Vehicles Acceleration Rate Study for Intergreen Time of a Signal Cycle Compute

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Abstract. Acceleration of vehicles is a parameter needed of calculation intergreen time of cycle length at signalized junctions. Its value is vary for different vehicles and must be averaged for aim of that calculation or be taken its maximum. The paper present acceleration rate of cars study in real traffic flows entered in three traffic light crossroads in Sofia city. The goal is determinate average and maximum value of that parameter due the road infrastructure condition of vehicles movement related with move direction, curves radii, slope of the road, etc. The result obtained in the research would be useful for intergreen time compute in case of traffic light time determination in similar movement condition.

INTRODUCTION

Vehicle acceleration is important dynamic indicator of their qualities that determine the time to increase to a certain speed. Its value is determined of vehicles manufacturers which they can achieved at ideal movement conditions. In real situations that values vary in wide boundaries depending mainly on characteristic of traffic flows and infrastructure and they are usually lower than manufacturers' one. It happens often actual accelerations of deferent vehicle to be approximately equal at equal traffic conditions.

Acceleration rate is constantly being studied in sequence of continuous change that the specialists make in traffic organization or the need to know it in unexplored urban areas as researched by Lybenov, Kirilov and etc. in [1] and [2]. On the other case of traffic conditions study which Mladenov shown in [3] and [4] must be used acceleration rates to achieve completely conclusion that assessing the possible parameters that affect the movement.

On the other hand acceleration mode is generate more harmful emission and that must be studied in similar way as Miletiev and etc. in [5] and Ambarev and Nikolov in [6]. That imposes to include more training related to smoothly start of candidate for a driver which mistakes was reviewed by Atanasova and Lubenov in [7]. In this way is necessary include and additional education for licensed driver especially that drive heavy trucks and buses.

Researchers work out the methodology to assess the impact of other vehicle elements on movement speed as Taneva and etc. in [8]. That may be tied to time to reach the studied speed using proving values of vehicle acceleration on relevant condition as present paper give. The same is true for important area of traffic accident analyses described in some papers by Karapetkov and etc. in [9] and [10]. In these cases may be search relation between established acceleration and deceleration of vehicles in other point of view according to commitment with totality of their qualities.

Determination of intergreen time of cycle length for traffic light junction is other area of road safety that require data for vehicle acceleration. It is a very important period that guarantee enough time the last passed vehicle of a phase to cross conflict area with first entry vehicle of a next phase (Figure 1). Its value can be reached using formula (1). Entrance time, which required acceleration value, is calculates in accordance of equation (2).

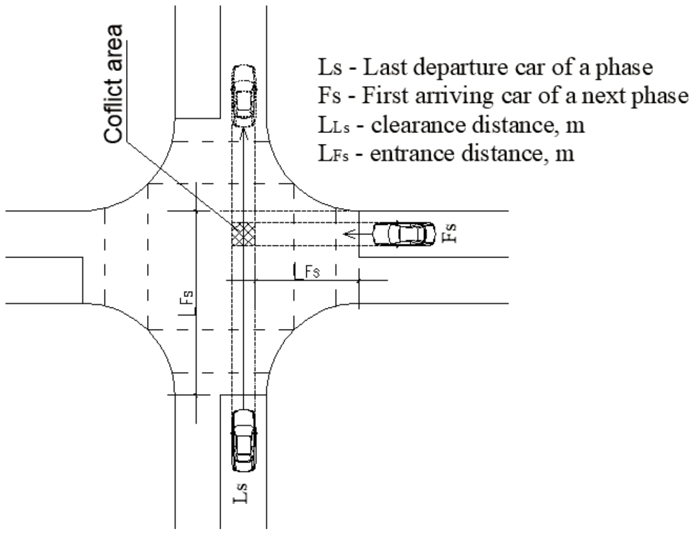

FIGURE 1. Clearance and entrance distance for intergreen time determination.

$$t_{ig} = t_y + t_c - t_e + t_{ad}, s \tag{1}$$

Where t_{ig} is intergreen time, s

t_y – Amber after green signal (its value is equal to 3 s, normatively defined in Bulgaria for speed limit of 50 kmh^{-1});

t_c – Clearance time, s

t_e – Entrance time, s

t_{ad} – Additional time by the specialists view, s

$$t_e = \sqrt{\frac{2L_{F_s}}{a}}\ , s \tag{2}$$

Where L_(F_s) is entrance distance of first arriving car of a next phase, m

a – Vehicle acceleration, ms^{-2}.

