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Determination of the Minimum Time of the Permission Signal of Traffic Lights at Intersections

Razzoqov Mashrab Ro'zievich
MIA DPS RSS, head of the center for the study of road safety problems
Ikromov Akmaljon G'ofurjonovich
MIA DPS RSS, Chief Specialist of the Center for the Study of Traffic Safety Problems

Abstract. This article presents a number of reasons for the traffic capacity of the intersection at the moment, which is based on the behavior of the vehicle when passing through the intersection and the time interval required to turn on the traffic light.

Key words: traffic intensity, traffic light cycle, intersection, driver, pedestrian, traffic rules.

The throughput capacity of the intersection depends not only on its geometry, but also on the width of the intersecting roads (the number of its lanes), the direction of movement (direct crossing or turning), the stop line relative to the beginning of the intersection. ini location also depends on the duration of the traffic light enabling signal.

Developed models of delays of vehicles at intersections provide a sufficient overview of various control periods - their arrival and departure speeds, entry to the intersection for queue formation, and the behavior of vehicles at the intersection. The purpose of the study is to justify the behavior of the vehicle when passing through the intersection and the time interval required to turn on the traffic light.

Let's look at the behavior of one car that is first in line in front of the parking line. When the green signal of the traffic light lights up, it starts moving along the intersection, which includes two stages - the acceleration stage (starting, increasing speed) and the main stage (the same movement at the fixed speed). It is assumed that there are no other obstacles at the intersection (narrowing of the road, bypassing the repair site, etc.).

The main equation of the transport flow is the ratio between the speed of movement V, the acceleration q and the flow density r:

$q = V\rho$

where r is the density of traffic flow, that is, the number of cars per unit length of a road section that is homogeneous in terms of transport and operational characteristics, usually 1 km;

q is traffic intensity, that is, the number of vehicles that pass through a part of the road per unit of time, usually per second, minute, hour, or day.

Thus, the higher the density of the traffic flow and the lower its intensity, the lower the overall speed will be correspondingly. This leads to traffic delays and traffic jams on the roads. If traffic jams occur due to natural causes (the density of cars on the road exceeds its carrying capacity) and are mainly observed during rush hours, the traffic light is often an artificial barrier that works around the clock.

It is known that the work cycle of the traffic light consists of three stages: a permissive signal (green), a warning (yellow) and a prohibitive (red). If the traffic light signal changes frequently, for example, green and red are changed within 15-20 seconds, then cars move only in the acceleration phase, i.e. at low speed, in this mode, the throughput of the intersection is low.

The maximum intensity of traffic at the intersection is reached at a speed of 60 km/h (allowed for urban conditions), that is, after the acceleration mode, the car passes the intersection at a high traffic speed.

The duration of this phase is limited only by the operation mode of the traffic light - signals change frequently during rush hour (approximately 2-4 minutes in each direction on roads with 3-4 lanes and 0.5-2 minutes on intersections with 1-2 lanes minute), where the transition time is determined in proportion to the number of lanes on the intersecting roads, at other times the

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traffic lights change less often or switch to a yellow flashing signal. In intelligent traffic light systems, the permissive signal is determined based on the queue at the intersection - if it is absent or small, then the permissive phase is continued. If its duration is large, the number of vehicles passing through the intersection in the right direction will be greater. At the same time, the minimum time of the green traffic light at any time of the day and in any queue should be determined by the mode of acceleration of the vehicle and the duration of the main phase. Therefore, it is necessary to determine the minimum duration of the green signal in the working cycle of the traffic light. When calculating traffic flow regulation at intersections, the state vector of the vehicle is set as follows:

$S_{TC} = (V, a, t, x)$,

where V is the speed of the car;

a – acceleration;

t – length of stay in STC conditions;

x is the coordinate of the car on the road.

The value of acceleration is constant when vehicles pass through the intersection with acceleration. In this case, the movement of vehicles in the area of the intersection is characterized by certain relationships:

$V(t) = V_0 + at$ (1.1)

$x(t) = x_0 + V_0 \cdot t + a \cdot t^2/2$ (1.2)

where V(t) is the speed of the vehicle at time t;

x(t) is the distance traveled by the vehicle at time t;

V_0 - initial speed; a – acceleration;

t - crossing time; x_0 is the initial path.

