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The Effect of Countdown Timer Signal on the Performance of Signalized Intersection- A case study at New Baneshwor and Narayan Gopal Intersection

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Abstract

This research tries to investigate the effect of countdown timer on the performance of signalized intersection at saturation flow rate, delay and start-up lost time. Two approaches of two different signalized intersections with a countdown timer have been studied for the present study. The data were collected at both intersection, with and without countdown case by switching timer off for one day at peak period on request to traffic police. The models are developed for saturation flow rate, delay and start-up lost time with and without timer case. The result shows that the saturation flow rate is increased but start-up lost time and delay are decreased at timer case. The Capacity of the signalized intersection is approximately increased by 4.68% and initial lost time is decreased by 28.02% & 14.52% for two-wheeler and car respectively due to installation of timer. Similarly the incremental delay and total delay of the intersections are reduced by 7.55% and 2% respectively at timer case.

Keywords

Countdown Signal, capacity of signalized intersection, saturation flow rate, start-up lost time, delay

1. Introduction

Countdown-signalized intersections, in which the remaining red or green times are displayed together with signal lights, have been widely applied to many countries such as China, Thailand, Turkey, and currently installed at two junctions of Kathmandu valley at New Baneshwor and Narayan Gopal Chowk. Signal countdown device is generally divided into a green signal countdown device (GSCT) and red signal countdown device (RSCT). Drivers can clearly see the remaining conversion time of electronic countdown display away from the junction and adjust their running speed through it. where the traffic signals are installed in Nepal, the cycle length is relatively longer than that of a developed country. In many signals at Nepal, there is no information on the remaining green time or red time provided to drivers. This causes driver's difficulties to correctly estimate the time when the signal changes to red during the green light or vice versa. Also, during the red light periods, drivers may feel uncomfortable and feel waiting a long time for the green signal display than the actual waiting time. This would possibly cause a mistake in the decision for drivers due to stress. Countdown signal is taken as one of the best measures to reduce driving stress. With the countdown signals, drivers can estimate the correct timing for maneuvers at intersections, resulting in a smoother traffic flow and improved traffic safety. However, there are still no studies related to drivers' interaction with the countdown signals in Nepalese context. Due to long cycle length and large start-up lost time, the capacity of signalized intersection is reduced.

The capacity of a signalized intersection may be increased mainly in two ways. One is to increase the saturation flow rate of automobiles and another is to increase the effective green time of each green phase. However, it is comparatively difficult to increase the saturation flow rate of automobiles at a signalized intersection since it requires a geometric modification. Thus, the alternative is to increase the effective green time of each green phase if the total start-up lost time of automobiles is to be reduced. In order to cut down the start-up lost time of automobiles, all motorists in the queue at a signalized intersection need to be informed when the signal is going to turn green. Generally, motorists in a queue at the start of the green phase will be move faster if they are prepared for a green light display. The sooner the motorist moves, the smaller the value of the total start-up lost time becomes. Theoretically, a countdown signal will reduce the total start-up lost time of automobiles, and increase the effective green time of each green phase that ultimately results in an increased capacity of signalized intersections.

So far, no studies on the effects of the countdown signals in regards to the saturation flow rate, delay and the start-up lost time of automobiles have been found in Nepalese condition.

2. Research Question

Based on the above discussion, this research tries to answer the following questions,

a) Is the capacity of a signalized intersection due to countdown signal is changed?
b) Is the initial lost time is changed due to count down timer?
c) Is the delay of signalized intersection is changed?

3. Objective

The objective of the present research is to investigate the effect of countdown signal on the performance of signalized intersection. More precisely, this research aims to study the intersection performance with and without countdown signal along the same and different roadway section with same and different geometric properties. Following are the basic objective of this research,

a) To developed modal for a capacity/ saturation flow rate of an intersection due to countdown signal.
b) To developed start-up lost time modal.
c) To developed delay model due to countdown signal.

