Study of the process of introducing coordinated management on the principle of «green wave»

S V Dorokhin1,*, A Y Artemov1 and A P Gigadlo2

1Voronezh State University of Forestry and Technologies named after G.F. Morozov, Voronezh, Timiryazeva Street, 8, Russia
2Siberian State Automobile and Highway University (SibADI), Omsk, Prospect Mira 5, Russia

*dsvvrn@yandex.ru

Abstract. The article analyzes the existing types of road network management, considers the process of introducing coordinated management in more detail. The basic principles of the organization of this type of control using traffic lights are determined, the basic parameters of the traffic flow necessary for its organization are established. An experiment was carried out on the main city highway using a simulation product and a comparative assessment of changes in the main characteristics of the traffic flow before and after the introduction of coordinated control was made.

1. Introduction

Today, one of the main directions of research in the field of transport is the optimization of traffic flows. The number of road users is constantly increasing every year, and the current street road network does not always cope with traffic. The prevention of congestion is a key activity, which is essential both for the environment and for the economy. Due to inefficient and uncoordinated traffic control, traffic delays can occur. Thus, coordinating traffic light regulation can be an effective solution to problems. In this regard, the main objective of the study is to study the process of introducing coordinated management.

A large number of studies are devoted to issues of coordinated management [1-4], the effectiveness of this type of management is due to the following factors:

- reducing the level of vehicle delay at intersections;
- reduction in the number of unjustified stops;
- reduction of acceleration noise figure;
- increase in the average speed of vehicles on the highway [5].

The main objective of the study is to study the process of introducing coordinated management and conducting experimental work on the introduction of this type of management on the main city highway with the subsequent evaluation of the results.

2. Key criteria for coordinated management input

The main essence of coordinated regulation is to turn on a traffic light enable signal to a group of cars one by one, so that they, in turn, can non-stop cross the network of traffic lights. This allows to reduce the delay time of the transport stream and increase throughput.
One type of coordinated regulation is the green wave. In this view, the average speed of the traffic flow is taken into account. The main conditions for the organization of coordinated management are presented in the diagram (fig. 1).

**Figure 1. Basic conditions for the organization of coordinated management**

- distance between intersections should not exceed 800 m
- flow transit must be at least 70%
- at least two lanes in each direction

The main parameters for calculating the "green wave" are:
- vehicle intensity;
- distance between intersections;
- the same duration of traffic lights at the intersection;
- vehicle speed.

The intensity of vehicles is an unstable parameter, which can vary depending on the time of day, season, weather conditions [6]. When calculating the «green wave», it is important to understand that the intensity of the traffic flow at the first intersection in the network will be very different from the intensity at the last one. This is due to cars from adjacent streets. Also, during peak intensity, a group of cars may simply not have time to cross the intersection. Based on this parameter, saturation fluxes and traffic light cycles are calculated, which in turn are needed to calculate the «green wave».

The distance between intersections is a constant parameter that determines the efficiency of the green wave. A network of intersections with a small distance between each other is much better.

The speed of movement at which the green wave was calculated cannot always be observed, and this may cause the opposite situation; the green wave will, on the contrary, accumulate large groups of cars [7]. This can be explained by the high traffic intensity, road traffic accident and repair work.

As a result of the analysis, the main criteria and parameters necessary for the organization of coordinated management are determined. In order to assess changes in the main characteristics of the traffic flow during the introduction of coordinated control, an experiment using the product of simulation modeling was performed within the framework of this article.

3.  Experiment
Using a simulation product on the main highway of the city of Voronezh, a procedure for calculating coordinated management on the basis of the «green wave» was carried out. On the model, you can notice some shortcomings and patterns. A group of cars from a secondary road will not get on the traffic light permitting signal, that is, it will create an obstacle for cars moving along the green wave. In fig. 2 shows traffic from a secondary road. In fig. 3 it can be seen that the right-hand flows from the first intersection create an obstacle for the green wave group. Based on the simulation model, studies have been conducted. The situations with the introduction of the green wave and the existing traffic light regulation are considered. Research was carried out on Moscow Avenue.
Based on the simulation model, studies were conducted [8, 9]. The situations with the existing type of management and with the introduction of coordinated management on the principle of «green wave» are considered. Studies were conducted on regulated areas of Moskovsky Prospet, in Fig. 4 shows graphs of changes in traffic density during the implementation of coordinated regulation and the existing traffic light regulation.

The graphs show that when the green wave is introduced, the flux density becomes higher than with the existing traffic light regulation. This can be explained by the fact that a coordinated movement gathers a large group of cars at the first intersection [10]. Then this group in dense flow with the same speed moves to the last cross in the green wave network [11]. In fig. 5 shows graphs of the speed of the traffic flow with the existing type of control and with the introduction of coordinated control on the principle of «green wave».

Based on the results obtained, it can be concluded that when organizing coordinated regulation, differences in the speed of the traffic flow are observed. The main reason for this result is traffic from a secondary road, which inhibits the main traffic moving along the main street. In fig. 6 shows graphs of delays in traffic flow when implementing coordinated regulation and existing traffic light regulation.
Figure 6. Indicator of average traffic flow delay: a) with the existing traffic management scheme; b) when introducing coordinated management.

