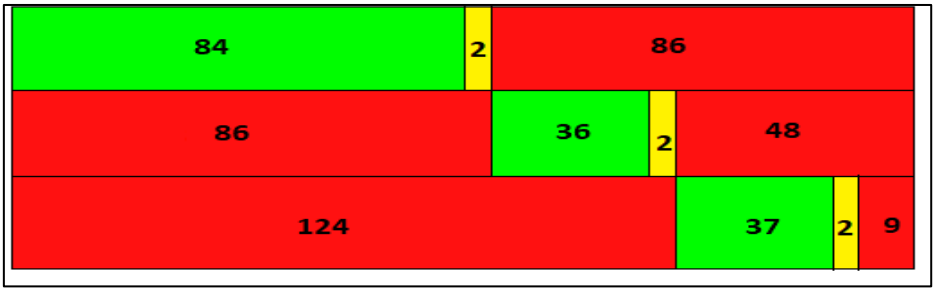

Figure 8- Signal Phase Diagram for Afternoon Session.

2) The PCU values for the morning session for the corresponding routes are as the below figure.

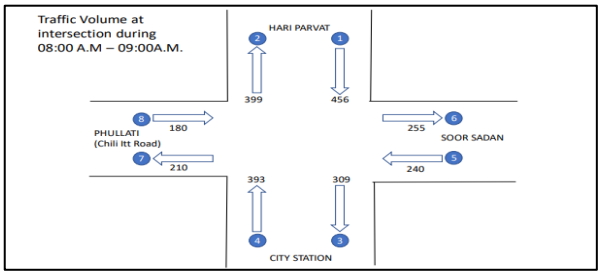

Figure 6- *Ghatiya Azam khan*. Intersection with PCU values for morning

Again, from the above PCU values, the maximum PCU value from each phase is considered for the calculation of cycle length. Since the there is good value of right turning traffic on the minor road, therefore there is need to increase phase for the turning traffic. The most appropriate signalling system for this road would be three phase signalling system.

Normal flows.

q_1=456 PCU/hr
q_2=240 PCU/hr
q_3=180 PCU/hr

For the calculation of cycle length, saturation value, Sa is required, and it is taken as 2250 for the length of lane 9m.

$Y_1=q_1/S_{a1}=456/2250=0.20$ PCU/hr
$Y_2=q_2/S_{a2}=240/2250=0.11$ PCU/hr
$Y_3=q_3/S_{a3}=180/2250=0.08$ PCU/hr

$Y=Y_1 + Y_2+ Y_3$
$=0.2+0.11+0.39$
$=0.39<1$, which is a safe condition.

Cycle length according to Webster method is calculated using the formula

$$C_0 = (1.5L+5)/(1- Y)$$

where L= 2n+R

Considering all red time = 9 seconds (time for pedestrian crossing),
Amber time = 2 seconds for each phase = 6 seconds for three phases.

L=lost time per cycle
n= number of phases=3
L=2(3)+9=15 sec

C_0= (1.5(15)+5)/(1-0.39)=45 sec

Calculation of Green time

(d) Phase 1

$G_1=Y_1/Y$ (C_0—L)
=0.20/0.39 (45—15)
=15 secs

(e) Phase 2

$G_2= Y_2/Y$ (C_0—L)
=0.11/0.39 (45—15)
=36 secs

(f) Phase 3

$G_3= Y_3/Y$ (C_0—L)
=0.08/0.39 (45—15)
=6 secs

CYCLE LENGTH=45 SEC

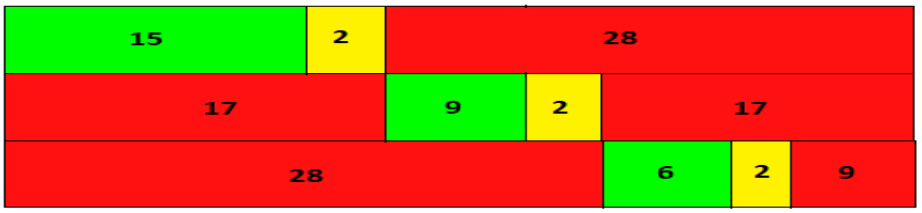

Figure 7- Signal Phase Diagram for Morning Session

3) The PCU values for the evening session for the corresponding routes are as the below figure.

