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RESEARCH ARTICLE

DESIGN OF TRAFFIC SIGNALS AT CLOSELY SPACED INTERSECTIONSIN TIRUPATI.

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Manuscript Info	*Abstract*

As we all know the traffic volume is increasing day by day in cities due to growth of industrialization and urbanization of cities. Thus to manage the present traffic volume new methods were adopted to provide better, easy and safe movement of traffic. The traffic conflictions are major on intersections of two roads. Traffic signals are a way to control the traffic at the intersections of the cities and to avoid the conflictions of the vehicles at the intersection. Traffic signals also help the traffic to move with safety and easily, which tends to minimize the collisions between the vehicles at the intersection. In this dissertation we surveyed the traffic volume of intersections of west church circle and Gandhi road intersections of temple city Tirupati and traffic signals were designed at each intersection. The one part of the thesis is survey of traffic volume, which is done by manual method, wherein the vehicles are counted manually without using any device or sensor with respective vehicle categories like passenger, commercial and agricultural etc. and the other part is design of traffic signals, which is done according to the IRC method of signal design by adopting maximum PCU on the intersection in each direction. The design of traffic signals at these intersections will help the growing traffic to move with ease and safety and also helps in reducing the accident rate at the intersections due to congestions and confliction between vehicles.

Introduction:-

Traffic Signals, also known as traffic lights, traffic lamps, traffic semaphore, signal lights, stop lights, and (in technical parlance)traffic control signals, are signaling devices positioned at road intersections, pedestrian crossings, and other locations to control conflicting flows of traffic.

Transportation is one of the essential components of the profession from its early days. As we see, the building of roads, bridges, pipelines, tunnels, canals, railroads, ports, and harbors has shaped the profession. Civil engineering is involved in developing, building, and operating transit facilities, including street railways and elevated and underground systems and so on. The role of civil engineering is to providing transportation infrastructure to accommodate a growing population and economy of city. If we look back towards history, transcontinental railroads, national highways, canals, petroleum and natural gas pipelines, as well as major urban transit systems, are testimonials to the achievement of civil engineering. In the last 200 years, railroads, transit lines, ports, and airports have helped to increase the range of cities and reduce the isolation of rural areas. They have brought the nation closer together. The assessment on traffic network routine has been worried by traffic managers, traffic planning designers and traffic engineers. The assessment on travel time of traffic network shows great meaning.Since it can neutrally reflect the service level of road network.

Traffic engineering is a branch of transportation engineering that uses engineering techniques to achieve the safe and efficient movement of people and goods. It focuses mainly on research and construction of the immobile infrastructure necessary for this movement, such as roads, railway tracks, bridges, traffic signs and traffic lights. Traffic engineering is also defined as phase of engineering which deals with planning & geometric design of streets, highways, abutting lands & with traffic operation thereon, as there use is related to the safe, convenient & economic transportation of persons & goods. Traffic engineering is a science of measuring traffic & travel, study of the basic laws relating to traffic flow & generation & application of this knowledge to the professional practice of planning,

designing & operating traffic system to achieve safe & efficient movement of persons & goods. Instead of building additional infrastructure, dynamic elements are also introduced into road traffic management. These use sensors to measure traffic flows and automatic, interconnected guidance systems to manage traffic, especially in peak hours. The relationship between lane flow (Q, vehicles per hour), maximum speed (V, kilometers per hour) and density (K, vehicles per kilometer) is