4. Assumption and Limitation

Many factors could influence the performance of signalized intersection, such as area type, approach grade, blocking effect etc. However, all these factors are not considered in this study because the previous study conducted in Nepal without timer situation shows that these parameters were not affected greatly [1] . Moreover, considering only two intersections with specific conditions limits the outcome of the study to a Nepalese condition of the mentioned problem from applicability perspective.

5. Literature Review

5.1 Vehicular Countdown

Lum and Halim (2006) conducted a before-and-after study on the effects of the device (including before installation and after installation for 1.5, 4.5, and 7.5 months). Their findings demonstrated clearly an improvement after the installation of Green Signal Countdown Timer (GSCT), especially when traffic volume is relatively high. [2]

Winai Reksuntorn (2012) conduct a comparative study on Bangkok and Thailand with and without timer situation. They found that the time headways between vehicles at signalized intersections is remained constant after the sixth automobile in queue crosses the stop line. Also, they find the countdown signals may be used to reduce the total start-up lost time of automobiles at signalized intersections. [3]

Ibrahim et al. (2008) analyze the six intersections in the Kuala Lumpur area to study the effect of the countdown timer on driver behavior and intersection approach headway. The study suggests that countdown timer has got the little effect on initial delay.[4]

Jie ZHANG et al. (2010) conduct a questionnaire survey and video graphic survey. The results of the investigative questionnaire showed more than 85 percent of drivers and pedestrians chose countdown signal and the findings showed that traffic volumes were quite increased before and after installing the countdown signal. [5]

Fujita et al. (2007, 2008) have conducted surveys to compare drivers' behavior with and without countdown signals at two intersections in Turkey. They analyzed the behaviors of drivers to pass through, to stop, or to start when signals changed. The findings suggest that the countdown signal can increase the proportion of premature starts.[6]

5.2 Saturation Flow Rate

[7] The saturation flow rate is the equivalent hourly flow rate at which previously queued vehicles can traverse an intersection approach under prevailing conditions, assuming that the green signal is available at all times and no lost times are experienced, in vehicles per hour of green or vehicles per hour of

green per lane. A simple rectangular model by Turner and Harahap (2) to understand the concept of effective green time is shown in Figure 1. At first when the traffic signal turns green, there is lost time due to response time. After the first vehicle the rate of vehicles crossing the stop line increases. Very soon the vehicles reach a state where the headways are nearly constant.

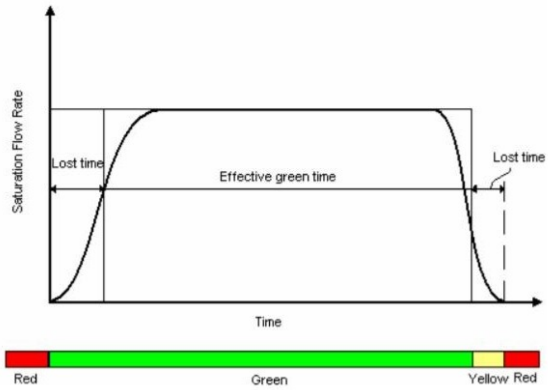

Figure 1: Saturation flow rate and effective green time

The HCM model for calculating saturation flow rate is, (Symbol carry their usual meaning)

$$S = So \times N \times fw \times fHV \times fg \times fp \times fbb \times fa \times fLU \times fLT \times fRT \times fLpb \times fRpb \quad (1)$$

Previous study:

Ibrahim et al. (2002) had carried out a study to determine the ideal saturation flow at signalized intersections under Malaysian road conditions. They adopted the method of measuring saturation flow published by the (then) Road Research Laboratory (1963). The averaged flow values were then regressed with lane widths to obtain a linear regression model:

$$S = 1020 + 265W; \qquad R^2 = 0.876$$

where, S: measured saturation flow rate in pcu/hr & W: lane width (m).

In Nepalese condition, Sambridhi Shrestha 2013, proposed following model for saturation flow of signalized intersection after regressing the data of three intersections of Kathmandu Valley:

$$S = 1107 + 398.22 * W$$

R-square value is only 0.415, so recommended method may not be fit because of the less variable. Where, S=saturation flow rate, w=width of study approach. [1]

5.3 Start-up Lost Time

[7] The additional time in the second consumed by the first few vehicles in the queue at a signalized intersection above and beyond the saturation headway, because of the need to react to the initiation of the green for and to accelerate. Total start-up lost is equal to the summation of individual start-up lost (fig-2).