This paper gives the value of that needed parameter – vehicle acceleration, which are result of field study on three traffic light junction in Sofia city.

PREREQUISITES AND MEANS FOR SOLVING THE PROBLEM

Acceleration rate in case of intergreen time computing is applied different values in countries. Retzko and Boltze in [11] were accepted 11.5 fts^{-2} (approximately 3.5 ms^{-2}) in their approach to determinate intergreen time called "German method". On the e other hand Hebenstreit in [12] says that in the German need to talk of entrance speed of first entry car which values depend on movement direction and curves radii of turning flows and they are 12 ms^{-1} for in general, 10 ms^{-1} in case of that flows are turning on radius smaller than 20 m and 7 ms^{-1} on radius smaller than 10 m. The same is look the situation in Italy. Hebenstreit also point out that in Austria the entrance speed values are 10 ms^{-1} in straight flows, 7 ms^{-1} for turning flows (not indicated turning radius) and 5 ms^{-1} for flows turning on radius smaller than 10 m.

Researchers in [13] note the acceleration rate of cars must be measured and were gave values of acceleration of trams (0.7-1.2 ms^{-2}) and buses (1.0-1.5 ms^{-2}). On the other side they were gave entrance speed for bicycles. The same was done in [14] where the authors have said the speed is 40 kmh^{-1} in general for every vehicles.

Hebenstreit and etc. have marked that in Netherlands was accepted acceleration value of 2.5 ms^{-2}. The same approach was followed in Bulgaria where is normatively defined acceleration of cars (2.0 ms^{-2}) and trams (1.0ms^{-2}) for intergreen time determination. For pedestrians and bicycles were accepted entrance speed respectively 1.5 ms^{-1}

and 5.0 ms^{-1}. Similarly was accepted entrance speed of vehicle of 40 kmh^{-1} in case of entering with “flaying start” (entering without stopping) [15].

Conducted research presented in this paper was used the obtained data at three consecutive signalized junction in Sofia city. They are between boulevard “St Kliment Ohridski” and “Osmi dekemvri” street (junction “1”), boulevard “St Kliment Ohridski” and “Traycho Stanoev” street (junction “2”) and boulevard “St Kliment Ohridski” and ”Dr G. M. Dimitrov” boulevard (junction “3”), located nearly to the Technical university of Sofia. Schemes of the crossroads are shown in Figure 2.

