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DETERMINATION OF PCU AND TRAFFIC SIGNAL DESIGNTHROUGH MULTIPLE LINEAR REGRESSION MODEL

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Abstract*—Economic growth of a developing city directly depends on the road infrastructure. Intersections are the nodal points in cities road infrastructure.Signalizing these road intersections can improve traffic handling capacity and safety of road users. Following is a case study was taken up in Srikakulam, Andhra Pradesh,India. Traffic data is collected from signalized intersections and analyzed to determine Passenger Car Unit (PCU) values of two wheelers, three wheelers, cars and buses. An attempt is made with the help of a case study to simplify the Webster's model of traffic signal designing into a multiple linearregression equation, and a non-signalized intersection in Srikakulam city is signalized with the help of this multiple linear regression equation.That intersections performance is analyzed with the help of a traffic simulation software named Tsignals.

Keywords*— Signalized intersection, PCU values, traffic signal phase time design, Webster's method, Multiple linear regression.

I INTRODUCTION

Intersections are the major elements of the road network and city's infrastructure. Effectively designing and regular maintaining of such intersections is necessary for the smooth movement of vehicles along the city. Safety is one of the major concern at At-grade intersections along with accommodating vehicles from several lanes. Signalizing the At-grade intersection can improve the vehicle carrying capacity of the intersection. By signalizing vehicles from three or more lane groups are controlled and allowed to cross the intersection one lane after another in a systematic manure with the help of traffic signal indications. Safety also increases as vehicles from several approaches allowed to move through the intersection in a systematic manure.

This signalling system consists of three colouredphases. Those are green, amber and red.The Greenlight indicates vehicles from a lane group are allowed to move through the intersection. Amber light provided immediately after green to provide time to the vehicles to clear the intersection before vehicles from other approach entering the intersection. This part brings the safety element to signalized intersections. In some places, amber time will be displayed before green time to indicate the drivers get ready for moving. This case is helpful to control the pollution caused by the vehicles when waiting for green time as they can turn off the vehicles until amber is displayed. Red time indicates to stop the vehicle. These signals are of three types. Those are pre-timed signals, partially actuated and fully actuated. Pre-timed signals are the signals with pre-defined time limits i.e. green time, amber and red phase timings are fixed and won't change along with the daily variations in traffic flow. Partially actuated signals can reduce the green time for the approach with less traffic. In a fully actuated signal type signal can even skip green time for the approach with no traffic. These partially actuated and fully actuated signalling types are used to reduce the delay for approaches with more traffic.

Passenger car unit (PCU) concept helpful in converting different categories of vehicles into single vehicle form which is a standard unit car. In countries like India with highly heterogeneous traffic at intersections, it is hard to analyze the performance of the intersections which will help in designing the intersection and maintaining it. The PCU values proposed by IRC in "Guidelines for the Design of at-grade intersections in rural & urban areas" (IRC SP 41) are proposed two decades back and never revised later. Vehicular characteristics and PCU values estimation methods had been changing for accurately counting the vehicle volume. (Pinakin and Ashish, 2015) used space to area ratio method and multiple linear regression to derive PCU values for the signalized intersections in Surat city. Theyanalyzed the PCU values vary based on queue formations, peak hour or non-peak hour and traffic behaviour.(Geetam Tiwari et al. 2011) presented if density method used for deriving PCU values for homogeneous traffic by HCM 2000 thanlinear density model can derive the PCU values for heterogeneous traffic. An experimental study is conducted at a signalized intersection in Delhi and PCU values derived based on linear density model.

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Webster's rational model is a major designing method for establishing traffic signal at an intersection. This model needs saturation headway of vehicle to decide intersection capacity and lane intensities to decide cycle length and green phase time. There are some researchers worked on simplifying the saturation flow models, finding PCU values using multiple linear regression method. (Dingxin Cheng et al. 2005) proposed an exponential cycle length model to base CORSIM simulation runs to reduce the delays at signalized intersections caused by using Webster's model to determine signal cycle length. This explains the need for improving Webster's rational model for heterogeneous traffic to improve intersection performance prediction. But this work has no literature because estimation of green time with a regression model is never been done.