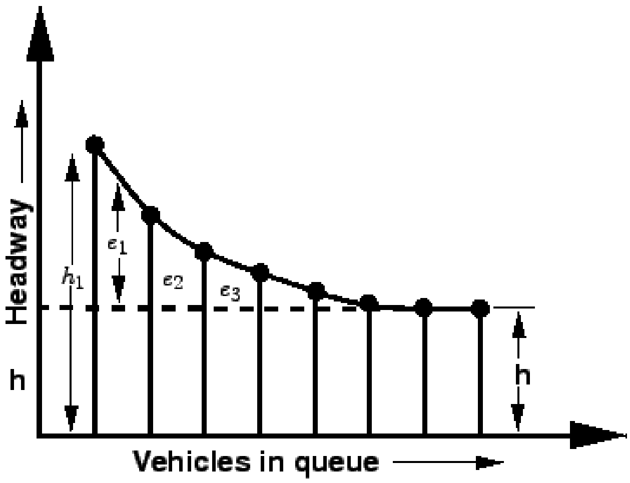

Figure 2: Start-up lost time

Previous Study:

Ke Yu and Huapu Lu (2014) studied on Behavior of the First Vehicle in the Queue Using the records from a video camera, driver's maneuvers at the intersections were observed and this is used for analysis of the factors causing start-up delay and premature start. Comparing a result between with countdown and no countdown the results show that countdown signal can reduce the average start-up delay by approximately a second. [8]

Professor Wang of Tongji University (2006) completed questionnaire survey and the result shows that about fifty percent of vehicles will experience smaller start-up lost time under countdown traffic control signals, and the lost time may be decreased to 2 seconds.[9]

M.R. Ibrahim et al (2008) show that the headway between automobiles at all intersections remain constant after the sixth automobile in queue crosses the stop line. After the first five vehicles, the effects of start-up reaction and acceleration are relatively minimal. With the use of the countdown signal, the total start-up lost time was reduced from 4.3 seconds to 2.9 seconds, or reduced by thirty-three percent. [4]

5.4 Delay

[7] Delay is a measure that most directly relates driver's experience and it is a measure of excess time consumed in traversing the intersection. Fig-3 shows the differences among stopped time, approach and travel time delay for a single vehicle traversing a signalized intersection. The desired path of the vehicle is shown, as well as the actual progress of the vehicle, which includes a stop at a red signal.

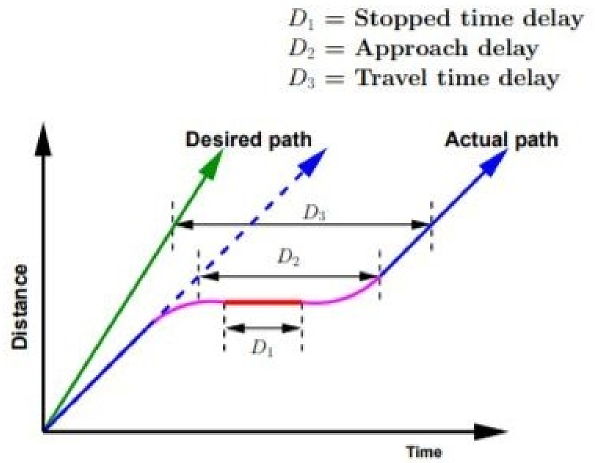

Figure 3: Illustration of delay Measure

HCM 2010 delay models The delay model incorporated into the HCM 2000 includes the uniform delay model, a version of Akcelik's overflow delay model, and a term covering delay from an existing or residual queue at the beginning of the analysis period. The control delay for the through movement is the appropriate delay to use in an urban street evaluation. The delay is given as,

$$d = d1(PF) + d2 + d3 \quad (2)$$

Where,
d = control delay, s/veh,
d1 = uniform delay component, s/veh,
PF = progression adjustment factor,
d2 = overflow delay component, s/veh,
d3 = delay due to pre-existing queue

