Influence of the Speed of Motion of Public Motor Transport and the Time of the Green Signal of the Light Traffic on the Formation of Their Transport Flow

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Abstract. The optimal traffic flow of public transport through a controlled intersection can be achieved by taking into account its speed and the time of the green traffic light. Regularities of the influence of the green traffic light period on the number of public transport passing through the intersection, the acceleration time of public transport on its speed, the green light duration on a distance that public transport can cover, and the distance covered by public transport on the passing time are revealed. The results of the study suggest that there are reserves for increasing traffic flow by controlling the high-speed mode of public transport and taking into account the operating time of a traffic light object.

1. Introduction

The main factor in the growth and development of the country is the transport system. In the largest cities of Russia and developing countries, due to the increasing growth rate of motorization, a serious problem arose in the transport system [13]. Buses are the predominant form of public transport. The effectiveness of the public transport system can be determined by the efficiency of the bus system and the number of potential passengers [7]. The use of private cars increases the overall traffic flow on the road network, which leads to congestion. In addition, private cars are loaded, at best, only by 50%, that is, 1-2 people per car, including the driver, while the bus fits ten times more people [15]. The optimal traffic flow of public vehicles through a controlled intersection can be achieved by taking into account its speed and the duration of the green traffic light. The topic of this study is relevant because it can increase the attractiveness of public transport and thereby partially solve the problem of the transport system in the big cities.

2. Literature review

The influence of the speed of public vehicles and the duration of the green traffic light on the formation of their traffic flow largely depends on the characteristics of the road network, in particular, on the location of the stopping points.

Ceder [2] proposes improving accessibility to bus stops on the grounds that passengers should not experience inconvenience. Bowerman et al. [1] developed a real model for the distribution of passengers by stops and calculated the best distance between stops, taking into account the reduced distance between them and the distance the passengers walk to them. El-Shair [6] proposed calculating the best distance between stops using a geographic information system (GIS) and data analysis,
suggesting that the distance between bus stops would be satisfactory if more than 80% of buildings and structures that are residential or commercial are located within a radius of 300 m from bus stops.

Vuchic and Newell [20] obtained a model for minimizing travel time, route length and number of stops. Fernandez and Planzer [8, 9] studied the capacity of bus systems and showed that buses spend a lot of time at stops, opening and closing doors.

Kazhaev et al. [14] argue that conflict situations at stopping points depend on the route configuration and parameters of the road network, and their number is in inverse proportion to the number of combined intervals for routing through stopping points and their throughput.

Shepelev et al. [16] determined that the duration of the traffic light resolving signal has the greatest influence on the traffic capacity of the intersection. In [18], the mutual influence of two generalized categories of transport standing in line in front of the stop line at the intersection was studied. In [17], the dependence of the location of the stop lines on the actual speed of the traffic flow crossing the intersection was examined and the degree of influence that the speed of vehicles entering the intersection and the acceleration of vehicles starting at a green traffic light have on traffic safety were determined.

Dell'Olio et al. [5] created a model based on optimization of the bus arrival time and the distance between stops simultaneously in real cases. Furth and Rahbee [10], using a combination of data related to the bus system and GIS, presented a model to minimize arrival time. They calculated the optimal distance by evaluating availability, operating costs and trip costs. Ghasemlou et al. [11] compared the models of the delay time in the conditions of a heavy traffic flow at controlled intersections and found that the optimization of the delay in the way provides the best fuel economy.

Chakroborty et al. [3, 4] used a binary search algorithm to find a solution to the schedule problem for buses at stops, trying to reduce transportation time, taking into account the total travel time and passenger waiting time at a stop.

3. Methods and results

The aim of the study is the formation of such a traffic flow of public vehicles, the speed of which is optimized and is directly dependent on the duration of the green traffic light. The objectives of the study are to identify regularities in the influence of the green light duration on the number of public vehicles passing through the intersection and the distance traveled, the time of acceleration of public transport on its speed, the distance traveled by public transport on the passing time, taking into account different average speeds.