Traffic simulation software helpful for the enthusiastic researchers to test their ideas on the road network in digital form. Conducting experiments on road patterns, transportation systems and traffic management in real traffic conditions is not possible as they cause disturbances to road users. This simulating software helpful for the greater good in transportation and planning field. Tsignals is such a simulating software used in this study to tests the results obtained in this experiment.

II DATA COLLECTION

Traffic data is collected from 3 signalized intersections in Srikakulam, a developing city in Andhra Pradesh, India. Day & Night junction, Ram-Laksman junction and 7-Road junction are the three intersections considered for this study. In these intersections Day & Night junction is a regularfour-lane junction, Ram-Laksman junction is T-intersection & 7-road junction is a very busy intersection with seven roads meeting at this point. In this seven roads, three of them are minor roads carrying lesser traffic so signalling for these roads isthe same as the major roads adjacent to them. All the lanes at these intersections can be divided into 2 types. One type is a lane group with 2 lanes i.e., one lane is for exclusive left turns and another lane is for through traffic and right turn traffic. The second type is a single lane where all turning movements happen through this single lane. All the lanes are properly marked and all are located in busy district areas. Traffic data is collected with video graphic survey during peak hours (8:30 a.m. - 10:30 am in morning and 5:00 p.m.-7 p.m. in evening). Data collection is done at all three intersections during weekdays and weather conditions are clear sunny). From these traffic recordings,450 signal cycle's data is noted randomly from all intersections. This data includes traffic volumes from the lane groups with detailed vehicle classification i.e., Number of cars (standard cars, LCV), two-wheelers (cycles, motorized two-wheelers), three-wheelers (autos, cycle rickshaws) and Buses). Data from exclusive let turn is collected only during the green time of cycle so that the volume of traffic moving through the intersection from the lane group is effectively counted.

Figure 1Data collection at Day & Night intersection

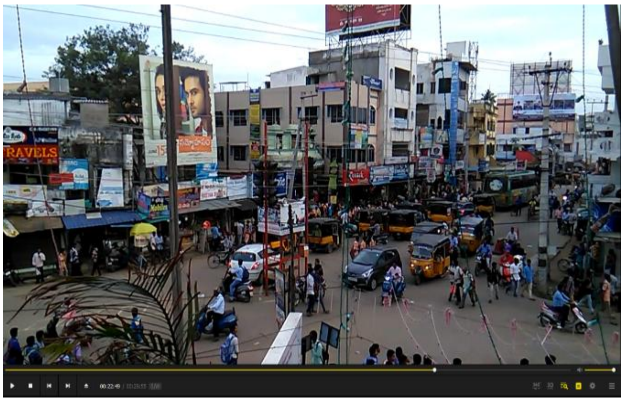

Figure 2 Data collection at Ram-Laksman junction

III DETERMINATION OF PCU VALUES

The traffic volume with detailed classification of two-wheelers (includes cycles and motorbikes), three-wheelers, cars and buses collected from the 200 signal cycles by playing the recorded videotapes. These number of TW, 3W, cars and buses passed through the intersection are regressed against that particular green time. Green time is the target variable and number of TW, 3W, cars and buses are predators. Regression is done at 95% confidence interval. A regression equation is framed with the obtained coefficients of Predators.

$$G = 23.7+ 0.192TW + 0.644\ 3W + 0.534\ Cars + 2.07\ Buses;\ R^2= 0.64 \quad (1)$$

The PCU values ofdifferent category of vehicles determined by dividing the coefficient of vehicle class with the coefficient of cars. For example to find the PCU values of TW the coefficient of two-wheelers is divided with thecoefficient of car.