Previous Study:
Arpita et.al (2017) [10] study presents an improved delay model for signalized intersections under heterogeneous traffic conditions. The proposed model has been developed by modifying the existing HCM model on the basis of traffic data collected from seven four-legged signalized intersections across the country. Variable mentioned in HCM are remarkably affect uniform delay, and therefore the theoretical part of delay formula (d1) is not changed. The incremental delay (d2) is primarily attributable to the arrival of vehicle platoons at different times of the signal cycle, and particularly during green time. Therefore, regression analysis was used to get a relationship between them, and this yields,

$$d2 = 6.23 - 15.35 \times Rp \quad (3)$$

Where Rp is platoon ratio (ratio between PVG = percentage of vehicle arriving during green and PTG = percentage of time green).

All above mention research was conducted in their own condition and they do not propose a worldwide model but they suggest this model to their condition. The condition of a developed and developing country like Nepal may be different.

6. Methodology

In the present study, two signalized intersections in Kathmandu valley are selected as study sites, with countdown timer. The data was collected at both countdown and without countdown case. Video recording technique using digital camera is adopted to carry out field data collection.

Following methodology are adopted as summarized below,

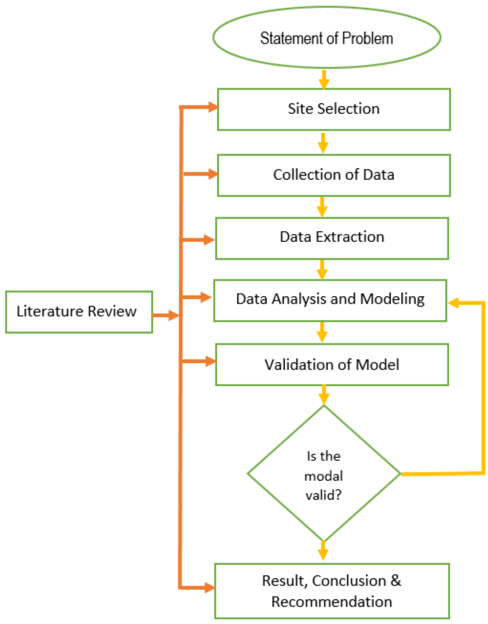

Figure 4: Methodology for conducting research

6.1 Statement of Problem

In many signals at Nepal, there is no information on the remaining green time or red time provided to drivers. This causes driver's difficulties to correctly estimate the time when the signal changes to red during the green light or vice versa. Also, during the red light periods, drivers may feel uncomfortable and feel waiting a long time for the green signal display than the actual waiting time. The resultant delay gives rise to frustration and stress, as well as inattention of drivers to signal changes. This would possibly cause a mistake in the decision for drivers due to stress. Ultimately this causes Higher start up delay, which reduces effective green time, and thus reduce capacity. Alternatively, with countdown signals, drivers can estimate the proper timing for maneuvers at intersections.

6.2 Site Selection

In order to study the effect of countdown timers on the performance of signalized intersection, two signalized intersections i.e. New Baneshwor and Narayan Gopal Chowk with timer were chosen for present study. Both are four-legged intersection having heavier through traffic flow. Most of the time these intersection remains over saturated. During peak hours (morning peak and evening peak), these intersection gets over saturated (Demand more than capacity). Traffic flow was recorded for the intersection coming from both approaches. Vehicles on both approaches comprise truck, big bus, mini bus, micro bus, car, motorcycle, taxi and tempo, having dominant amount of two-wheeler.

Site 1: New Baneshwor Intersection: - The average annual daily traffic of the intersection is 81,190 veh/day and 21,921 PCU/hr. Among them the majority of the vehicle is two-wheeler of about 70 %, Truck and bus constitute about 7 % and car of about 20 %. The total cycle length is 290 sec and amber time is 3 sec and 5 seconds. There are 76 % of straight, 15 % of left and 9 % of right turning traffic in terms of PCU.