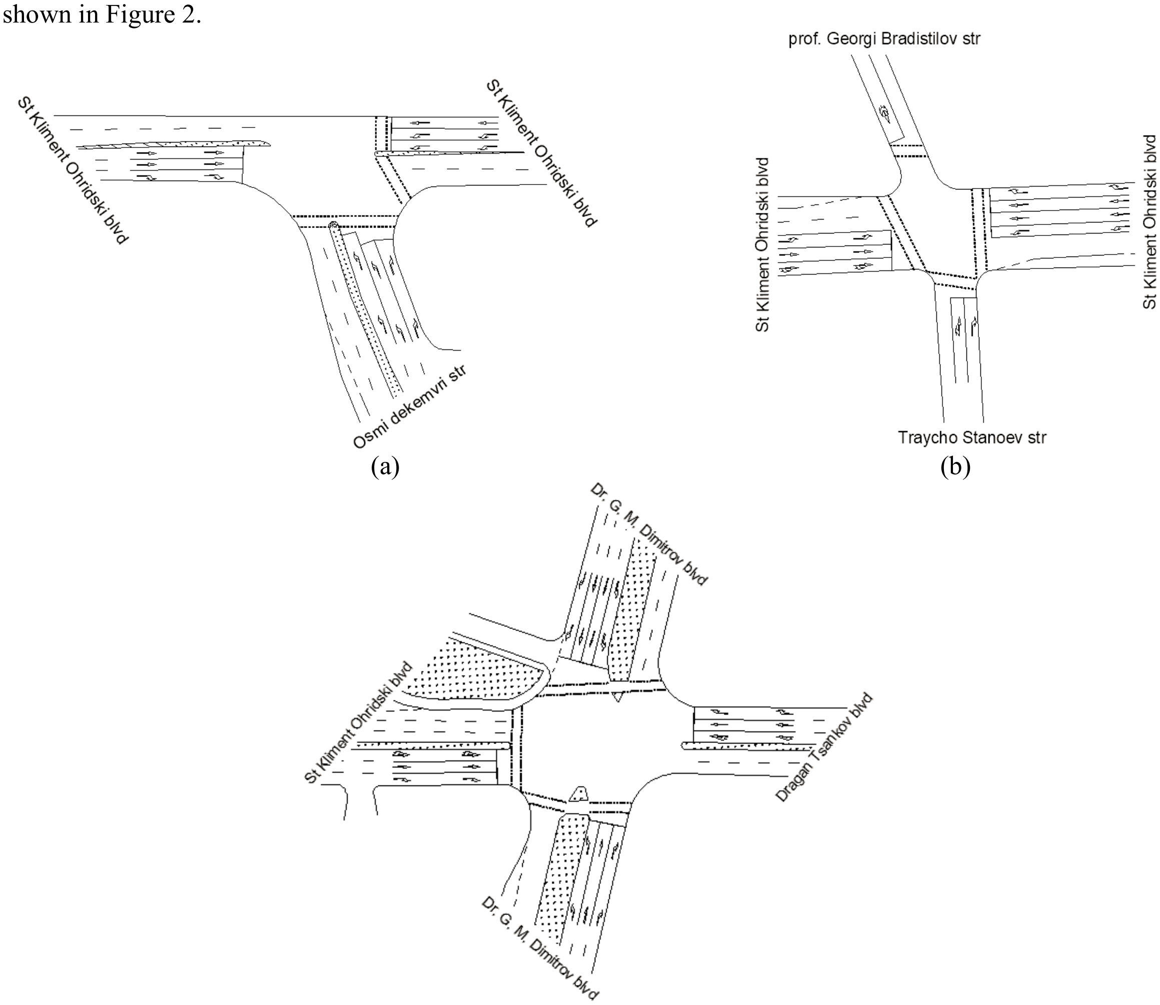

FIGURE 2. Scheme of junctions – (a) – junction “1”, (b) – junction “2”, (c) – junction “3”

The research include determine the distance in junction for every traffic flows entering in the junctions and time to pass the distance from first entering vehicle of the arriving flows of a stage. Curves radii of turning flows also were measured for the purpose of the study. The data were obtained by hand measurement from video captured whit unmanned aerial vehicle known as a drone.

Obtained data apart from needed of intergreen time determination may be useful for researches about intelligent and smart cities for which there are works of researchers presented by Dimitrov and Valkovski in [16], Dimitrov and Velchev in [17], Miletiev and etc. in [18]. Also this data and that of similar measurements can be used in developments related to vehicle acceleration in deferent condition which is presented by Zhilevski and Hristov in [19].

RESULTS AND DISCUSSION

For the purpose of the study traffic flows of each junction were indicated as shown in Figure 3 for junction “1”, Figure 4 for junction “2” and Figure 5 for junction “3”.

The needed data about distance junction which first entering vehicle passed, average time to pass the distance by flows, curves radii and result about average and minimum time to pass and computed vehicle acceleration of each junction were presented in Table 1 for junction “1”, in Table 2 for junction “2” and in Table 3 for junction “3”.