Any linear marking system can be taken for account, for example, 4 strips 3 meters wide, two strips in each direction

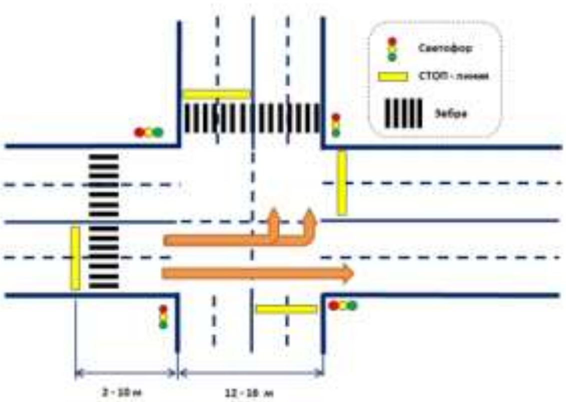

Figure 1. Intersection crossing scheme

The number of lanes is not important, but non-central city highways with such a configuration make up a significant part in Uzbekistan. The width of the pedestrian crossing (zebra) varies from 2 to 6 meters. The distance from the stop line to the beginning of the intersection is from 1 to 10 meters, we take it as 6 meters.

Thus, in order to completely cross the intersection, when moving with a right or left turn, the car must travel 18 meters.

The selection of the acceleration value is based on the following rules.

According to the technical characteristics of popular passenger cars, the car accelerates from 0 to 100 km/h from 4.0 s (Ferrari, Lamborghini) to 18.2 s (OpelCorsa), the average acceleration time is 15.75 s , the acceleration value changes from 25.0 to 5.49 m/s2, respectively

According to experts, this indicator has only psychological meaning, and in practice, a car with high initial parameters (Mazda) will be overtaken by a car (Kia) with a large acceleration time up to 100 km/h . The driver independently chooses the maximum acceleration, for example, when overtaking.

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Usually, starting from the stop line, after starting, the driver will gradually increase the pressure of the gas pedal, not suddenly, and thus ensure that the acceleration value of the car is uniform until the end. Therefore, it is considered permanent. If we take the acceleration of the vehicle movement to be sufficiently large - a = 15 m/s2 = const, then at each step of increasing the time, the speed of the vehicle at the next position of the intersection will gradually increase based on the linear law.

Table 1 shows the data calculated for functions (1) and (2): when one vehicle moves through the intersection from the beginning of the stop lane to the end of the intersection and then in the discrete state. time t = 0.2 s.

In Table 1, the data calculated by functions (1) and (2) are the movement of one vehicle from the beginning of the stop lane to the end of the intersection zone and beyond t = 0.2 s. given by the time discreteness.

Table 1.
Condition of vehicles

t, s	**a, m/s²**	**V(t), km/hour**	**x(t), m**	**q(t), avt/s**
0	15	0	0	0,0
0,2	15	3	0,6	1,4
0,4	15	6	1,8	2,8
0,6	15	9	3,6	4,1
0,8	15	12	6,0	5,5
1	15	15	9,3	6,9
1,2	15	18	12,6	8,3
1,4	15	21	16,8	9,7
1,6	15	24	21,6	11,1
1,8	15	27	27,0	12,5
2	15	30	33,0	13,9
2,2	15	33	39,6	15,3
2,4	15	36	46,8	16,7
2,6	15	39	54,6	18,1
2,8	15	42	63,0	19,5
3	15	45	72,0	20,8
3,2	15	48	81,6	22,2
3,4	15	51	91,8	23,6
3,6	15	54	102,6	25,1
3,8	15	57	114,0	26,4
4	**15**	**60**	**126,0**	**27,8**
4,2	15	60	138,6	27,8
...	...	...	...	...
6,4	15	60	277,2	27,8

Table 1 shows that the first car crosses the intersection in 1.5 seconds and reaches a speed of 22 km/h. The average speed of crossing the intersection is 40-45 km per hour.

According to the calculated data of the acceleration phase and the main phase, the graph of the change of the speed and amount of movement of the first car in the queue of the stop line is presented in Figure 2.

From Figure 2 (up to the ring line), during acceleration with constant acceleration, the speed of the vehicle increases linearly, and the distance traveled by the car increases in degrees, that is,

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the higher the speed of the vehicle, the more time per unit of time, respectively goes most of the way.

Thus, the car reaches a speed of 60 km/h in 4 seconds, covering a distance of 126 m from the beginning of the stop line to the end of the intersection (such wide intersections are rare, mainly on the central highways of large cities). The average length of a passenger car is 4 meters, the distance between cars in the queue is intuitively chosen to be about 2 m, so the distance for the acceleration mode for the second vehicle increases by 6 m, and for the third - by 12 m.