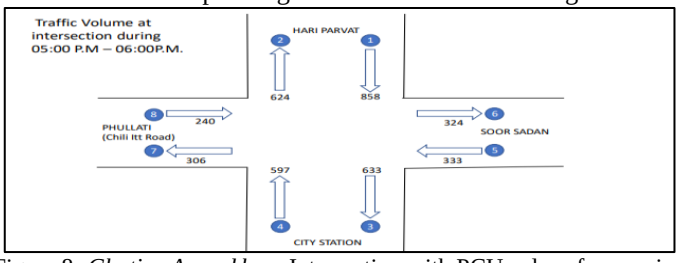

Figure 8- *Ghatiya Azam khan*. Intersection with PCU values for evening

Again, from the above PCU values, the maximum PCU value from each phase is considered for the calculation of cycle length. Since the there is good value of right turning traffic on the minor road, therefore there is need to increase phase for the turning traffic. The most appropriate signalling system for this road would be three phase signalling system.

Normal flows.

q_1=858 PCU/hr
q_2=333 PCU/hr
q_3=270 PCU/hr

For the calculation of cycle length, saturation value, S*a* is required, and it is taken as 2250 for the length of lane 9m.

$Y_1=q_1/S_{a1}=858/2250=0.38$ PCU/hr
$Y_2=q_2/S_{a2}=333/2250=0.15$ PCU/hr
$Y_3=q_3/S_{a3}=270/2250=0.12$ PCU/hr

$Y=Y_1 + Y_2+ Y_3$
$=0.38+0.15+0.12$
$=0.65<1$, which is a safe condition.

Cycle length according to Webster method is calculated using the formula

$$C_0 = (1.5L+5)/(1- Y)$$

where L= 2n+R

Considering all red time = 9 seconds (time for pedestrian crossing),
Amber time = 2 seconds for each phase = 6 seconds for three phases.

L=lost time per cycle
n= number of phases=3
L=2(3)+9=15 sec

C_0= (1.5(15)+5)/(1-0.65)=79 sec

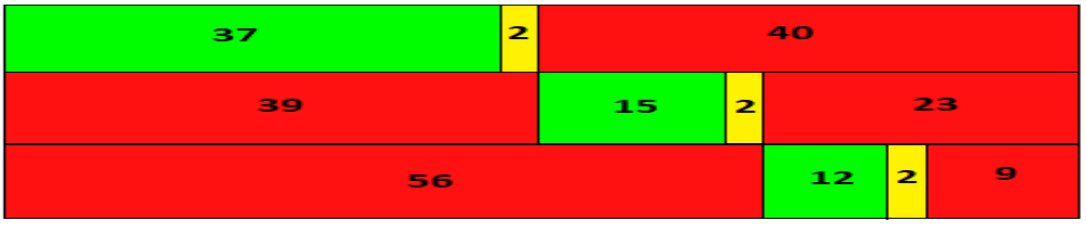

Figure 9- Signal Phase Diagram for Evening Session

Calculation of Green time

(g) Phase 1

$G_1=Y_1/Y$ (C_0—L)
=0.38/0.65 (79—15)
=37 secs

(h) Phase 2

$G_2= Y_2/Y$ (C_0—L)
=0.15/0.65 (79—15)

=15 secs

(i) Phase 3

$G_3 = Y_3/Y\ (C_0 — L)$

=0.12/0.65 (79—15)

=12 secs

Cycle length= 79 sec

VII. CONCLUSION

It is observed that in figure on hari Parvat road (major road), the majority of traffic goes straight having fewer number of right turning traffic, thus creating less conflict point and no need to give separate phases for right turning traffic. But in case of phullat road (minor road), a good number of vehicles turns right towards the major road, thus creating large conflict points and right turning traffic. Hence separate phases should be provided for the straight traffic road and their personal vehicles at the same time, nearly around 2 pm. The variation of PCU from morning to evening are shown in figure and the variation of the types of vehicle during that afternoon session as there is leaving of different school students, vans period are shown in figure.