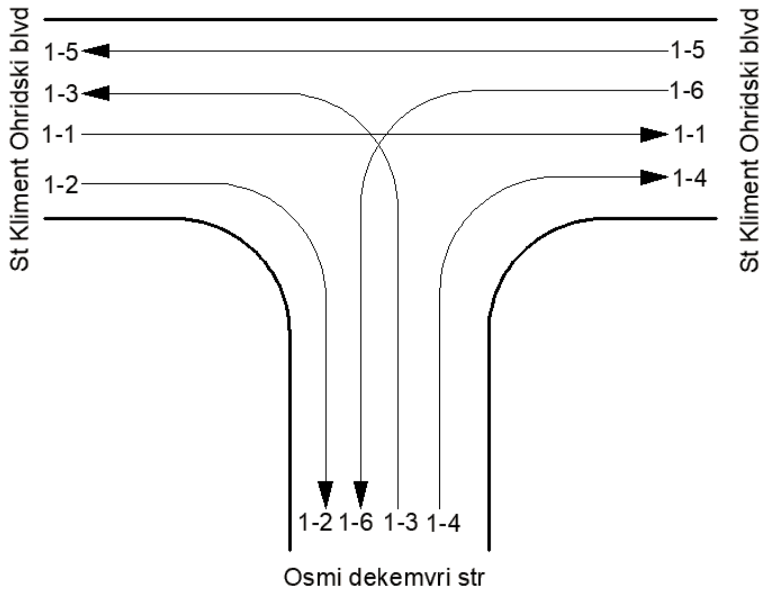

FIGURE 3. Traffic flows indication at junction “1”.

TABLE 1. Needed data and obtained results for junction “1”.

Traffic flows	Passed distances, m	Turning radii, m	Data of first entering vehicle			
			t_{av}, s	t_{min}, s	a_{av}, ms^{-2}	a_{max}, ms^{-2}
1-1	45	-	6.56	5.25	2.16	2.37
1-2	20	14	5.36	4.11	1.50	3.27
1-3	40/31	37/33	6.82	5.35	1.60	1.95
1-4	17	12	6.60	4.18	0.93	2.64
1-5	30	-	5.52	4.52	2.09	2.94
1-6	40/30	18/16	6.60	4.78	1.75	2.63

As shown Table 1 the traffic flows 1-3 and 1-6 have two turning radii because of that the flows turning from tow lines. Preliminary measurements of passing time for first entering vehicle of these flows showed that they had not big differences. Therefore their result by the flows were pooled.

The result analysis shows that the right turning flow 1-2 have different values of more than 60 % of average and more than 20% of maximum values of the other one right turning flow 1-4. It can be explain by the different turning radii.

It gives an impression that the other flows according to their direction there are not significant differences regardless of presence of slope and different radii which of traffic flow 1-3 are twice bigger than these of flow 1-6. It is also interesting that the observed time of vehicles are approximately equal independently from the others factors (distances, curves radii, road slope).