Site 2: Narayangopal Chowk: - The annual average daily traffic of the intersection is 21,663 veh/day. Among them, the majority of the vehicle is occupied by motorcycle which has about 52 % in terms of vpd, truck & bus count only 18 % , and car constitutes about 23 %. The total cycle length is 280 sec and amber time is 3 sec and 5 seconds. There are 77 % of straight, 10 % of left and 10 % of right turning traffic in terms of PCU.

Figure 5: Some photos of site

6.3 Collection of Data

For the collection of one day peak hour data of without countdown case at these location the countdown timer was off by traffic police on formal request through Department of Road. Therefore data are available for both countdown and without countdown case at same location. To provide a better view of signalized intersection performance, video cameras were set up at the location to meets all requirement as mention in site selection. Two cameras are utilized for traffic and signal related data collection and the output from them were synchronized.

The work has been carried out in 3 different sunny days in a week by videographic technique, two of them were in weekdays and the rest were in weekend. Two weekdays and a weekend are considered for data collection to capture the scenario of the whole week's condition at a particular time period. The data was collected at both peak and off-peak period. In this study data of morning 8:30 am to 11:00 am and evening 4:00 pm to 7:00 pm were used for developing peak time modal. Another independent data of one days at a different time was collected to validate the model.

The data collected from video graphic method is also verified from manual method. The secondary data available of the proposed location are also used to study the effect of the countdown signal on the performance of signalized intersection. The secondary data are available from Department of Roads (HMIS Unit, DoR) and Traffic Metropolitan Office.

6.4 Data Collection Method

a) Saturation Flow rate

The width of study approach was measured directly on the field, length of green time was measured manually by the help of stopwatch and through video data extraction, and other data was determined from classified volume count.

b) Initial Start up Lost Time

The starting response time (SRT) of the first vehicle in the queue and the subsequent headways was measured on a cycle-by-cycle basis. The SRT of the first vehicle is the elapsed time from the display of the green to the time when the first vehicle begins to move. For subsequent headways, the time was noted when the first vehicle in queue began to move, and the time when every vehicle's rear axle passed the stop line was recorded.

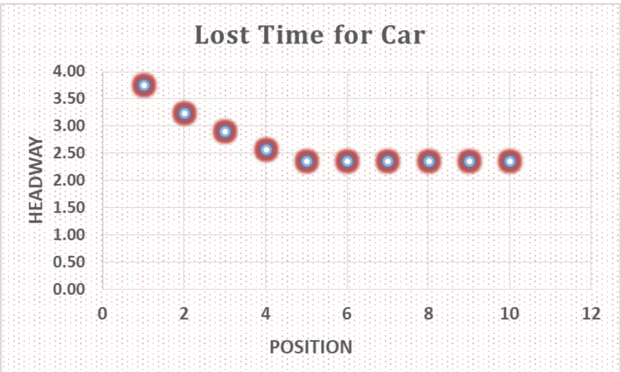

Figure 6: Sample of Lost time for car

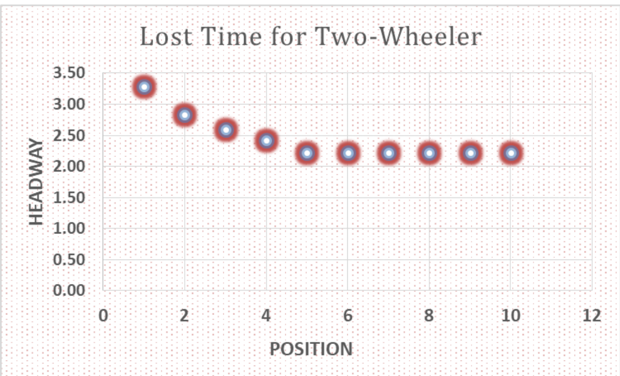

Figure 7: Sample of Lost time for Bike

c) Delay

The total delay of the automobile is find out by video graphic method by averaging delay of several vehicles. The uniform delay of the vehicle is find out from HCM 2010 model and incremental delay is thus obtained by subtraction of uniform delay to total delay. The pre-existing queue (d3) is zero for this study because only under saturated cycles where no vehicles was left after completion of a cycle have been considered.The platoon ratio is the ratio between PVG/PTG, where, PVG = percentage of vehicle arriving during green and PTG = percentage of time green.