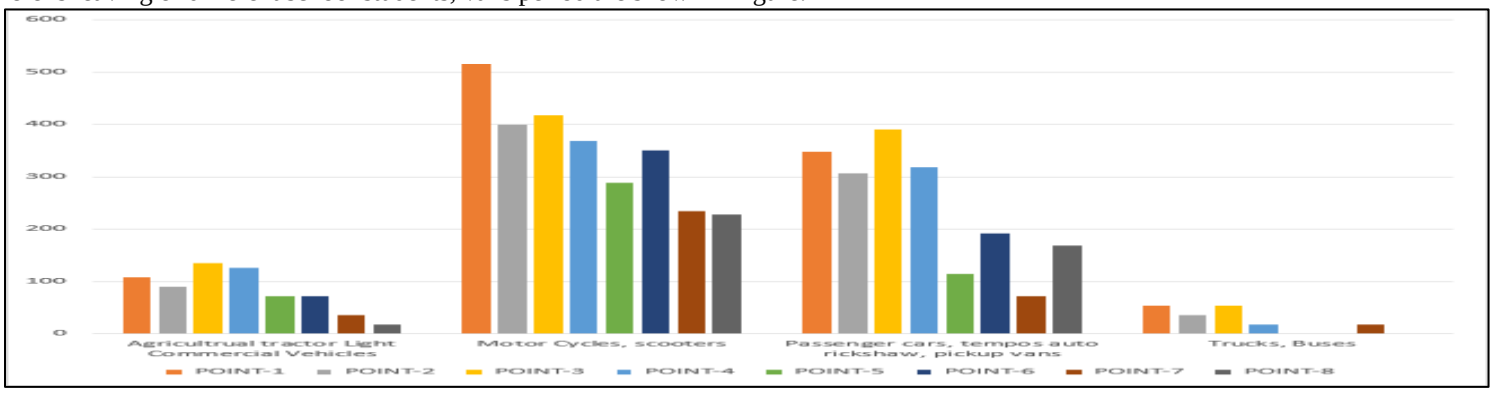

Figure13-Number of vehicles on major and minor roads in afternoon session

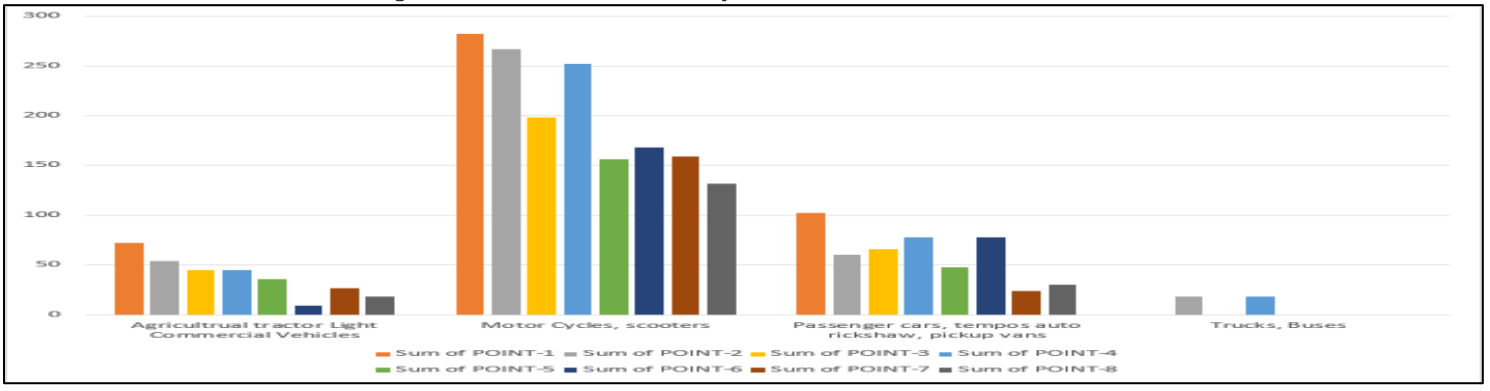

Figure14-Number of vehicles on major and minor roads in morning

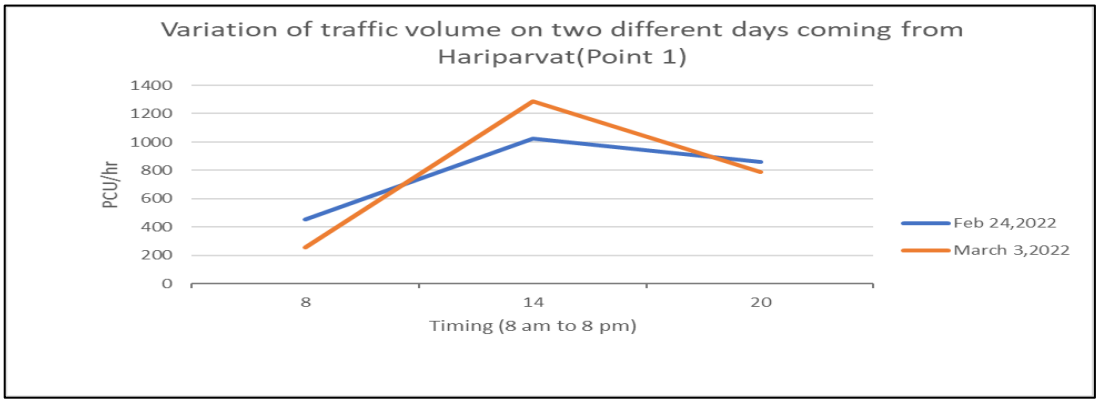

Figure 15- Variation of PCU in a day.

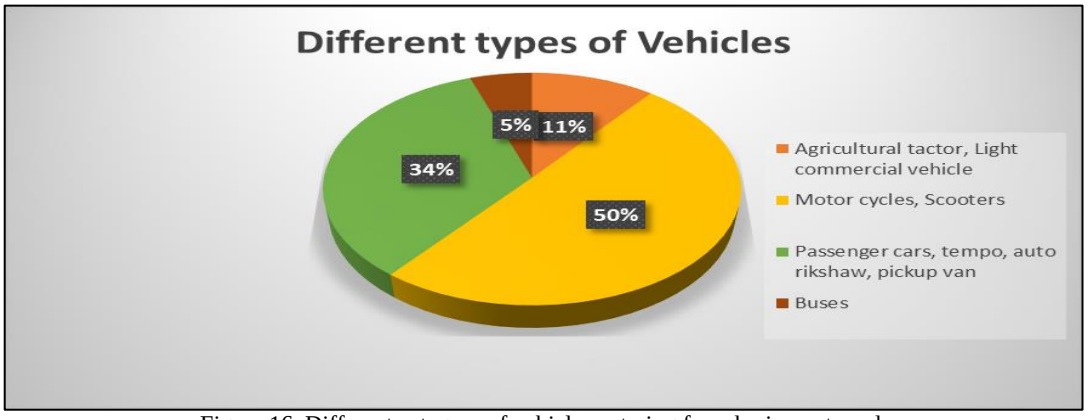

Figure 16 Different category of vehicles entering from hariparvat road.

Due to abrupt variation of traffic volume, the designing of traffic is done using **Automatic traffic-actuated signal.** This signal allows the timing of phase and cycle to change according to the traffic demands. Therefore, we calculate different cycle length for the three sessions of the day as shown in figure 15, 17 &19. This technique is highly efficient and reduces the useless delays of the vehicles during non-peak hours.

There can be many suggestions that would be given in order to improve the traffic congestion at the intersection. They are as follows-

1) Traffic management agencies should take disciplinary actions against motorist who reduce lane width by on-street parking around the intersections so as to increase saturation flow and to claim spaces meant for reserve capacity.
2) Local vendors near vegetables market area which are in proximity to the intersection have taken off their shop to other places where area is enough for them. We would find
3) Another place to accommodate them near market.
4) Introduction of traffic signal at the intersection would reduce conflict and accidents that occur at intersection.
5) Delay time due to frequent traffic jam occurs at the intersection will be reduced, only some delay will be faced by road user due red light which is quite good as compared to those long delays.
6) Many schools are located near the intersection. We can managed their timing in such a way their leaving would not be the same time so that no traffic jam occur at peak hours.
7) We may make the vegetables market area as no four wheeler zone because the road width is low so that no four will not block road. All E-rickshaws are asked to take passengers 20m far from the intersection.

Based on the calculations done on the PCU values obtained from the traffic survey, the Signal Cycle Length for Morning session is 45 seconds, for Afternoon session is 172 seconds and for evening session is 79 seconds.

By providing signals and increased lane width, there will be reduction in the conflicts. And also there will be an orderly movement of traffic in the cross- section for the roads from Hariparvat to city station and Phullati to soorsadan. As well, there is no need for traffic police to regulate the traffic at the intersection.

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