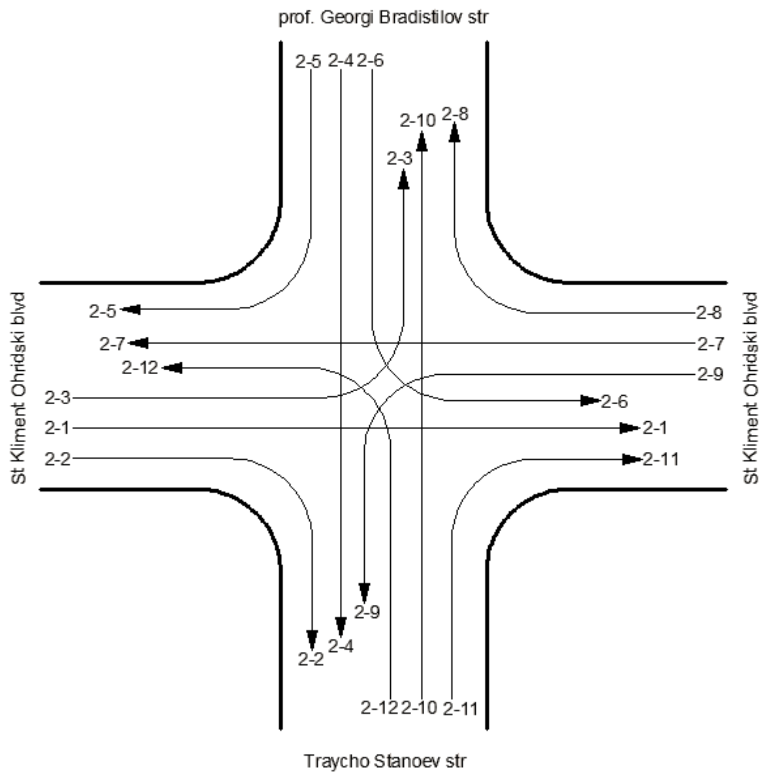

FIGURE 4. Traffic flows indication at junction “2”.

TABLE 2. Needed data and obtained results for junction “2”.

Traffic flows	Passed distances, m	Turning radii, m	Data of first entering vehicle			
			t_{av}, s	t_{min}, s	a_{av}, ms^{-2}	a_{max}, ms^{-2}
2-1	22	-	4.54	3.13	2.43	4.49
2-2	13	6	3.39	3.39	2.26	2.26
2-3	25	15	5.13	4.29	2.01	2.72
2-4	37	-	6.38	5.34	2.01	2.60
2-5	18	7	6.33	4.33	1.10	1.92
2-6	36	25	7.83	6.66	1.24	1.62
2-7	25	-	4.91	3.11	2.24	5.17
2-8	22	10	5.74	4.11	1.44	2.60
2-9	16	15	4.66	3.27	1.61	2.99
2-10	38	-	7.01	5.76	1.66	2.29
2-11	9	6	2.77	2.31	2.44	3.37
2-12	28	15	9.54	3.68	1.10	4.14

Results about junction “2” show that the straight ahead flows had approximately the same values for average and maximum acceleration of opposite flows exception of which makes vehicles of traffic flow 2-10. It have smaller value more than 20% from others. It can be explained with uphill slope that flows overcomes. That is also true for the left turning flow 2-12 which entering from the same approach. Flow 2-3 and flow 2-9 turn in the same condition but value of 2-9 is 20% smaller than 2-3. This may be due to the way the drivers perceive the situation entering from its approach.

The right turning flow are in the same rate expect the flow 2-11 which stands out with a significantly higher value than the others. Differences is more than 70%. Traffic flow 2-2 have the equal values for average and maximum acceleration. The reason of this is that one vehicle was detected during the measurement and its value cannot be taken in account.

It can be seen that the acceleration rate depend on distances and values decrease with increasing distance value especially in combination with the change of curves radii. For example flow 2-11 and 2-2 have small radii and distance and respectively high acceleration rate. Flows 2-6 and 2-12 have more than twice bigger distances and curves radii than 2-11 and 2-2 and respectively twice smaller acceleration rate than those of others.