$$Q = KV$$

Observation on limited access International Journal of Multidisciplinary Research and Development 2015; 2(3): 133-137 ~ 134 ~ International Journal of Multidisciplinary Research and Development facilities suggests that up to a maximum flow, speed does not decline while density increases, but above a critical threshold, increased density reduces speed, and beyond a further threshold, increased density reduces flow as well. Therefore, managing traffic density by limiting the rate that vehicles enter the highway during peak periods can keep both speeds and lane flows at bottlenecks high. Ramp meters, signals on entrance ramps that control the rate at which vehicles are allowed to enter the mainline facility, provide this function. With this plan, we are focusing on efforts to improve traffic signal coordination. Such signal coordination ranks as one of the most cost effective and successful strategies to reduce congestion problems. Each dollar spent optimizing signal timing and implementing system improvements can yield up to $40 in fuel savings. Additionally, signal coordination can also have a dramatic impact on the drivers themselves. As most of us realize, delays and frustrations caused by the operation of traffic signals can lead to accidents and road rage. By bettering our equipment, maintenance practices, and signal programming methods, we can improve the lives of our motoring public by shortening their travel times and providing easier drives.

Problem Definition:-
The problem of congestion and accident is very acute in highway transport due to complex flow pattern of vehicular traffic, presence of mixed traffic and pedestrian. Traffic accident may involve property damage, personal injuries or even causalities. The main objectives of traffic engineering are to provide safe traffic movement. The Tirupati city is under development. The rapid growth in industrialization, urbanization, tourism has increased transportation activities causing acute traffic problems particularly at intersections, due to mix complex flow pattern. It is important to design regulation system for this rotary stems for efficiency of operation, safety, speed, cost of operation, capacity are directly governed by design. A best design can reduce the major and minor accidents, delay and can orderly movement of traffic. The primary aims of signal control at intersections are.
- To reduce the rate of accidents.
- To better regulate and orderly traffic movement, and
- Hence reduce delays

Tirupati the pilgrim city in Andhra Pradesh with about 3.747 million people is the center point of tourism in the state. The traffic is growing rapidly; the ever increasing number of two wheelers, four wheelers along with public transport and pedestrians poses a serious question mark for a smooth congestion free movement of traffic. The roads were built decades ago to meet the demands then. But now, the population has increased leaps and bounds and there is hence an urgent need to take necessary preventive measures.

Methodology:-
The methodology involved in the project is of two stages.
a. Data Collection
b. Designing of traffic signal
c. In Data Collection stage, traffic volume is collected for 15 days .on daily basis 7hour data is collected at two intersections .They are:
    1.   West church circle
    2.   Gandhi road circle
d. Designing of traffic signal involves mainly four methods. They are:
    - Trail Cycle Method
    - Approximate Method Based on Pedestrian Crossing Requirement
    - Webster's Method
    - IRC Method

Trail Cycle Method:-

The 15 minute –traffic counts n1 and n2 on road 1 and road 2 are noted during the design peak hour flow. Some suitable Trail cycle C1 is assumed and the number of the assumed cycles in the 15 minutes or 15*60 seconds period is found to be (15*60)/C1 i.e.(900/C1).Assuming an average time headway of 2.5 seconds ,the green periods G1 and G2 of roads 1 and 2 are calculated to clear the traffic during the trail cycle .

$$G1 = 2.5n1C1/900 \text{ and } G2 = 2.5n2C2/900$$

The amber periods A1 and A2 are either calculated or assumed suitably (3 -4 seconds) and the trail cycle length, is calculated, C1'= (G1+G2+A1+A2) seconds. If the calculated cycle length C1' works out to be approximately equal to the assumed cycle length C1, the cycle length is accepted as the design cycle. Otherwise the trails are repeated till the tail cycle length works out approximately equal to the calculated value.

Approximate Method Based On Pedestrian Crossing Requirement:
The following design procedure is suggested for the approximate design of a two phase traffic signal unit at cross roads, along with pedestrian signals:

- Based on pedestrian walking speed of 1.2m per second and the road way width of each approach, the minimum time for the pedestrians to each road is also calculated.
- Total pedestrian crossing time is taken as minimum pedestrian crossing time plus initial interval for pedestrians to start crossing, which should not be less than 7 sec and during this period when pedestrians will be crossing the road, the traffic signal shall indicate red or stop
- The red signal time is also equal to the minimum green time plus amber time for traffic of the cross road
- The actual green time needed for the road with higher traffic is then increased in proportion to the ratio of approach volumes of the two roads in vehicles per hour per lane
- Based on approach speed of vehicles, the suitable clearance interval between green and red period i.e., clearance periods are selected. The amber periods may be taken as 2, 3,4 seconds for low, medium and fast approach speeds.
- The cycle length so obtained is adjusted for the next higher 5sec interval, the extra time is then distributed to green timings in proportion to the traffic volume
- The timings so obtained are installed in the controller and the operations are then observed at the site during peak traffic hours; modifications in signal timings are carried out if needed

Webster's Method:-

It is an analytical approach of determining the optimum signal cycle time C_0 corresponding to minimum delay to all the vehicles at the approach roads of the intersection. The field work consists of determining the following set of values on each approach road near the intersection:

- The normal flow q on each approach during the design hour and
- The saturation flow ,S per unit time

The normal flow values q1 and q2 on road 1 and road 2 are determined from field studies conducted during the design hours or the traffic during peak 15 minute's period. The saturation flow of vehicles is determined from careful field studies by noting the number of vehicles in the stream of compact flow during the green phases and the corresponding intervals precisely. In the absence of data the approximate value of saturation flow is estimated assuming 160 PCU per 0.3 m width of approach road.

Based on the selected values of normal flow,the ratio y1=q1/S1 and y2=q2/S2 are determined on the approach roads 1 and 2.In the case of mixed traffic,it is necessary to convert the different vehicle classes in terms of suitable of PCU values at signalized intersection;in case these are not available the may be determined separately.

The normal flow of the traffic on the approach roads may also be determined by conducting field's studies during off-peak hours to design different sets of signal timings during other periods of the day also,as required so as to provide different signal settings

The optimum signal cycle is given by the relation:

$$C_o = 1.5L + 5/1 - Y$$

<div align="center">Where L= Total lost time per cycle sec=2n+R</div>

n = is the number of phases

<div align="center">R=all-red time or red-amber time;</div>

Y=y1+y2
y1=q1/s1 and y2=q2/s2

<div align="center">Then,G1= y1/Y (C$_o$-L), G2=y2/Y (C$_o$-L)</div>

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

IRC Method:-

- The pedestrian green time required for the major and minor roads are calculated based on walking speed of 1.2 m/sec. and initial walking time of 7.0 sec.
- Theseare the minimum green time required for the vehicular traffic on the minor and major roads respectively.
- The green time required for the vehicular traffic on themajor road is increased in the proportion to the traffic on the two approach roads.
- The cycle time is calculated after allowing amber time of 2.0 sec. Each
- The minimum green time required for clearing vehicles arriving during a cycle is a determined for each lane of the approach road assuming that the first vehicle will take 6.0 sec. And the subsequent vehicles (PCU) of the queue will be cleared at a rate of 2.0 sec. The minimum green time required for the vehicular traffic on any of the approaches is limited to 16 sec.
- The optimum signal cycle time is calculated using Webster's formula The saturation flow values may be assumed as 1850,1890,1950,2250,2550and 2990 PCU.
- IRC Method has been adopted for designing of traffic signal at the two intersections in our project .Trail cycle method is also adopted for comparison purpose.

Warrants for installation of traffic signal:-

Traffic control signals should not be installed unless one or more of the following signal warrants are met. In order to decide the specified warrants, the necessary data should be collected by means of traffic engineering studies.

Minimum vehicular volume warrant:-

The average traffic volume for eight hours of the day on both approaches should be at least 650 motor vehicles per hour on major streets with single lane and 800 vehicles on the streets with two or more lanes. Further the number of motor vehicles approaching the intersection on minor and 250 vehicle per hour when there are two or more lanes. However when the average approach speed or the 85th percentile speed on major street exceeds 60 kmph or when the intersection lies within built-up area ,the vehicular volume warrant may be decreased to 70 percent of the above requirement

Interruption of continuous traffic flow on major road:-

when the traffic flow on the major street is 1000 to 1200 vehicles per hour and there is undue delay or hazard to traffic on minor road with a traffic of 100 to 150 vehicles per hour in one direction only during any eight hours of an average day.