6.5 Extraction of Data

The video recorded at the site was played back on a computer to extract the required data. The classified volume was count for every 15 minute interval for peak time. Among three days data; the first day data is with timer at working day, the another day data is without timer case (i.e. timer off case) at working day and last day data is with timer case at non-working day (i.e. Saturday). From the video, the signal timing & phasing, classified vehicle count, directional movement of each vehicle and start-up lost time was extracted.

The saturated flow rate was measured in PCU/hr by converting 15 minute PCU data to one hour. Altogether there was **2400 no of summerised data** which are used for regression analysis. Among them 1600 data was for countdown case and remaining 800 data for the without countdown case. Likewise there was 144 no of summerised data for start-up lost model (among them 68 for car & 76 for bike) and 216 data for delay modeling.

7. Data Analysis and Modeling

Extracted data was analyzed to assess the effect of the countdown timer on saturation flow rates,start-up lost time,and delay at both cases (with and without timer). The multiple regression analysis was conducted on IBM SPSS Statistics 23 to developed Saturation flow rate (in PCU/hr) modal with & without countdown timer situation. To developed a model the value mention in NRS is static PCU, so dynamic PCU value proposed by Sambridhi Shrestha was used. [11] [1]

Saturation Flow Rate

After the collection W, GT, %RT, % LT, % HV, %TW, %OLT, SF, and classified vehicle count at these intersection, regression analysis was conducted on IBM SPSS Statistics 23 to developed Saturation flow rate (in PCU/hr) model with and without countdown timer situation. Nine Different type of models are prepared, among them the best fit model is,

$$\begin{aligned} SF = & 1351.03 + 381.89 \times W - 17.844 \times LFT \\ & - 5.921 \times RHT - 35.674 \times HV - 82.429 \times TW \\ & - 19.185 \times OLT + 4.174 \times GRT + 89.646 \times TIM \end{aligned} \tag{4}$$

The R-square value is comparatively good of this model as compared to other 8 models. Relationship between Saturation flow with width, and green time are positive means they are proportional to each other. On the other hand the relation between saturation flow with percentage of left turn vehicle, percentage of right turn vehicle, percentage of heavy vehicle, percentage of two wheeler vehicle, and percentage of opposite lane left turning vehicle are negative means they are inversely related. Therefore this model is best fit model for the calculation of saturation flow rate at signalized intersection.

Where,
SF = Saturation flow rate per hour
W = Width of study approach at stop line being surveyed
LFT = % of left turn,
RHT = % of right turning vehicle,
HV = % of heavy vehicle,
TW = % of two-wheeler,
GRT = Length of signal green time for approach being surveyed,
OLT = % of opposite lane left turn vehicle,
TIM = Presence of timer or not (1 for Timer case and 0 for without Timer case).

Total Start-up Lost Time of Automobile

After the collection of lost time (with and without case), saturation flow rate and saturated headway data, five different type of models are prepared. Among them the best fit models are,

$$LOST = 3.494 - 0.979 \times TIM \quad \text{for bike only} \tag{5}$$

$$LOST = 3.801 - 0.552 \times TIM \quad \text{for car only} \tag{6}$$

The R-Square value and T- parameter are relatively significant for individual model as compared to combined model. So models are fit for car and two-wheeler individually. It is seen that the initial lost time is decreased from 3.801 second to 3.249 second for car and 3.494 second to 2.515 second for two wheeler due to installation of countdown timer.

Where,
LOST= Initial Start-up Lost time in second,
TIM= Presence of timer or not (1 for Timer case and 0 for without Timer case).

