Effect of Countdown Timer on Acceleration-Deceleration Rates of Different Vehicle Types at Signalized Intersections

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Abstract. This research work tried to compute the impact of countdown timer on vehicle acceleration and deceleration rates of different vehicle types at signal controlled intersections under non-lane disciplined traffic conditions. For the present research work, eight approaches of two different signalized intersections with countdown timer were selected from Hyderabad city. The data required for the present study was collected, from all the study approaches both during the absence and presence of countdown timer, by switching off the countdown timer with traffic police permission. In the present research work, the acceleration and deceleration models were proposed for both without and with countdown timer conditions, for different vehicle categories: Two-Wheeler (TW), Three-Wheeler (3W), car, Light Commercial Vehicle (LCV), and Heavy Vehicle (HV). The result showed that, the acceleration and deceleration rates of vehicles were decreased when the countdown timer is absent, compared to with timer condition. The acceleration rates of two-wheeler, three- wheeler, car, LCV, and HV were reduced by 10.68%, 6.21%, 10.19%, 4.30%, and 8.33% respectively, and deceleration rates were reduced by 5.04%, 7.36%, 7.12%, 7.45%, and 3.50% respectively, due to the absence of timer compared to with timer condition.

Keywords: Acceleration Rate, Deceleration Rate, Vehicle Types, Countdown Timer, Non-lane Disciplined Traffic Conditions.

1 Introduction

In any urban road network, signal controlled intersections play a vital role in achieving the better performance of the entire road network system. It is expected to control intersection safety and efficiency especially at inter-green periods at signalized intersections because that time affects the occurrence of traffic collisions and delay and driver's

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acceleration and deceleration rates as well. Drivers who approach a signalized intersection during amber time must make choice either cross the intersection or stop safely. It is difficult for them to take decision when they are in dilemma zone which relates to a situation that a single driver faces in the signals, or can safely stop over time. A rear end collision generally takes place when two consecutive drivers make opposing decisions at the end of the green signal, meaning that the long wait at the traffic lights often leads to frustration, stress, and their inattention changes the signal. The countdown timer display remaining time for the drivers approaching signalized intersections, are assumed to reduce fuel consumption, queuing driver's anxiety, causing collision, improving acceleration/deceleration rates and capacity. Interestingly, their intended effect has been achieved in a mixed manner by various researchers in developing countries, particularly Asia. Countdown timers are expected to reduce driver anxiety, fuel consumption, and frequency of crashes. Countdown signals are quite common in most of the countries but only few studies reported earlier to evaluate their performance on various operational performances of signalized intersections.

The present research work evaluates the impact of signal countdown timer on deceleration and acceleration rates of several categories of vehicles. Vehicle acceleration and deceleration rates are important driver behavior parameters used to quantify control delay and to assess the Level of Service (LOS) of signalized intersections. Acceleration and Deceleration rates are also useful to for designing acceleration/ deceleration lanes, ramps, storage bays etc., Acceleration/ Deceleration rates depend on type of the vehicle, presence of countdown timer, driver age, driver gender, number of lanes, sight distance visibility, performance characteristics of vehicles etc., Most of the studies done in the past were conducted for cars where vehicles follow lane discipline. However, in India, vehicles do not follow any lane discipline and traffic stream is heterogeneous in nature where traffic mixture containing various vehicle types like three wheelers, two wheelers, Cars, and trucks etc. The methods used for data collection for speed, deceleration and acceleration behavior was GPS (Global Positioning System), Videography technique etc., Because of weak lane discipline and slow-moving vehicles like three wheelers and trucks cannot accelerate to their full capabilities. Therefore, to capture all these variations and to estimate the length of cycle time (green, red and amber) and to observe the behavior of vehicles in deceleration/acceleration the accurate knowledge of deceleration/acceleration behavior of these vehicles is required. Also to overtake the vehicles minimum sight distance is required. The deceleration and acceleration data of vehicles is needed for estimating the least sight distance and for estimating the lengths of the intersection sight triangles. A limited number of studies are done considering all vehicle types simultaneously, the development of existing models considering all the vehicle types simultaneously is required. Therefore, the present study focuses to develop unified models of deceleration and acceleration for three wheelers, two wheelers, Cars, Light Commercial vehicles, and Heavy vehicles considering countdown timer effect.