On the graph of the existing traffic light regulation, one can trace the growth trend. As the intensity increases, unconnected traffic lights will trigger delays. Based on the simulation model, studies were carried out on the introduction of coordinated control on the principle of «green wave». It can be noted that with the existing traffic light control, the delays were much greater, as well as with the introduction of fixed coordinated control, the value is 13 units higher. The graph shows (Fig. 6) that an increase in time is observed from 30-45 minutes, this occurs due to the formation of groups of cars from adjacent streets. When comparing the graphs, we can conclude: the adaptive system selects the optimal cycles. With low traffic on minor streets, the phase time of the enable signal increases. This eliminates the creation of groups at each traffic light, so the density relative to the existing regulation and fixed below.

4. Discussion of the results
A study in the implementation of coordinated regulation has reduced the delay time. The spasmodic schedule is caused by groups of cars with a secondary street. Recent coordinated regulatory systems include an adaptive system. This allows the “green wave” and other types of traffic regulation to adapt to having data received from vehicle detectors or video cameras. Such systems at times more efficiently regulate traffic objects, which is graphically presented in table 1.

Table 1. Change in the main indicators of traffic flow with the existing type of control and the introduction of coordinated management on the principle of «green wave»

| Traffic indicators               | Values with an existing control type | Values for a coordinated type of control according to the principle of «green wave» |
|----------------------------------|--------------------------------------|-----------------------------------------------------------------------------------|
| Average traffic delay, (sec/km)  | 83.35                                | 71.81                                                                             |
| Traffic density, (units/km)     | 21.87                                | 19.13                                                                             |
| Intensity of a transport stream, (unit/h) | 5272                                | 5272                                                                             |
| Average traffic speed, (km/h)   | 29.66                                | 32.50                                                                             |

They automatically select a traffic light cycle, depending on the intensity of movement. Adaptive systems are more flexible as opposed to a fixed green wave. In large cities, such systems should be a priority when organizing traffic control, because the usual fixed green wave will not work effectively during peak hours due to the high traffic intensity.

As a result of the experiment, it was found that the transport situation improved according to the results of the study of the obtained results, the average delay observed in the studied area - Moskovsky Avenue decreased by 14%, traffic density decreased by 13%, traffic flow rate increased by 9%, which confirms the effectiveness of implementation coordinated type of management.
5. Conclusion

As a result of all the results obtained, it can be said that the introduction of fixed coordinated regulation («green wave») will be effective, with a low traffic intensity. Due to adverse road conditions, traffic cannot always move at a design speed. In case of heavy traffic from adjoining streets, the «green wave» of cars will not have time to pass the traffic light allowing signal. Vulnerable to peak intensities. A fixed system is much simpler than an adaptive one, so expensive controllers and specially trained people are not needed to create it. The adaptive traffic light control system is more complex and expensive, therefore it is more rational to apply it in large cities, when the fixed system does not cope with the intensity.

References

[1] Vlasov V M, Nikolaev A B, Postolit A V and Prikhodko V M 2006 Information Technologies in Road Transport (Moscow: Science) p. 283
[2] Tallapragada P and Cortés J 2015 Coordinated intersection traffic management IFAC-Papers Online Volume 48, Issue 22 pp. 233-239
[3] Jiang Y, Zanon M, Hult R. and Houska B 2017 Distributed algorithm for optimal vehicle coordination at traffic intersections IFAC-Papers Online Volume 50, Issue 1, 2017, pp. 11577-11582
[4] Hafner M.R., Cunningham D., Caminiti L. and Del Vecchio D 2013 Cooperative collision avoidance at intersections: Algorithms and experiments. IEEE Transactions on Intelligent Transportation Systems 14 (3) pp.1162–1175
[5] Petrov E A 2003 Technology of coordinated traffic management of high-intensity traffic flows on the city road network Economy, organization and management. Omsk Scientific Herald Volume 22 pp. 193 -194
[6] Dinges E 2014 Methods for predicting the intensity of vehicles on highways along one time series and their scope Roads and bridges Volume 2 (32) pp. 145-156
[7] Nekrasova E E and Shevtsova A G 2015 Main criteria for evaluating the effectiveness of intersections Current Trends in 21st Century Research: Theory and Practice Volume 3 Issue 4-1 (15-1) pp. 363-366
[8] Dorokhin S V, Zelikov V A, Strukov Y V, Likhachev D V, Novikov A N, Novikov I A and Shevtsova A G 2018 Investigation of methods for calculating duration of light signal regulation cycle Journal of Physics: Conference Series Volume 1015 pp. 032128
[9] Novikov A, Novikov I and Shevtsova A 2019 Modeling of traffic-light signalization depending on the quality of traffic flow in the city Journal of Applied Engineering Science Volume 17(2) pp. 175-181
[10] Wang F J, Wei W., Qi H.S. et al. 2014 Research on discontinuous flow speed-density relation model Journal of Highway and Transportation Research and Development Volume 31 (7), pp. 108–114
[11] Heydecker B G and Addison J D Analysis and modelling of traffic flow under variable speed limits Transportation Research Part C: Emerging Technologies Volume 19 (2) pp. 206–217