Minimum pedestrian volume warrant:-

When 150 or more pedestrians per hour cross a major street with over 600 vehicles per hour on both approaches. However when the average approach speed or the 85th percentile speed exceed 60 kmph ,70 percent of the above requirement may be adopted

Accident experience warrant:-

If the accident record shows that other measures have failed to decrease the accident frequency or when five or more accidents have occurred within 12 months period. However signal installation should not seriously disrupt the traffic flow.

Combination of warrants when no signal warrant is satisfied:-

when no single warrant is satisfied but indicates that two or more warrants of (a),(b) or (c) above are satisfied to the extent of 80 percent or more of the stated volume.

Description of study area:-
Two areas are chosen for designing of traffic signal .They are:
- West Church Circle
- Gandhi Road Circle

West church is a rotatory intersection located 4km from Tirupati Bustand. It is an intersection where many college buses, autos and number of motor vehicles pass daily leading for the flow of high traffic where a signal is necessary for smooth flow Though Rotary island is constructed for regulating the traffic, it does not suffice the requirement
In the circle the three roads connecting at junction are all two way road. Congestion and commotion are always common in these stretches

Gandhi Road Circle is an intersection located 2.2km from Tirupati Bustand.
Gandhi Road is the circle of shopping area with wide variety of fruit markets, grocery shops, small and large shopping malls, where there wills high density traffic in single lane width roads.

At the intersection there is lot of cognition of vehicles during peak time and there is
Chance of accidents at the intersection due to wrong siders at one way.

Traffic Data Collection:-
In this project traffic count is taken on hourly basis for the period of 7 hours for 15 days at west church circle and Gandhi road intersections.

At west church circle data collection is done at three road junctions.
- Balaji colony to MR palli
- MRpalli to Balaji Colony
- Padmavati college to Balaji colony

Table.1:- Sample data for one day on hourly basis of west church circle.

Time	Motor Cycles	Autos	Cars	Buses	Heavy Vehicles
7 to 8 AM	420	188	60	15	3
8 to 9 AM	879	242	50	25	6
9 to 10 AM	635	254	94	13	5
1 to 2 PM	298	140	43	9	3
4 to 5 PM	553	200	62	25	4
5 to 6 PM	627	281	115	22	5
6 to 7 PM	638	240	108	5	6

Passenger car unit (PCU):-
Different classes of vehicles such as cars, vans, buses, trucks, auto rickshaws, motor cycles, pedal cycles, bullock carts etc. are found to use the common road facilities without segregation on most of the roads in developing countries like India. The flow of traffic with unrestricted mixing of different classes of vehicles on roadways forms the heterogeneous traffic flow or the mixed traffic flow. The different vehicle classes have a wide range of static characteristics such as length, width etc. and dynamic characteristics such as speed, acceleration etc. Apart from these, the driver behavior of different characteristics are very much complex when compared to homogenous traffic consisting of passenger cars only. It is rather difficult to estimate the traffic volume and capacity of the roadway facilities under mixed traffic flow, unless the different classes of vehicles are converted to one common standard vehicle unit.

The PCU may be considered as measure of the relative space requirement of a vehicle class compared to that of a passenger car under a specifies set of roadway traffic and other conditions.If addition of one vehicle of a particular class in the traffic stream produces the same effect as that due to the addition of one passenger car, then that vehicle class is considered equivalent to the passenger car with a PCU value equal to 1.0.The PCU value of a particular vehicle class may be considered as the ratio of the capacity of a roadway when there are passenger cars only to the capacity of the same roadway when there are vehicles of that class only.

