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Research analysis of coordinated traffic lights

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Abstract. Traffic patterns in cities depend on the geographical environment, population density and the percentage of motorisation, which is expressed most often in densely populated areas. This necessitates the provision of measures to increase throughput, reduce delays in transport flows, combined with minimizing construction costs. One of the approaches that is applied to satisfy these conditions and efficiently use the space of the street network is to coordinate the operation of traffic lights. This publication analyzes the scientific research carried out in this area, which aims to determine the main indicators that influence the choice of applied approaches, when coordinating the traffic light systems, the weight of their quantitative indicators and their connection. Subsequently, the necessary studies are determined to coordinate the work of a selected section of the street network of the city of Sofia.

INTRODUCTION

In recent years, the number of vehicles in urban areas has increased, which causes serious problems of social, environmental and economic level. The main problem is the increase in delay time at intersections. This impact on travel time, travel costs, fuel consumption, etc. These problems are solved by optimizing, and in the best case minimizing the total delays of vehicles. In the event that this approach is not effective, it requires a solution related to new road capacity, intelligent traffic system in a new approach to traffic management. Traffic lights are an important aspect of road infrastructure that regulate road traffic. They are used to control traffic and ensure the safety of pedestrians and drivers. Coordinated traffic lights are a key element in urban traffic management. They help improve the flow of vehicles, reduce congestion and help reduce harmful exhaust emissions. Many cities around the world successfully use coordinated traffic lights to improve city traffic. They are making significant investments aimed at improving throughput and reducing delays. Adaptive traffic light control systems have proven their effectiveness and are an important part of urban infrastructure modernization. The cities of New York, Manhattan, Melbourne and Adelaide have advanced traffic management systems that include coordinated traffic lights. These systems are integrated with other technologies such as real-time traffic monitoring and data analysis, enabling even greater efficiency and safety on roadways. Coordinated traffic lights use complex algorithms to synchronize the lights of the traffic lights along the main thoroughfares. This allows traffic flows to move with fewer interruptions, resulting in faster and more efficient passage through the urban environment. The systems are based on real-time and historical traffic data to determine the optimal intervals between green signals [1], [2], [3], [4], [5], [7].

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PREREQUISITES AND MEANS FOR SOLVING THE PROBLEM

The study of indicators of transport flows is the basis for all activities related to planning, organization of traffic management in cities. At the same time, it is necessary to take into account their unevenness in different periods of the day, days of the week and months of the year.

As the authors point out in [6], traffic can be further improved by coordinating the signals of two or more traffic lights and optimizing the speed. They further note that signal timing and vehicle speed can be jointly optimized to more accurately plan vehicle passage at light-controlled intersections to make more efficient use of the green signal duration.

The research they are conducting for coordinated speed optimization and coordination of traffic lights in urban street networks is implemented with the Vissim algorithm. Their results show that speed optimization and traffic light coordination reduce travel time by about 2%, average delay by about 5%, average number of stops by about 30%. Comparison with the individually optimized signals of traffic lights. The authors note the advantages of coordinating the actions of connected vehicles when operating the traffic lights in a coordinated control mode [6].

A key point they make Tajalli et al. is that traffic lights improve the performance of transport networks if the right cyclograms are implemented. Condition that they are coordinated with respect to the intensity of transport flows. In addition, they argue that speed optimization reduces fuel consumption due to the reduced number of stops and starts. The input parameters they use are the intensity of transport flows for each lane and its throughput.

The authors in [7] point out that, previous studies have shown that signal coordination can reduce delays and downtime by up to 40%.

The coordination of signals significantly improves the movement condition of transport flows, but creates some restrictions for pedestrian and bicycle flows, as well as for vehicles from uncoordinated phases [7]. When coordinating the traffic lights and imperatively increasing the duration of the cycle of the traffic lights, leads to prerequisites for increasing the speed of the vehicles. On the other hand, reducing the duration of the cycle has a beneficial effect on the change of pedestrians, which improves traffic safety [7].

The coordination of cycles along a section of track usually assumes that the majority of vehicles travel from one end of the track to the other. This is true for some of the vehicles, but others only go through a few intersections before making a turn.