To justify the formation of the public transport flow in the largest cities of Russia with a population of over 1 million on the example of the city of Chelyabinsk, we accept the following conditions:

1. The considered section of the road network is Lenin Avenue, taking into account the possible allocation of a separate lane for public transport.
2. The minimum distance from a stop point to a regulated intersection is 60 m, and the maximum distance is 480 m, according to Yandex.Maps.
3. The total cycle time of the traffic light object is 100 s, while the green signal time is 58 s, according to the time diagram of the traffic light.
4. The rolling stock of public transport in Chelyabinsk includes MAZ 203.945 and LiAZ 5292.67 buses, the theoretical acceleration of which is on average 0.583 m/s², taking into account their technical characteristics, and the actual acceleration according to experimental data [12] is 0.335 m/s².
5. The bus crosses the controlled intersection on average for 31 s while the first 6 vehicles waiting in line in front of the stop line add 2 s, and the next ones 1.5 s each to the total passing time, according to observations.

To determine the pattern of the influence of the green light time on the number of public vehicles passing through the intersection, 2 options were adopted. The first option assumes that the first 6 buses add 2 s each, and the rest 1.5 s each for the total intersection time, and the second option assumes that all buses add 2 s. The average bus passing time was taken to be 31 s, and the green traffic light time was taken to be 58 s (Fig. 1).
Figure 1. The pattern of the influence of the green traffic light time on the number of public vehicles passed through the intersection.

The change in the number of public transport passing through the crossroads from the time of the green traffic light is both exponential and linear. The exponential nature shows the changes for the first option, while the number of public transport traveled will be 22 vehicles. The linear character shows the changes for the second option, while the number of the public transport that traveled will be 17 vehicles. This circumstance must be taken into account when organizing the flow of public transport vehicles.

To determine the regularity of the effect of the public vehicle acceleration time on its speed, the following conditions were accepted. The distance from the stopping point to the regulated intersection was on average equal to 270 m, and the duration of the green light signal was 58 s (Fig. 2).

Figure 2. The pattern of the influence of the public transport acceleration time on its speed.

The character of the effect of the public transport acceleration time on its speed has a linear relationship, while the peaks for reaching the maximum safe speed [19] of 50 km/h are different. With the public transport acceleration of 0.583 m/s², the maximum safe speed of 50 km/h is achieved in 24 s, and when acceleration is 0.335 m/s², in 42 s. The difference between the theoretical and experimental time to reach the maximum safe speed of 50 km/h was 18 s, which indicates that there is a reserve for increasing the flow of public transport vehicles.

To determine the pattern of the influence of the green light time on the distance that public transport can pass with various accelerations, we assume that the theoretical acceleration is 0.583 m/s², and the experimental one is 0.335 m/s², and the green light time is 58 s (Fig. 3).
The influence of the green light time on the distance that public transport can cover is of an exponential character. The dependences show that public transport will travel 981 m and 563 m in 58 s with accelerations of 0.583 m/s$^2$ and 0.335 m/s$^2$, respectively. The difference in distance traveled by public transport is 418 m, which indicates a great potential that can be used with the appropriate organization of its traffic flow.

To detect the regularity of the influence of the distance traveled by public transport on its passing time at various average speeds, we used three average speeds (10, 20, and 30 km/h), the average distance from a stop to a regulated intersection 270 m, and the time of a green traffic light 58 s (Fig. 4).

The influence of the distance covered by public transport on the time it is covered at various average speeds is linear. It should be noted that at speeds of 20 and 30 km/h, the time to pass 270 m by public transport differs by 16.2 s, and at speeds of 10 and 20 km/h by 48.6 s. At 10 km/h, the passing time is not enough, since it is 97.2 s, which is 1.67 times longer than the time of the green traffic light. At 20 km/h, the passing time of 270 m will be 48.6 s, which is within the green traffic light period, but under real conditions, if traffic hindrance occurs, this speed will not be enough. The best option for passing 270 m by public transport is an average speed of 30 km/h, as in this case it has a time reserve of 25.6 s.

4. Conclusion
Based on theoretical studies of the influence of the public vehicle speed and the green traffic light time on the formation of the traffic flow, the following was established:
1. The number of public vehicles passing through the intersection from the time of the green light to the end, based on theoretical and experimental data, depending on the speed, is 22 and 17 vehicles, respectively, which indicates the possibility of increasing traffic flow.

2. The difference between the theoretical and experimental time to reach the maximum safe speed of 50 km/h was 18 s, which indicates the possibility of increasing the flow of public transport.

3. The dependence of the influence of the green traffic light time on the distance that public transport can cover shows that with accelerations of 0.583 m/s$^2$ and 0.335 m/s$^2$, it will cover the distance of 981 m and 525 m, respectively, which indicates a great potential, which can be used in the appropriate organization of traffic.

4. The best option for passing 270 m by public transport is an average speed of 30 km/h, since in this case there is a time reserve of 25.6 s.

5. References

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