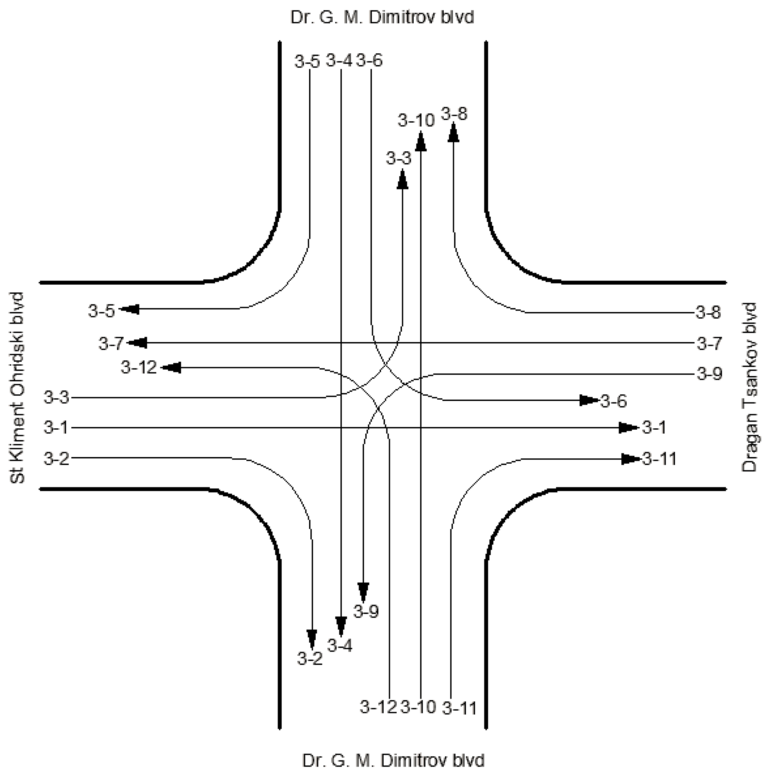

FIGURE 5. Traffic flows indication at junction "3".

TABLE 3. Needed data and obtained results for junction "3".

Traffic flows	Passed distances, m	Turning radii, m	Data of first entering vehicle			
			t_{av}, s	t_{min}, s	a_{av}, ms^{-2}	a_{max}, ms^{-2}
3-1	48	-	6.82	5.13	2.21	3.65
3-2	12	10	5.12	3.25	1.12	2.27
3-3	50	37	7.24	6.55	1.99	2.33
3-4	41	-	6.41	5.16	2.08	3.08
3-5	21	16	5.47	4.41	1.56	2.16
3-6	38	30	6.73	5.99	1.72	2.12
3-7	50	-	7.67	4.98	1.82	4.03
3-8	14	14	4.73	3.91	1.35	1.83
3-9	48	38	7.80	6.63	1.61	2.18
3-10	40	-	5.95	4.38	2.41	4.17
3-11	23	16	4.73	3.66	2.16	3.43
3-12	37	26	6.94	5.46	1.60	2.48

Shown results in Table 3 make clearly view of that the average acceleration value of straight ahead flows are not much different from each other (about 2.2 ms^{-2}). The only exceptions is a flow 3-7 which starting under uphill slope conditions. It makes an impressions that the maximum value of this flow is approximately equal to other straight flows. This point out that there are vehicles which have the same behavior as vehicles from other straight ahead flows which fact must be taken under considerations in intergreen time determination.

Analysis shows that the right one of the right turning flows (3-11) have an average acceleration rate as straight ahead flows and this is not from reasons related with distances, curves radii and other of reported data for this study.

The reason for this can be found in the lack of conflict with pedestrian traffic which is true only for that right turning flow. About other – left turning flows there are not extremely differences of their value. Their values of average acceleration are closed to the straight ahead flows. This can explained of similar values of distances, time to be passed from firs entering vehicles and despite of road slope at the junction. This not does apply for the maximum values. For left turning flows they are smaller more than 40% which indicates relation between drivers behavior when they start straight and cornering.

Analysis shows that maximum acceleration rate obtained for the three junction are bigger about 40% in most cases than average one. It have a situation for more than once bigger maximum value from average. That is very important and must be taken in account for entrance time compute of intergreen time determination.

CONCLUSION

Presented in this paper research has given results about average and maximum vehicle acceleration rate that covered at three signalized junction in Sofia city. The aim of the study was to obtained real data of this vehicle parameter which is important to compute entrance time of first entering vehicle of the next phase a part of intergreen time determination.

Obtained results show that the acceleration of vehicle depends mainly of road slope with some exceptions that are tied to the specific traffic conditions. In some cases, especially on right turning, acceleration depended on curves radii which with combination with slope of the road can be have a seriously impact of entering time. The same can be said of impact of conflict with pedestrian flows.

Authors recommended to be used obtained data for vehicle acceleration rate for every crossroads which requires traffic light regulation, respectively intergreen time determination. In other cases can be used acceleration rate obtained on the basis of this study between 2.5 ms^{-2} and 3.0 ms^{-2}. Conclusion to these values are strongly defined by evaluation of determined factors of impact – distance to pass of first entering vehicle, curves radii and road slope. In every state of compute intergreen time the specialists must taking into account the specifically traffic conditions.

ACKNOWLEDGMENTS

The authors would like to thank the Department of combustion engines, automobile engineering and transport at the Technical University of Sofia for the financial support.

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