2 Literature Work

This section provides a brief literature of earlier studies done around the world, in the field of present research area. In the previous research work, [2] performed a roadside survey in Turkey and used video cameras for collecting data at signalized intersections with a countdown device. After analyzing the traffic sign from user's point of view, it was observed that there is an improvement in user satisfaction. It was found that the countdown displays at a reported intersection reduced startup lost time and smoothened traffic flow. The study showed that the driver's irritation at the reported intersections was diminished by knowing the time remaining to accurately change the signal, and that the countdown display had an impact on the driver's calm mind. Reducing the number of horns at the reported intersections had also proved this, and the countdown display helps in reducing the driver's aggression. A study [3] inspected six signalized intersections, without and with countdown timer. They were studied and compared to investigate the effect of countdown timer on driver behavior. The study found that the countdown timer had minute impact on initial delay, but observed a significant impact on headway. In a research work [4] it was observed the effect of traffic signal countdown timer in European countries, Russia and Turkey. Different shapes and configurations have been observed for the signal countdown timers. In many countries like Iceland, Swedan, Poland, Austria, Argentina, Colombia, Paraguay, Israel, Denmark, Germany, United Kingdom, the red and amber signals light up at end of red phase to aware the drivers that the signal phase is going to be changed from red to green, which helps to shorten the startup lost time at the starting of the green by warning the driver to the upcoming green phase.

An investigation was done [1] to find the effect of Green Signal countdown timer and Red Signal countdown timer in Taiwan. The study observed and analyzed these countdown timers at four different stages: after installation and before installation. The early start rates for waiting vehicles in several waiting areas were initially dropped, but back to same level at peak time as well as non-peak time prior to installation of Red Signal Countdown timer. The study results showed that, due to the presence of Red Signal Countdown timer, the red light violations got reduced and also the number of crashes were reduced. Authors [5] investigated the effect of countdown timer in different phases of signal cycle. For this purpose, an opinion poll survey and a traffic analysis survey have been conducted in Bangkok. Poll survey revealed that more than half of the drivers expressed that timers help them to reduce the frustration. Also, it is observed that, during the green phase, there is a slight reduction in saturation flow. In a previous research work [9] authors studied the influence of cycle time and green signal countdown timer on discharge pattern of queue in China at signalized intersections. The study results showed that, the green signal countdown timer associated with longer cycle times, increased the start-up lost time and reduced the lost time for clearance.

A study was conducted [6] to find the efficiency of green light countdown timer in minimizing dilemma zones at signalized intersection in Delhi, with and without countdown timer. The study found that, the green light countdown timer has significantly reduced the length of dilemma zone. A research work was conducted earlier [10] to study the effect of green signal countdown timer on long-term and short-term basis on road safety using a combination of natural and driver simulation experiments. This short term and long-term observations showed that the green signal countdown timer decreased the red-light violations during short term compared to the long term. A study [7] presented a comprehensive review on traffic efficiency and safety due to countdown signals. The study found that the research done earlier on evaluating countdown signals was not sufficient and a future direction is shown to study the impact of physiological and psychological characteristics of driver with countdown timer effect. Authors [8] analyzed the driver anticipation by deceleration and speed in the presence and absence of countdown timer. The study found that, at the onset of yellow, there is a significant difference in driver behavior. Based on the results of the earlier studies, according to some studies, the signal countdown timer is associated with a reduction in length of dilemma zone, start-up lost time and violations during red light. There are some other studies which contradict these observations. The main reason for these contradictory results may be different traffic situations with different driver behavior among the countries. On the other hand, it is observed that there are only a very few studies reported to observe the effect of countdown timer on acceleration and deceleration rates of vehicles, especially under heterogeneous traffic conditions. So, the present study aimed to evaluate the acceleration/deceleration rates of different vehicle types at signalized intersections under heterogeneous traffic conditions, with and without countdown timer.

3 Methodology

This section explains the study methodology with the help of a flow chart shown in Fig. 1.

