Study of the influence of the driver’s reaction time on the road traffic situation at a controlled intersection using simulation modeling

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Abstract. The role of the human factor in ensuring safe intensification of road traffic is great. This can be achieved with good traffic management and a sharp reduction in motor vehicle collisions (MVC). Nowadays, in countries with a high level of motorization, MVCs lead to great amount of deaths and material losses. This happens because, no matter how reliable the vehicles, roads, and traffic rules, the outcome of the MVC in the vast majority of cases depends on the actions of the driver. The continuing rapid growth of the fleet leads to an increase in the intensity of traffic flows, which imposes ever-increasing demands on drivers. Therefore, improving the reliability of drivers becomes an urgent task, without the resolution of which it is impossible to achieve a significant reduction in MVC and improve traffic safety. The information obtained in the process of studying the patterns of perception by a driver of a road stop will help to solve this problem; therefore, this work is devoted to the urgent topic of the analysis of the influence of the driver’s reaction time on traffic safety and traffic capacity of the road network and is performed using the simulation method.

1. Introduction
Safe traffic on roads is determined by many factors: compliance with traffic rules, mutual respect of drivers, pedestrian behavior when crossing highways. One of the main conditions for trouble-free transport movement is the response time of the driver.

The following factors affect the response of the driver and his perception of a dangerous situation:

1. Gender - men who drive a vehicle respond more quickly to the appearance of a danger signal, the response time for them is 1.8 seconds, and for women - 2.8 seconds. However, they perceive a simple situation almost the same way.

2. Age - for car owners whose age does not exceed 30 years, the perception of a dangerous situation occurs quicker than for drivers from 40 years and above. But older people make the right decisions faster, and their reaction time is stable. To solve a simple situation, a young motorist needs 0.17 sec., for a complex one - 1.54 sec. By the age of 60, the indicators change: for a simple situation - 0.26 sec., for a complex - 2.05 sec.
3. Experience - in the event of an emergency on the road you can always see an experienced driver. He does not panic and does not fuss, his actions are quick and accurate.

4. Physical training - sports aimed at developing reaction and endurance help drivers to perceive a dangerous situation faster and choose the right strategic actions.

5. Workplace - a combination of little things that can distract a motorist (an uncomfortable seat, stuffiness in the cab, loose doors, improperly installed cargo in the trunk, noisy passengers) increase the reaction time.

6. Time of day - a person’s biological clock is set so that at night there is a decrease in concentration, he often wants to sleep. At night, the period of perception increases by 20-25%. The predawn hours and time before sunset are also difficult for the driver. Therefore, he reacts longer even to a simple traffic situation, and this can lead to MVC.

7. Weather conditions - rain, snow, fog, icing of the road complicate driving, increase the reaction speed of the driver.

8. Medications - there is a large list of medicines that can not be taken if you plan to drive. These may be the most common medications that relieve pain symptoms that help with colds.

9. Alcohol - it's no secret that alcohol and car driving are incompatible concepts. The responsible driver will not allow himself to drink alcohol on the eve of the trip. Most of the MVC occurs because alcohol reduces the concentration of attention, narrows the vision, inhibits motor reflexes. The time to prevent MVC is increased several times.

10. Working conditions - oddly enough, it is easier for the driver to respond to a danger signal within the city than on suburban routes. The monotonous road relaxes and reduces the level of attentiveness, as a result, the motorist incorrectly assesses the situation [1].

11. We should also note the use of gadgets, which despite the prohibition of their use while driving, still take a lot of driver’s attention.

12. Most often, it is the speed of decision that prevents MVCs on the road. An important role is played by the time period during which the driver manages to take the necessary actions. In the paper, we consider traffic situations in details taking into account the reaction time of drivers that occurs in the zone of influence of traffic control.

2. The main part

Given the complexity of determining traffic conditions, due to the large number of influencing factors, the study used the method of simulation of traffic flows, allowing:

- to take into account any combination of road conditions, the availability of means of traffic management, as well as the whole variety of situations that arise when traffic flows;
- significantly reduce the duration of the study and the preparation of practical measures to improve traffic conditions;
- establish the main characteristics of traffic flows and give them a quantitative and qualitative assessment, as well as clarify the formulation of analytical problems and verify the reliability of analytical dependencies [2].

AIMSUN specialized program, a microscopic model for simulating the movement of vehicles, was used to simulate the conditions of automobile traffic flows taking into account the reaction time of the driver and the subsequent assessment of the traffic situation. Models of this class allows to describe in detail the behavior of each of the road users.