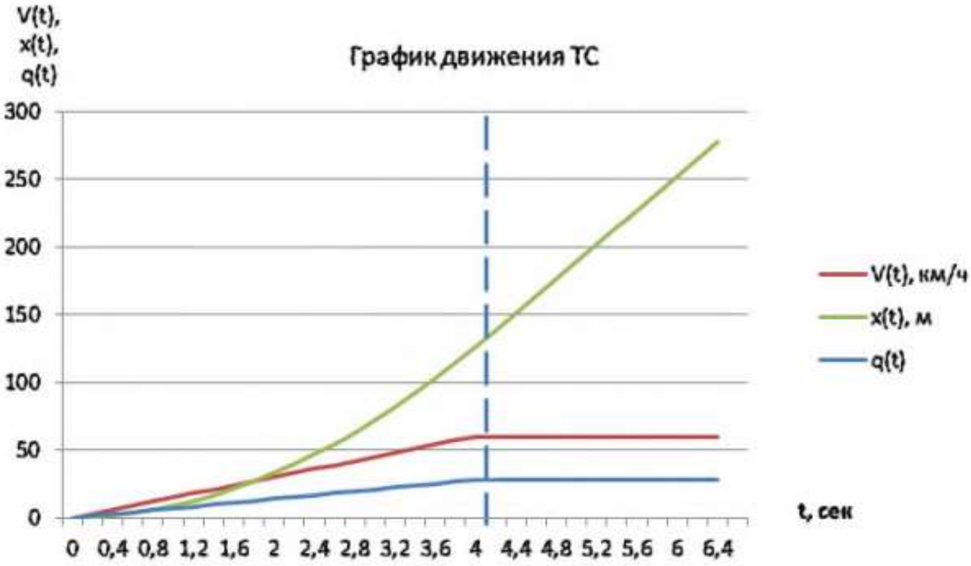

Figure 2. Acceleration and main phase of the car

Since the acceleration area is 126 m, the acceleration phase ends for car 21 (126 m / 6 m) when passing the intersection, which crosses the intersection at a speed of 60 km/h. Car 22 enters the stop lane and intersection at a speed of 60 km/h in the main phase.

The minimum time of the traffic light's permissive signal for car 22 (for the given data) is 4 s in the acceleration phase and the time of crossing the intersection in the main phase. During this time, 22 cars pass through it. The minimum time for an acceleration of a = 10 m/s2 is 6 s. is

The intensity of movement of vehicles at the intersection depends on their speed and number, which is determined by the following relationship

$q = V\rho$

where r is the density of traffic flow, that is, the number of cars per unit length of a road section that is homogeneous in terms of transport and operational characteristics, usually 1 km;

q is traffic intensity, that is, the number of vehicles that pass through a part of the road per unit of time, usually per second, minute, hour, or day.

After the ring line in Figure 2, the state of the vehicle in the main phase is shown.

At the main stage, when the vehicle is moving at a speed of 60 km/h, the traffic flow density r 1000 m / 6 m = 167 cars for a 1 km long queue, the traffic intensity q is 60 km/h * 167 cars. = 10,000 cars or 27-28 cars per second. During acceleration, the intensity gradually increases from 0 to 28 av/s.

When the accepted length of the intersection from the stop lane to the end of the crossing is 18 m, the first car (Table 1) manages to pass it in 1.5 seconds, and about 22 km /h reaches a speed that corresponds to an intensity of about 10.4 av/s. The acceleration path of the second car is 6 m longer, so at the exit speed of 25.5 km/s for 1.7 s, it provides an intensity of about 11.8 av/s, for the third car q reaches 13.2 av/s . Car 22 enters the intersection at a speed of 60 km/h and the traffic intensity is equal to 28 av/s.

These rules apply to the turn of a vehicle located in one lane of the road in front of the stop line of the intersection.

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For each lane of multi-lane roads, the rules discussed above apply, that is, a car reaches 60 km/h in 4 seconds, by which time the car has traveled 126 m, which is greater than the length of any intersection , that is, the main part of the queue (up to the 22nd car) crosses the intersection in the acceleration phase. All parameters (speed, acceleration, distance traveled, traffic intensity) are valid for any lane, but the total traffic intensity of the intersection with all queues is directly proportional to the number of lanes.

Thus, the intensity of two-lane roads increases by 2 times - up to 56 v/s, three-lane - by 3 times, up to 84 v/s, but they all move in the acceleration phase. The intensity of traffic at the intersection increases, but the average speed in all lanes remains the same as in one lane.

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