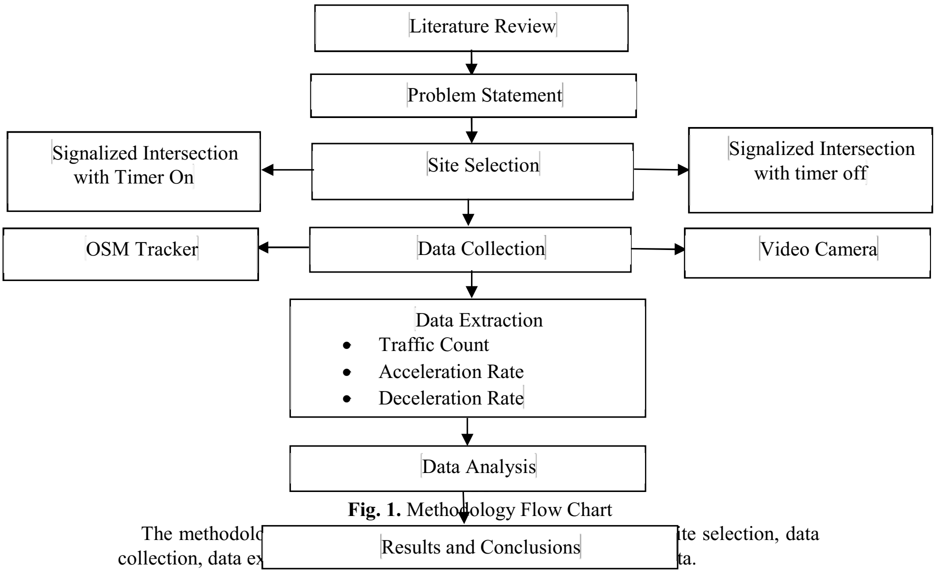


Fig. 1. Methodology Flow Chart

The methodol te selection, data collection, data ex ta.

4 Study Area

Two study intersections were chosen for the present study. Suchitra Intersection and Bachupally Intersection. Both the study locations are in Hyderabad city, India, and both the intersections are signalized intersections with countdown timer. Both the study intersections are two legged intersections with two roads minor and two roads major. To keep the geometric and traffic characteristics similar, data is collected with timer on and timer off conditions at same intersection. There is no road side parking, no bus stop, colleges and schools nearby considered leg of intersection. Fig. 2 Shows the google map image of the Suchitra Intersection and Bachupally Intersection.

(a) (b)

Fig. 2 (a). Suchitra Intersection **(b).** Bachupally Intersection

Both the study intersections chosen in the present study are free from fly over ramps and metro stations.

5 Data Collection

Data collection is carried out by two methods: one with videography technique and another one by using OSM tracker mobile application. Both the data collection methods were used to collect data both during the absence and presence of countdown timer at study locations. In videography method, the observer is stationary and it records movements of vehicles. Another method employed for data collection is through OSM Tracker which is a mobile application. The observer who is holding the mobile, records the data of its own vehicle moving along the traffic stream. Both the observer and traffic are in motion unlike previous method.

The lane was divided longitudinally by making lines with lime at every 10 meters distance intervals from reference line to identify the deceleration distance. Video recording was done from 10:30 AM to 12:30 PM and 5:30 PM to 8:30 PM on a week day under clear weather condition. OSM tracker is a mobile application which requires a good internet connection. There is an option called Track details which is clicked once the vehicle is made to run from the check points fixed earlier. Check points are fixed at a distance of at least 500m from the approach of the intersection. The android application is started once the vehicle type reaches the check point. Vehicle were made to start beyond the check points to get good results. The save option is operated once the vehicle crosses the intersection and reaches the check point on the other side of the intersection. For each approach 15 runs were made with different vehicle categories: TW, 3W, Car, LCV, and Heavy Commercial Vehicle (HV).

By using videography method, classified traffic volume data, turning movements, deceleration distance, deceleration time, acceleration distance, and acceleration time for study vehicles were noted down. From OSM tracker mobile application, the speed corresponding to each point, time, and latitude and longitude of each point were known. The signal timings such as cycle time, red, green, and amber were noted down in the field. The geometric details of study locations such as width of the approach was measured in the field using tape. The width of each approach and signal timings of each approach of selected intersections are given in Table 1.

Table 1. Width and Signal Timings of Study Approaches of Intersections

Intersection	Approach	Width of Approach (m)	Cycle length (sec)	Green time (sec)	Amber time (sec)
Suchitra	N-1	10	180	50	2
	S-1	9.5		60	2
	E-1	10.5		30	2
	W-1	10.0		30	2
Bachupally	N-2	7.5	162	45	2
	S-2	7.3		30	2
	E-2	6.4		30	2
	W-2	5.3		45	2

All the approaches of Suchitra intersection have three lanes, three approaches of Bachupally intersection contains two lanes and one is intermediate lane. The cycle time of Suchitra intersection is observed to be 180 seconds, whereas it is 162 seconds for Bachupally intersection.