Vehicle class	PCU
Two-wheeler	0.36
Three-wheeler	1.2
Car	1.00
Bus	3.8

Table 1. PCU values of TW, 3W, Car and Bus

Observations:

Following are the observations analyzed from the obtained PCU values.

- PCU values are nearly same asthe values proposed by IRC and greatly differ from the values proposed by other researchers. This is because ofthe dynamic nature of the PCU values which varies based on the traffic conditions, geometric conditions of intersections and local driver'sbehaviour.
- PCU value of three wheeler is more than PCU value of cars. This is attributed to the volume of the 3W and number of passengers carrying by 3W are more than allowed capacity.This might reducing their speeds.

Table 2 shows the comparison of PCU values obtained in this study with the PCU values of the previous researcher's studies. These PCU values differ greatly with other's PCU values. This is attributed to highly heterogeneous nature of traffic in Srikakulam.

Vehicle classes	IRC (1994)	Pinakin and Ashish(2015)	Geetam and Mariya(2011)	Chang quio and jainrong (2011)	Arasan and vedagiri (2006)	Hayjay and ramaswamy (2016)	Radhakrishnan and Mathew (2011)	Present study
Car	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Two wheeler	0.5	0.18	0.40	0.58	0.35	0.4	0.34	0.36
Three wheeler	1.00	0.66	5.6	1.00	0.60	0.73	1.88	1.2
Bus	3.00	-	7.9	1.77	-	2.06	-	3.8

Table 2. Comparison of proposed PCU values with literature PCU values.

IV DETERMINATION OF TRAFFIC SIGNAL GREEN TIME

This is a simplified form of Webster's rational model used for designing signal cycle time and phase timings. It is developed based onmultiplelinear regression concept. Here number of two wheelers, three wheelers, cars and buses are used as predators to regress against known green time from the data collected. This forms a regression equation which explains the relation between variables with the target variable (green time) and relation between variables with other variables. This relation is explained with the coefficients of variables. Traffic data is collected from 250 signal cycles. This data includes volume of selected vehicle class during saturation green time. Errorpercent is reduced as minimum as possible by regressing with a number of observations and 95% confidence level is maintained. The best regression equationform several observations which can predict the signal green time is presented below.

$G = 21.05 + 0.292\,TW + 0.68\,3W + 0.385\,Cars + 1.97 Buses;\ R^2 = 0.7$…………… (2)

Here,

G = green time needed for the volume of traffic to cross the intersection (S).

TW = number of two-wheelers in the traffic volume.

3W = number of 3W in the traffic volume.

Cars = The number of cars in traffic volume.

Buses = number of buses in traffic volume.

Observations:

- The equation is made upon the data collected from signalized intersections in Srikakulam city only. So it won't give satisfactory results when tested on other traffic conditions or signalized intersection conditions.

***Calibrating of the obtained regression equation*:**

For calibrating the equation a signalized intersection data is used from mentioned three intersections. The peak hour intensities of each lane meeting at that intersection are counted. Then the obtained equation is calibrated by comparing the green times obtained with green times already using at the intersection. These filed values are designed based on Webster's model. So this comparisonexplains the effectiveness of proposed model instead of Webster's model.

Lane approach	Vehicle volume in peak hour	Green time by Webster method /hour	Green time by proposed equation/hour	Average Error percentage	Corrected green time
SB	1916	1102.5	817.3	0.39	1135
WB	1397	742.5	539.3		746
NB	1788	990	703.15		974
EB	1308	765	537.87		745

Table 3. A comparison of green phase time by current method with Webster's method.

There is an error in estimated green time because the regression equation framed is mathematically not balanced. The R^2 value is not near to 0.9. So the green time values can be corrected by multiplying with a correction factor 0.39.