Delay

After the collection total delay, uniform delay, vehicle passed during green time and total vehicle passed during study period, five different type of models for incremental delay(I delay) are prepared. Among them the best fit models is,

$$\text{I Delay} = 34.964 - 6.136 \times Rp - 2.653 \times TIM \tag{7}$$

Hence,

$$\text{Control delay} = d1 + (34.964 - 6.136 \times Rp - 2.653 \times TIM) + d3 \tag{8}$$

The adjusted R-square value is 0.809, means 80.9 % of variance of original field data is explained by the variance of field data obtained from MLR equation. Sign of the coefficient is also logical because increase in platoon ratio leads to reduction in delay. So, this model is fit for incremental delay. It is seen that the incremental delay is reduced by 2.65 second due to installation of countdown timer. That means the incremental delay and total delay of the intersections are reduced by approximately 7.55 % and 2 % respectively by the installation of countdown timer.

8. Validation of Model

Data from the same intersection:

The prepared models are verified from the independent data of the same intersection. The one day's data which are not used in preparing model are used to validate the model.

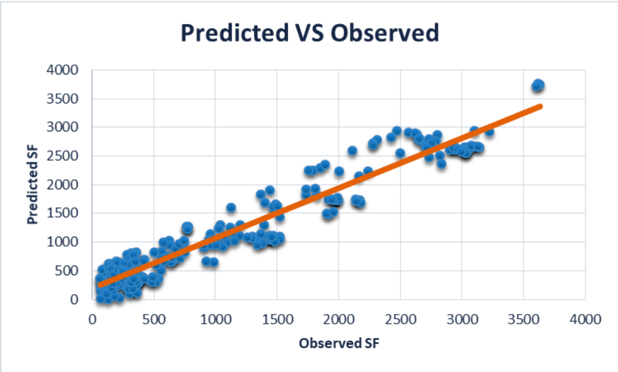

Figure 8: Line of fit plot for Saturation Flow model validation

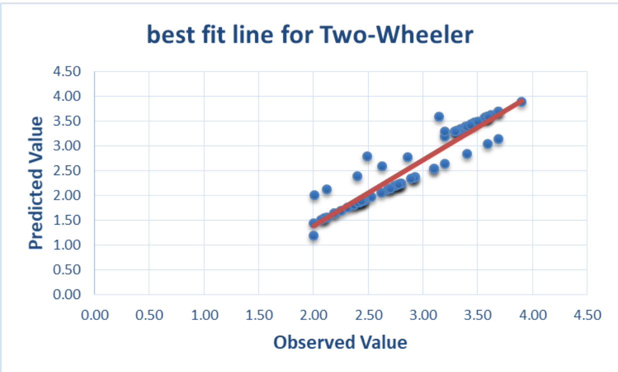

Figure 9: Line of fit plot for Start-up Lost model validation for two-wheeler

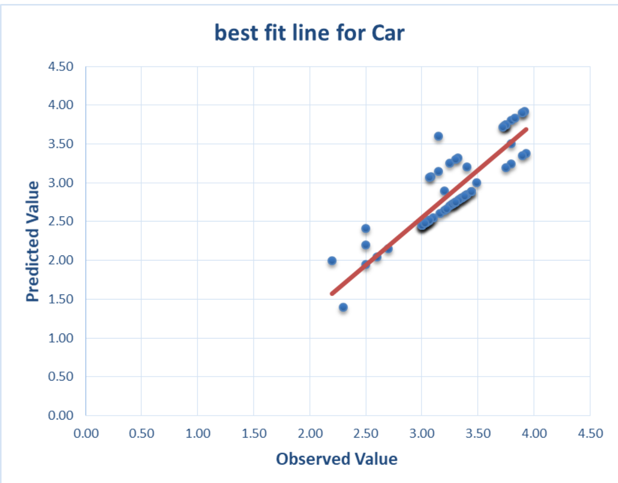

Figure 10: Line of fit plot for Start-up Lost model validation for car

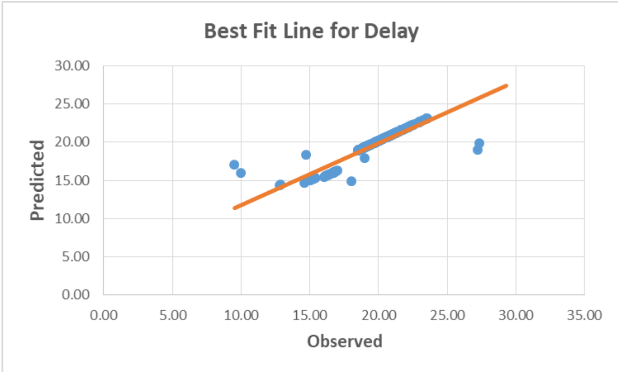

Figure 11: Line of fit plot for Delay model validation

The Regression analysis between observed value and predicted value yielded following result,