6 Data Extraction

From the recorded videos at study locations, the total traffic count for different classes, along approaching legs at both the study locations were obtained for whole period and the corresponding vehicle composition is given in percentages in figure 3.

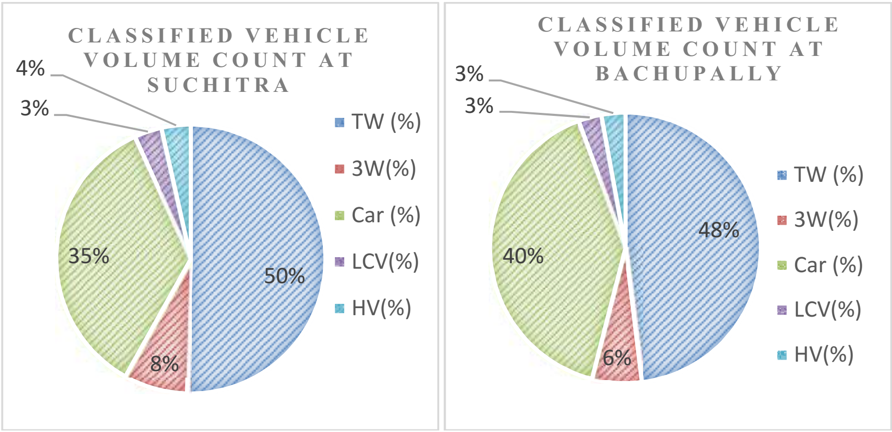


Fig. 3. Classified vehicle volume count at Study Intersections **(a).** Suchitra **(b).** Bachupally

At both the study locations the percentage of two wheelers and cars are high when compare to percentage of three wheeler, LCV and HV. The data collected using OSM tracker mobile application was extracted. Before going to extract the data, the data was converted to GPX format in the application, which contains latitude and longitude of each point in the track and speed corresponding to each point in the track. Also, the same data was extracted using VLC media player from the recorded videos, in which stop watch was used to measure the time elapsed for vehicles to cross the lines. From the speed and time data extracted, the acceleration and deceleration rates of the vehicles were extracted for different vehicle types, in both presence and absence of countdown timer. The average speed data observed with and without countdown timer during acceleration and deceleration behavior is given in Table 2.

Table 2. The average Speed values of different vehicle types, during acceleration and deceleration manoeuvres, with and without countdown timer

Vehicle Type	Average Speed (m/s) during acceleration with countdown timer	Average speed (m/s) during acceleration without countdown timer	Average Speed (m/s) during deceleration with countdown timer	Average speed (m/s) during deceleration without countdown timer
TW	5.80	5.43	4.55	4.03
3W	4.07	3.87	4.65	4.35
CAR	5.31	4.85	4.39	4.00
LCV	4.35	4.02	5.23	4.95
HV	3.00	2.86	3.34	3.04

From Table 2 it is observed that, there is a significant difference between observed speeds with and without countdown timer condition. The acceleration rates observed for different vehicle types were given in Table 3, both in the presence and absence of countdown timer.

Table 3. Acceleration rates of different vehicle types, with and without countdown timer

Approach	Accelerate Rate (m/s^2) with countdown timer					Accelerate Rate (m/s^2) without countdown timer				
	TW	3W	CAR	LCV	HV	TW	3W	CAR	LCV	HV
NB1	0.61	0.421	0.499	0.477	0.224	0.564	0.404	0.425	0.456	0.202
SB1	0.582	0.443	0.462	0.452	0.296	0.507	0.41	0.44	0.445	0.276
EB1	0.542	0.413	0.466	0.466	0.254	0.521	0.389	0.418	0.438	0.243
WB1	0.654	0.446	0.491	0.469	0.207	0.526	0.402	0.423	0.429	0.199
NB2	0.598	0.464	0.487	0.462	0.286	0.579	0.441	0.412	0.453	0.237
SB2	0.564	0.432	0.476	0.471	0.275	0.548	0.458	0.438	0.435	0.221
EB2	0.551	0.409	0.493	0.458	0.247	0.503	0.385	0.458	0.449	0.263
WB2	0.693	0.455	0.475	0.468	0.228	0.532	0.379	0.442	0.452	0.219

From Table 3, it is observed that, in the presence of countdown timer at study locations, the average acceleration rates of TW, 3W, cars, LCV, and Heavy vehicle, were found to be 0.599 m/s^2, 0.435 m/s^2, 0.481 m/s^2, 0.465 m/s^2, 0.252 m/s^2 respectively. Whereas, in the absence of countdown timer at study locations, the average acceleration rates of TW, 3W, cars, LCV, and Heavy Vehicles, were found to be 0.535 m/s^2, 0.4085 m/s^2, 0.432 m/s^2, 0.444 m/s^2, 0.2325 m/s^2 respectively. The deceleration rates observed for several vehicle categories were given in Table 4, both during the absence and presence of countdown timer.