***Validation of the proposed method*:**

A non-signalized intersection is selected in the same Srikakulam city where there is a need for traffic signal installation. The peak hour intensities of each lane meeting at that intersection are counted. This data count includes the volume of each class of vehicle in that peak hour from all the lanes of the intersection. By substituting this lane volume according to vehicle classification in the obtained equation, green phase time required for that lane in one hour period obtained. Likewise,the green phase time required for all lanes for respected volumes can be obtained. This green time values are adjusted by multiplying with a correction factor. A total green time required for lanes for one hour is calculated. Cycle length is fixed as 120s which is acceptable minimum value by IRC to reduce vehicle delay for all approaches. From knowing the total green time and cycle length green time for each cycle is calculated. Amber time is fixed as 3s as per local traffic conditions. Tsignals is a simulation software used to check the accountability of the proposed signal phase times with noted traffic volumes. The intersection is found functioning properly with no traffic congestions and minimum vehicle delay.

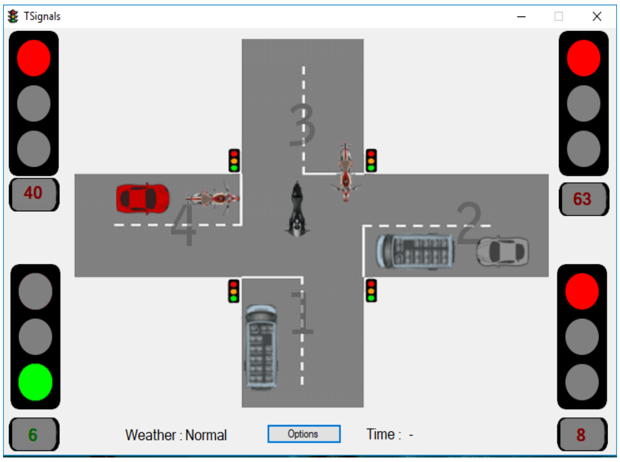

Figure 3Simulation of intersection in Tsignals

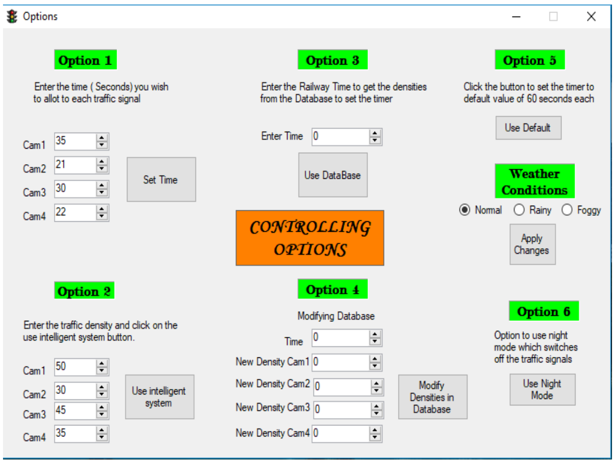

Figure 4 Traffic details of simulating intersection

V CONCLUSION

In this study Multiple Linear regression model is used on traffic data collected at signalized intersections and Passenger Car Unit values are developed for the major vehicle class present in Srikakulam. Results shows that PCU value of TWis 0.54, 3W is 1.33 and the bus is 3.4. These PCU values proposed here are mostly representing the intersection conditions and traffic nature of Srikakulam city. These valuesare different from the literature value proposed by various researchers. Because ofPCU valuesfrom the literature based on vehicularcharacteristics like dimensions of vehicles, acceleration characteristics, vehicle headway, vehicle clearance distances, intersection conditions and road user behaviour. No one proposed the standard PCU values by considering all these affecting factors.So the values obtained here may not be wrong even they differ from past studies. The linear regression equation proposed for estimation of green time needs improvement. It is not predicting the green time needed accurately when compared with the green phase time values by Webster. This is because of the independent nature of predators causing more complexity to establish a relation between variables which are considered for the regression. So the effective relation cannot be achieved by the Linear regression model. Fine Gaussian SVM is a mathematical model seems to form a reliable relation between the selected predators and targeted green time. Finally, this equation is developed base on Srikakulam traffic conditions. So it may not give proper results when used in other cities or other traffic conditions.

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