Table 1: Result of validation test from same road data

Model	R^2 value	F-value	T-value	(r)
SF	.933	0.000	sig	.966
LOST(T)	.818	0.000	sig	.905
LOST(C)	.807	0.000	sig	.90
Delay	.976	0.000	sig	.948

From Multiple Regression tests:

The model are also verify from the regression test. R Square delineates to what degree the output variable's variance is explained by the input variable's variance with respect to the real data. Significance F indicates whether the regression output could have been obtained by certain circumstances. The validity of regression output is confirmed by the small Significance F value.

Table 2: Result of validation test from statistics

Model	R^2 value	F-value	T-value	(r)
SF	.841	.000 to .021	sig	-.392 to 1
LOST(T)	.779	0.000	sig	.854
LOST(C)	.782	0.000	sig	.886
Delay	.809	0.000	sig	.925

9. Conclusions and Recommendation

The Models for saturation flow rate, delay and start-up lost time due to countdown timer are developed in this research. The result shows that the saturation flow rate is increased but start-up lost time, and delay are decreased at timer case. The Capacity of the signalized intersection is approximately increased by 4.68% due to installation of countdown timer. The start-up lost time models are prepared for car and two-wheeler individually. It is seen that the initial lost time is decreased from 3.494 to 2.515 second (i.e. decreased by 28.02%) for two-wheeler and 3.801 to 3.249 second (i.e. decreased by 14.52%) for car due to installation of timer because all motorists in the queue at a signalized intersection are informed when the signal is going to turn green. This result indicates that the two-wheeler are more sensitive to timer than car. Based on results obtained from analysis, HCM 2010 delay model has been selected to modify. The incremental delay and total delay of the intersections are reduced by approximately 7.55% and 2% respectively by the installation of countdown timer.

References

[1] Sambridhi Shrestha. Development of saturation flow and delay modal for signalized intersection in kathmandu. *IOE*, 2013.

[2] K.M. Lum and H. Halim. A before and after study on green signal countdown device installation. *Traffic Psychology and Behavior*, 2006.

[3] Winai Raksuntorn. The effects of countdown signals on intersection capacity. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, 2012.

[4] Ibrahim MR, Karim MB, and kidwai FA. The effect of digital countdown display on signalized junction performance. *American Journal of Applied Sciences*, 2008.

[5] Jie ZHANG, Yulong HEm, and Xiaoduan SUN. The effects of countdown signal on driver behavior at intersection in a city. *Tenth International Conference of Chinese Transportation Professionals (ICCTP)*, 2012.

[6] Fujita M, Suzuki K., and Yilmaz C. Behavior and consciousness analyses on the effect of traffic signals including countdown device for vehicles. *Journal of the Eastern Asia Society for Transportation Studies*, 2007.

[7] Highway Capacity Manual. Hcm. *Manual*, 2010.

[8] Ke Yu and Huapu Lu. Effects of countdown signals in red phase on drivers: A comparative study between japan and turkey. *Institute of Transportation Engineering, Tsinghua University, Beijing 100084, China*, 2018.

[9] Cong ZHANG, Yongfeng MA, and Jian LU. Study on start-up lost time of traffic signals with count-down display and the driving behavior at the end of green signal. *The Twelfth COTA International Conference of Transportation Professionals*, 2012.

[10] Arpita Sahai, Satish Chandra, and Indrajit Ghosh. Delay at signalized intersections under mixed traffic conditions. *American Society of Civil Engineers*, 2017.

[11] Department of Roads. Nepal road standard. *NRS*, 2070.