Table 4. Deceleration rates of different vehicle types, with and without countdown timer

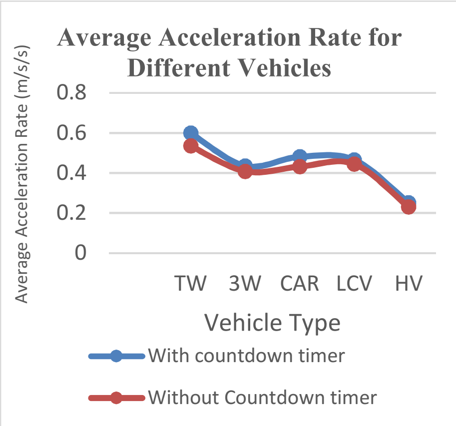
Approach	Accelerate Rate (m/s^2) with countdown timer					Accelerate Rate (m/s^2) without countdown timer				
	TW	3W	CAR	LCV	HV	TW	3W	CAR	LCV	HV
NB1	0.552	0.548	0.625	0.785	0.685	0.52	0.538	0.598	0.701	0.635
SB1	0.562	0.564	0.619	0.743	0.657	0.536	0.527	0.603	0.72	0.634
EB1	0.543	0.595	0.638	0.748	0.663	0.529	0.535	0.589	0.7	0.619
WB1	0.566	0.586	0.645	0.777	0.639	0.527	0.54	0.587	0.712	0.608
NB2	0.569	0.556	0.642	0.769	0.672	0.525	0.532	0.588	0.698	0.648
SB2	0.547	0.55	0.619	0.758	0.648	0.529	0.509	0.6	0.701	0.675

E B2	0. 552	0. 583	0. 635	0. 746	0. 659	0. 527	0. 537	0. 559	0. 722	0. 629
W B2	0. 56	0. 584	0. 638	0. 794	0. 64	0. 534	0. 52	0. 579	0. 716	0. 636

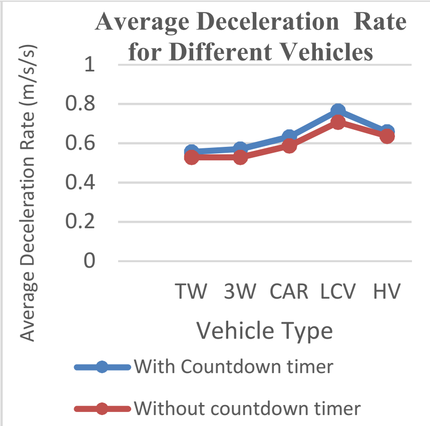
From Table 4, it is observed that, in the presence of countdown timer at study locations, the average deceleration rates of TW, 3W, cars, LCV, and Heavy vehicle, were found to be 0.556 m/s^2, 0.571 m/s^2, 0.631 m/s^2, 0.765 m/s^2, 0.657 m/s^2 respectively. Whereas, in the absence of countdown timer at study locations, the average deceleration rates of TW, 3W, cars, LCV, and Heavy Vehicles, were found to be 0.528 m/s^2, 0.529 m/s^2, 0.587 m/s^2, 0.708 m/s^2, 0.635 m/s^2 respectively.

7 Data Analysis

The acceleration and deceleration rates of different vehicle types considered in the present study, showed a significant difference in their values when evaluated them under with and without countdown timer conditions. The Figure 4 represents the variation of acceleration and deceleration values for different vehicle types, under two different prescribed conditions.



(a)



(b)

Fig.4. (a). Average Acceleration and **(b).** Deceleration rates for different vehicle types with and without countdown timer

From Figure 4, it is observed that, the average acceleration rate (m/s^2) and Deceleration rate (m/s^2) varies from one vehicle category to another vehicle category. Also, it is observed that, the average acceleration and deceleration rates are higher with countdown timer, compared to without countdown timer.