The object of the study is the intersection of six-lane main streets of citywide significance with allocated lanes for public transport and dividing lanes with traffic lights (Figure 1).
Figure 1. Intersection of main streets of citywide significance with allocated lanes for public transport.

The work of traffic lights at an intersection with a cycle time of 90 seconds is shown in Figure 2. First and second phases are equal to 39 seconds with an intermediate cycle of 6 seconds of which 3 seconds are a yellow signal.

Figure 2. Traffic lights at the intersection of the main streets of citywide significance with highlighted lanes.
Table 1. Intersection traffic intensity matrix.

|       | East  | West  | North | South | Total |
|-------|-------|-------|-------|-------|-------|
| East  | 900   | 200   | 100   | 1200  |       |
| West  | 900   | 100   | 200   | 1200  |       |
| North | 100   | 200   | 900   | 1200  |       |
| South | 200   | 100   | 900   | 1200  |       |
| Total | 1200  | 1200  | 1200  | 1200  | 4800  |

To conduct an experiment to determine traffic conditions, 6 values of the reaction time of drivers ($t_{pv}$) were allocated: 0.5; 1.0; 1.5; 2.0; 2.5; 3.0 sec. The values of motion parameters obtained during simulation are presented in table 2.

Table 2. The results of simulation.

| Movement parameters \ $t_{pv}$ | 0.5   | 1.0   | 1.5   | 2.0   | 2.5   | 3.0   |
|-------------------------------|-------|-------|-------|-------|-------|-------|
| Travel time, sec/km           | 206.62| 205.34| 307.22| 381.29| 461.64| 476.19|
| Delay time, sec/km            | 136.83| 146.39| 248.15| 322.15| 401.98| 416.26|
| Stop time, sec                | 116.55| 122.2 | 215.82| 286.95| 364.05| 376.92|
| Total travel time, h          | 67.03 | 66.63 | 98.5  | 117.13| 130.75| 124.88|
| Total traveled distance, km   | 1165.96| 1166.07| 1152.73| 1103.46| 1019.94| 943.2 |
| Number of stops, #/vehicles/km| 3.95  | 4.04  | 5.62  | 6.33  | 7.37  | 7.8   |
| Density, vehicles/km          | 18.39 | 18.27 | 27.24 | 33.22 | 36.31 | 34.95 |
| Capacity, vehicles/h          | 4876  | 4877  | 4820  | 4614  | 4265  | 3945  |
| Speed, km/h                   | 25.02 | 26.8  | 18.77 | 13.36 | 10.1  | 9.32  |

Indicators of delay time, density, speed and traffic capacity with increasing driver response time from 0.5 to 3.0 seconds are shown in Figure 3.

Figure 3. Charts of delay time, density, capacity, speed.

The delay time increased by 204%, the density increased by 90%, the speed decreased by 63%, the capacity decreased by 19%.
3. Conclusion

According to the results of the comparative analysis, it is clear that the reaction time of the driver has a significant impact on the road traffic situation at the regulated intersection of main streets. A study of the perception of the driver of the road situation shows that there are quite large reserves in solving the problem of ensuring road safety. This is, first of all, an increase in knowledge in the norms and methods of road design due to relying not only on the stability of the car against skidding and rollover, but also on the psychophysiological capabilities of the driver.

Rationing the parameters of roads is a technical and economic task and the success of its solution depends on the perfection of the methods of economic calculations and the availability of indicators that take into account both direct costs during the construction of the road and the costs associated with the subsequent operation of the road, accident rate on it and the convenience of drivers and passenger movements. The road is the place of work of thousands of people, and the working conditions on it should not only be safe, but also convenient. The information obtained in the process of studying the patterns of perception by the driver of the road situation will help solve this problem.

There are two ways of use of the listed facts. The first is the development of methods to assess, taking into account the created road conditions, the reliability and convenience of drivers and, if necessary, make adjustments to design decisions. The second way is to improve the norms and methods of road design, the use of which eliminates the creation of visually obscure roads that are uncomfortable or dangerous for traffic. Both of these paths do not exclude, but complement each other.

Further development of science and improvement of the practice of road design and traffic management require the expansion of knowledge about the driver, his reactions, his capabilities as an operator of a complex system. To ensure the reliability of drivers, a high level of professional skills and good psychophysiological training are required. An individual approach to training can be of great help in the formation of such qualities, taking into account the psychological characteristics of the trainees. The introduction of psychological selection and the improvement of medical control over the condition of drivers before the trip and on the road can contribute to increasing the reliability of drivers.

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