Factors affecting PCU values:-
- The PCU values of different vehicle classes depend on several factors. Some of them are:
- Dimensions of vehicles such as width and length
- Dynamic characteristics of vehicles such as power, speed, acceleration and braking.
- Transverse or longitudinal gaps between moving vehicles which depends on the speeds, driver characteristics and the vehicle classes at the adjoining spaces.
- Roadway characteristics such as road geometrics including gradient and curves, access controls, rural or urban road, presence of intersections and the type of intersections.
- Traffic stream characteristics such as composition of different vehicle classes, mean speed and speed distribution of the mixed traffic stream and volume to capacity ratio.
- Regulation and control of traffic such as speed limit, one way traffic, presence of different traffic control devices, etc.
- Environmental and climate conditions.

The PCU values obtained for west church circle are listed below:-
For the road Balaji Colony to MRpalli:-

Table 2:- The PCU Values of west church circle for the road Balaji colony to MRPalli.

Vehicle type	Motor Cycles	Autos	Cars	Buses	Heavy Vehicles
PCU	1559	781	522	223	66

(i)Total PCU =3170   (ii) PCU per hour = 453
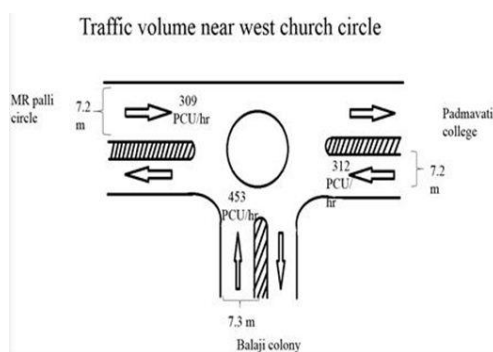

Figure.1   **Figure.2**

Design procedure:-
The signals are designed for both the intersections i.e., Gandhi road intersection and west church circle as per the guidelines of the IRC. Also the design is compared with a approximate method known as trial cycle method. For the purpose of simplicity, two phase traffic signals with no turning movements are illustrated here. The methods may be suitably extended for multi-phase operation.

Signal design at west church based on IRC method:-
The design for traffic signal is based on IRC Method which is as follows:

Step 1:-
Let amber time be 3 seconds (medium approach)
Pedestrian green time for road 1= (7.3/1.2)+7 = 13.08 sec
Where Pedestrian Walking speed = 1.2m/sec
Initial walk period   =7sec
Pedestrian green times for road 2 & 3 = (7.2/1.2)+7 = 13 sec
Therefore green time for vehicles on road 2, G2 = 13.08 sec
Step 2:-

Green time for Road 1, G1 = 13.08*(453/309)

$\qquad\qquad\qquad\qquad$ = 19.17 sec

Green time for Road 3, G3 = 13.08*(312/309)

$\qquad\qquad\qquad\qquad$ = 13.20 sec

Step 3:-

Adding respective amber times and 2.0 sec inter-green period,

Total cycle time required =(3+19.17+2) + (13.08+2+2) + (13.20+3+2)

$\qquad\qquad\qquad$ = 59.45 sec

For convenience Signal time is set as 60 sec.

The extra 0.55 sec is proportioned to green time for road 1,2 and 3 as 0.23, 0.12 and 0.10 sec.

So now G1= 19.40 sec

G2= 13.20 sec

G3= 13.30 sec

Step 4:-

Vehicle arrivals per lane-cycle on Road 1

$\qquad$ 453/60 =7.55 PCU

Minimum green time for clearing vehicles on road 1

$\qquad\qquad\qquad$ = 6 + (7.55-1.0)2

$\qquad\qquad\qquad$ = 19.1 sec

Similarly the minimum green times are calculated for road 2 & 3 which are 15.24 and 15.34 sec respectively.

Step 5:-

Lost time per cycle = (amber time + inter-green time + time lost for initial delay of first vehicle) for 2 phases

$\qquad\qquad\qquad$ =(3+2+4) * 2 = 18 sec

Saturation flow for road 1 = 525w = 525* 7.3 = 3832 pcu/hr.