8 Modelling Acceleration and Deceleration Rates

The unified Acceleration and Deceleration models were developed in this section for each selected vehicle types by using travelling speed as an independent variable. The linear form of the model was preferred after analyzing the rends between acceleration rates and speed data, as well as deceleration rates and speed data. The coefficients of the acceleration rate model and results of the statistical tests performed related to model development are given in Table 5.

Table 5. Coefficients and statistical summary of developed acceleration model with Countdown timer and without countdown timer

Acceleration Model with countdown timer								
Vehicle type	**Model coefficient A=(a+bV)**		**R^2**	**Standard Error**	**P- Value**		**t-value**	
	Intercept (a)	**Speed (b)**			**Intercept**	**Speed**	**Intercept**	**Speed**
TW	0.33	0.05	0.89	0.039	0.001	0.000	11.012	9.078
3W	0.30	0.04	0.68	0.034	0.001	0.000	10.000	5.224
CAR	0.27	0.04	0.88	0.032	0.002	0.000	14.565	10.390
LCV	0.32	0.038	0.70	0.041	0.004	0.003	8.955	5.455
HV	0.25	0.032	0.65	0.053	0.003	0.002	6.450	5.650
Acceleration Model without countdown timer								
Vehicle type	**Model coefficient A=(a+bV)**		**R^2**	**Standard Error**	**P- Value**		**t-value**	
	Intercept (a)	**Speed (b)**			**Intercept**		**Intercept**	**Speed**
TW	0.300	0.035	0.86	0.036	0.000	0.001	10.980	9.125
3W	0.280	0.037	0.64	0.031	0.000	0.001	11.001	5.455
CAR	0.210	0.034	0.82	0.029	0.001	0.000	13.235	9.654
LCV	0.287	0.032	0.67	0.037	0.002	0.003	8.865	5.675
HV	0.20	0.024	0.61	0.063	0.002	0.001	7.945	6.450

The t-stat values of the variables are greater than ±1.96 and p-values are less than 0.005 at 5% significance level. The coefficients of the deceleration rate model and results of the statistical tests performed related to model development are given in Table 6.

Table 6. Coefficients and statistical summary of developed Deceleration model with Countdown timer and without countdown timer

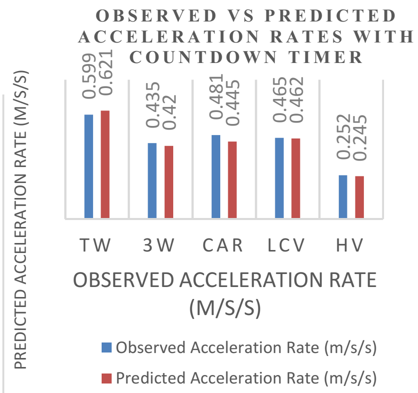
Deceleration Model with countdown timer								
Vehicle type	**Model coefficient A=(a+bV)**		**R^2**	**Standard Error**	**P- Value**		**t-value**	
	Intercept (a)	**Speed (b)**			**Intercept**	**Speed**	**Intercept**	**Speed**
TW	1.10	-0.08	0.88	0.059	0.002	0.001	24.255	-11.240
3W	0.75	-0.041	0.45	0.089	0.000	0.003	10.245	-3.232
CAR	0.98	-0.073	0.63	0.091	0.004	0.001	12.256	-4.345

LCV	1.13	-0.078	0.81	0.069	0.000	0.002	18.986	-15.675
HV	0.68	-0.056	0.76	0.072	0.003	0.002	12.125	-10.245
Deceleration Model without countdown timer								
Vehicle type	**Model coefficient A=(a+bV)**		**R^2**	**Standard Error**	**P- Value**		**t-value**	
	Intercept (a)	**Speed (b)**			**Intercept**		**Intercept**	**Speed**
TW	0.978	-0.07	0.85	0.045	0.001	0.002	20.567	-10.345
3W	0.71	-0.038	0.50	0.090	0.003	0.002	9.244	-4.356
CAR	0.92	-0.065	0.61	0.078	0.000	0.001	10.235	-5.455
LCV	0.99	-0.067	0.78	0.072	0.002	0.000	20.235	-15.356
HV	0.61	-0.045	0.70	0.082	0.004	0.003	11.245	-9.452

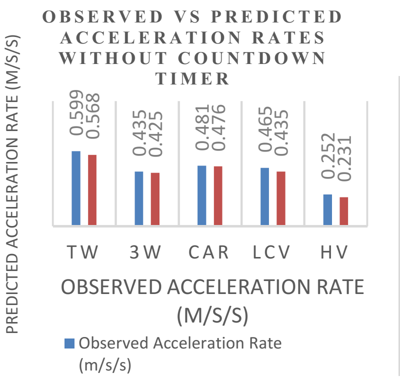
The t-stat values of the variables are greater than ±1.96 and p-values are less than 0.005 at 5% significance level.