This reduces the benefits of coordinating traffic light cycles and lowers the average speed of traffic flow, as coordinated traffic lights require longer cycle times [7].

Authors Cesme and Urbanik address this important aspect of coordinated traffic lights in which they present a study of 17 coordinated sections of the Orlando, Florida street network with varying route lengths (from 1 mile to 12 miles). and number of intersections (from 5 to 18 intersections). The results show that about 10% of the vehicles travel from one end of the route to the other.

Another study presented by the same authors in [7], conducted in Washington, DC along Georgia Avenue NW, shows similar conclusions. It also proves that cyclists cannot keep up with the speed of vehicles, as the average speed of a bicycle is around 10-12 mph. This usually results in cyclists stopping repeatedly at intersections, which increases dwell time and slows them down due to longer cycle times.

To overcome this problem, several cities in the US limit their signal times by imposing lower urban traffic speeds [7].

The authors in [7] used the following input parameters - intensity of transport flows and pedestrian flows, the distance between intersections and the speed of cars and cyclists.

Skwarcan in [8] emphasizes that the coordination of traffic light cycles can be for both directions or at a high intensity of traffic flows, as traffic increases during the peak periods of the day. At these times, coordination of traffic light cycles must be done carefully, taking into account the influence of turning vehicles. In addition, the author takes into account the fact that in order to achieve a positive effect of coordinated traffic lights, it is necessary to regularly collect traffic data in order to optimally adjust the traffic light cycle and, if necessary, make a change in the traffic organization (change of road markings and road signs).

Mathew in [10] draws attention to a very important aspect in coordinating traffic lights, namely when two intersections are closely located they should be considered as one, and which two intersections are far from each other should be considered independently.

Some authors [11] propose the optimization of coordinated traffic lights using the theory of variations and considering the stochastic nature of the traffic flow process.

And others [12] propose an innovative approach to determine the main cycle time, the main inputs being intensity and throughput. In which the authors in [12] also consider traffic lanes.

Similar to the authors in [7] and Yue et al. [13] propose a methodology of the negative consequences for the cars of the uncoordinated directions, taking into account the intensity of the transport flows, the number of stops, and the waiting time, at different durations of the cycle time.

A global trend in traffic management, which reflects significantly in the coordination of traffic lights, is the introduction of the use of artificial intelligence and machine learning in the management of these processes, this is supported by some publications such as Pham et al. [14] and Chaphadkar et al. [15].

Some developments of research teams point to the essential topic of environmental protection, for which the coordination of the operation of traffic lights has a significant impact, given that the smooth movement of cars with a small number of stops and starts is ensured [16], [17].

RESULTS AND DISCUSSION

The analysis of literary sources and the conducted scientific research highlighted the following advantages of coordinated traffic light regulation:

- Reduction of the frequency of stops and starts;
- Reduction of waiting time and transport delays;
- Reduction of travel time;
- Increasing the throughput;
- Ensuring smooth movement of cars;
- Reduction of pollution from transport;
- Improving traffic safety.

Futhermore, the following disadvantages are also noted:

- Difficulties in the passage of transport flows;
- Difficulties in crossing bicycle streams;
- Entrained waiting time prerequisites for uncoordinated flows.

The main input parameters in all cases of introducing coordinated traffic light regulation are:

- Intensity of transport flows;
- Capacity of road lanes;
- Movement speed;
- Distance between intersections.

In some cases, these parameters are supplemented by: the intensity of pedestrian flows; percentage of cars passing the entire length of the track; number of traffic accidents, etc.

A key point in introducing coordinated traffic light regulation is determining the number and type of phases at individual intersections and the duration of the cycle to achieve minimum waiting time for traffic flows.

CONCLUSION

The study and subsequent analysis of publicly available research in the field of coordinated traffic light regulation showed its importance and the need to expand its application.

This is supported by the prominent advantages in its use related to the improvement of traffic conditions; reduction in transport delays, savings in travel time, perceived environmental benefits and improved traffic safety.

When coordinated traffic light management was implemented, the main input parameters for its implementation stood out very clearly, part of which are intensity of transport flows, the capacity of the traffic lanes and the speed of traffic.

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