Saturation flows for road 2, 3 = 3780 pcu/hr.

Y1= 453/3832= 0.118

Y2 = 309/3780= 0.082

Y3= 312/3780= 0.082

Y =0.118+0.082+0.082 =0.282

Step 6:-

Optimum cycle time

Co = (1.5L+5)/(1-Y)

$\quad$ = (1.5*18+5)/(1-0.282)

$\quad$ = 44.56 sec < 60 sec

Therefore the cycle time of 60 sec. is acceptable.

Signal design at west church based on Trail cyclemethod:-

The design of signals at west church circle based on trial cycle method:

- Assume Trial Cycle C1= 65secs.
- Number of cycles in 15 min= 900/(40)= 14
- Green time for road 1, allowing an average head way of 2.5 sec, per vehicle
- G1= 130*2.5/14=23 sec
- Green time for road 2, G2= 100*2.5/23=18 sec
- Green time for road3,G3=113*2.5/23=20
- Amber times A1,A2 and A3 3, 2, 2 sec respectively.
- Total cycle length=G1+G2+G3=A1+A2+A3sec

$\qquad\qquad\qquad\qquad$ =23+18+20+3+2+2=70sec

- Gross 3 seconds is reduced from G1,G2,G3.The revised green timings are:

G1=23-1=22sec

G2=18-1=17sec

G3=20-1=19sec

Comparison of Green times by IRC Method and Trail Cycle Method at West Church circle
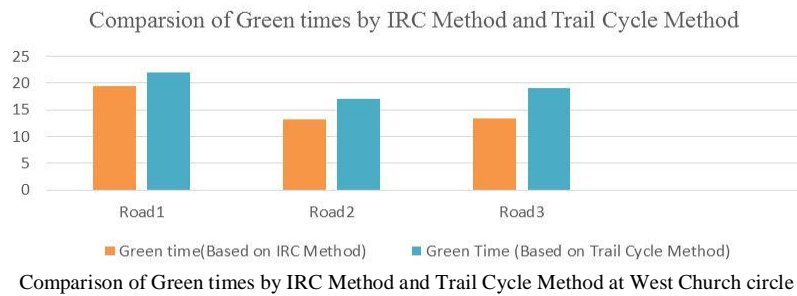
Result and Discussion:-

- By studying the road traffic of the city we analyzed that the major accident cause is collision of vehicles at the intersections. The collision may be rear shunt on approach to junction, right angled collision, principle right turn collisions and pedestrian collision. These collisions can be avoided if proper design of signal is done so that the main objective of the dissertation is to provide better and safe movement of traffic through signal design at the intersection. The signal is designed as per IRC guidelines so that the signal can justify the proper movement of the traffic.

- The effect of the signal design can be seen in reduction of accident cause by which the reduction in fatal injuries at the intersection, thus provide a better and safe movement of the traffic. The signal design can also help the pedestrian to cross the road safely. The signal timing plays an important role in traffic movement. Thus the timing of the signal should be such that it does not cause delay to the vehicles. If the timing is causing extra delay to the vehicles then the driver will disobey the signal, resulting in cause of accident. Thus the signal timing should justify the movement of vehicles so that extra delay by the RED signal will not affect the total journey time.

- Vehicles were classified into only five different categories. Multi axel trucks, heavy truck and tippers; mini bus were all considered in a single group. Vehicles will consume less amount of fuel if they don't have to wait at signalized intersections for a longer time. It also helps in reducing annual fuel consumption cost and environmental pollution. Two wheelers, particularly motorcycles is the most preferred mode of transport. Public transport system needs to be strengthened so that use of individual vehicles is restricted, thereby reducing traffic density.

"Traffic control signal shall be installed at Gandhi road and west church circle for the following signal warrants meeting."
- As the average traffic flow for 8 hours on both approaches are exceeding 800 vehicles.
- Interruption of continuous traffic flow on the major street is exceeding 1000 vehicles per hour.

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