9 Validation

Model validation is an important criterion for development and deployment of the model. This step involves evaluating how well the developed model meets the desired performance criteria. In the present study, out of eight approaches selected, six are used for model development and two are used for model validation. The acceleration rate models with and without countdown timer and the deceleration rate models with and without countdown timer are validated. The observed vs predicted values of the acceleration and deceleration rate models were plotted in Fig. 5 and 6 respectively.

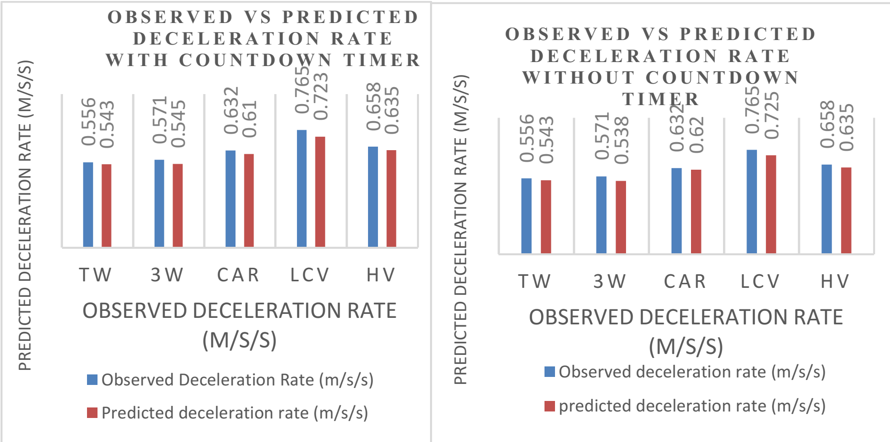


(a)



(b)

Fig 5. (a). Acceleration rate model with countdown timer **(b).** Acceleration rate model without countdown timer



(a) (b)

Fig. 6. (a). Deceleration rate model with countdown timer **(b).** deceleration rate model without countdown timer

The validation results showed that, the observed acceleration rates (with and without countdown timer) and deceleration rates (with and without countdown timer) were very close to the predicted acceleration rates (with and without countdown timer) and deceleration rates (with and without countdown timer). This result indicates a well prediction of the proposed models.

10 Conclusions and Discussions

Acceleration and deceleration rates of different vehicle categories, are important in order to evaluate the control delay at signalized intersections, because this control delay is a combination of acceleration rate, and deceleration rate. The present research work evaluated the impact of countdown timer on acceleration and deceleration rates of different vehicle categories. The average acceleration rates with countdown timer, for different vehicle types: TW, 3W, Cars, LCV, and HV is observed to be 0.599, 0.435, 0.481, 0.465, and 0.252 m/s^2 respectively. The average acceleration rates without countdown timer, for different vehicle categories: TW, 3W, Cars, LCV, and HV is observed to be 0.535, 0.408, 0.432, 0.445, and 0.231 m/s^2 respectively. There is a significant reduction of acceleration rate for different vehicle categories; TW, 3W, cars, LCV, and HV which is observed to be 10.68%, 6.21%, 10.19%, 4.30%, and 8.33% respectively. The average deceleration rates with countdown timer, for different vehicle categories: TW, 3W, Cars, LCV, and HV is observed to be 0.556, 0.571, 0.632, 0.765, and 0.658 m/s^2 respectively. The average deceleration rates without countdown timer, for different vehicle categories: TW, 3W, Cars, LCV, and HV is observed to be 0.528, 0.529, 0.587, 0.708, and 0.635 m/s^2 respectively. There is a significant reduction of deceleration rate for different vehicle categories; TW, 3W, cars, LCV, and HV which is observed to be 5.04%, 7.36%, 7.12%, 7.45%, and 3.5% respectively.

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