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METHODOLOGY FOR COORDINATED MANAGEMENT OF GROUP TRAFFIC FLOWS

Abstract: Determination of traffic light throughput at busy intersections. Traffic flow calculations were carried out based on road safety, comfort, reliability and other indicators. Some recommendations were made to improve the quality of the full digitalization of the traffic management system by improving road infrastructure and creating safe traffic conditions.

Keywords: Intersection, traffic light, green wave, traffic flow, road, time, distance, speed, traffic light.

Coordinated control achieves the efficiency of coordinated operation of a number of traffic light devices to reduce vehicle downtime.

The coordination principle is that the green signal at the next intersection is turned on with a certain time shift relative to the previous intersection. This shift time depends on the time of movement of vehicles between intersections. As a result, vehicles along the highway (or the direction of movement), according to the route plan, reach each subsequent intersection exactly when the green signal is turned on in this direction. This reduces the number of unjustified stops and braking, as well as the level of traffic delays.

The ability to coordinate the operation of traffic light devices in this way led to the fact that this control method was called the “green wave” at the time. This term is still widely used in domestic and foreign practice.

The introduction of advanced methods of traffic flow management allows us to achieve the greatest efficiency in the shortest possible time and maximize the potential of the city's road network in the current conditions.

In this regard, the President of the Republic of Uzbekistan has announced the 2022-

The Development Strategy of New Uzbekistan for 2026 sets out the tasks of “reducing road accidents and fatalities by improving road infrastructure and creating safe traffic conditions, including fully digitizing the traffic management system and ensuring broad public participation in this area” [1].

To organize coordinated management, the following conditions must be met:

- ✓ There must be at least two traffic lanes in each direction;
- ✓ The control cycle must be the same at all intersections included in the coordination system;
- ✓ The distance between adjacent intersections should not exceed 800 meters.

The same cycle at all intersections ensures the maintenance of the required frequency of signal exchange and the calculated phase shift that allows movement along the coordination direction [2-3].

The limitation of the distance between intersections is associated with the process of group formation in the traffic flow. A group of cars is formed when a queue of cars waiting for a traffic light signal disperses. After the intersection, at the beginning of the road, the density of such a group is close to the saturated flow. Then, the group breaks up during the movement due to the different speeds of the vehicles in it. The difference in speeds is due to the influence of the structural diversity of the traffic flow and the personal characteristics of the drivers. Fast cars tend to be at the front of the group, and slow cars tend to be at the back or behind it. This process intensifies as the group moves away from the previous intersection, the group's travel time increases, and its average density decreases. Figure 1.1 shows a typical example of the dispersion of a group of cars. The horizontal axis shows time T , and the vertical axis shows the average number of cars on a street section located at a certain distance from the stop line in the direction of traffic [4-6].

Observations show that at a distance of 600 meters from the intersection, the length of the group in time more than doubles.

- The dispersion of the group occurs due to the different speeds of the cars

- As the distance increases, the shape of the group stretches and its density decreases
- This process has a significant impact on the efficiency of the "green wave"
- Changes observed at a distance of 600 meters are important for understanding traffic flow dynamics [7].

An attempt was made to translate in a scientific manner, clearly and intelligibly. The terminology of the transport sector was observed, while the text was adapted to the speech rules of the Uzbek language. As a result of numerous observations, it was found that a group of cars completely disperses at distances of more than 800-1000 meters. The arrival of cars at an intersection located at a distance of more than this distance from the previous intersection is random, and the flow connection between neighboring intersections is interrupted.

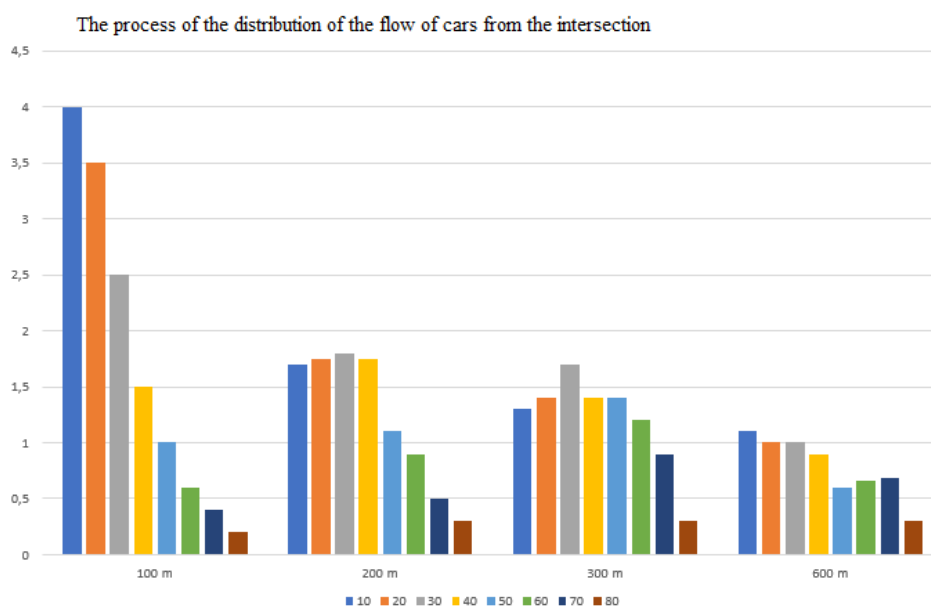


Figure 1 The process of dispersal of the flow of cars through the intersection

Numerous observations have shown that a group of cars completely disperses at distances of more than 800-1000 meters. The arrival of cars at an intersection located further from the previous intersection is random, and the flow connection between neighboring intersections is interrupted.

The following factors influence the dynamics of this process:

1. Structure of the transport flow

2. Individual characteristics of drivers
3. Number of lanes in the direction of traffic
4. Intensity of movement
5. Availability of public transport stops
6. Important places for pedestrians, etc.

To quantitatively assess the dispersion of a group of cars, an empirical formula was proposed by Russian scientists as a result of processing a large amount of experimental data.

$$t_x = t_r * e^{0,008} * t_d$$

here is the t_x – the length of time (minutes) of the flow of cars at a section located at a distance x from the intersection.

t_r – the amount of time it takes for a flow of cars to exit the intersection (minutes).

t_d – the amount of time (minutes) for the flow of cars to reach the next intersection from one intersection.

time duration – the total time it takes for a stream of cars to pass a given point (for example, if 10 cars pass in 2 seconds, the group length is 2 seconds).

The movement of traffic flows in groups is important in a coordinated control system. As the distance between intersections decreases, the probability of the group of vehicles breaking up decreases, and thus the time required to pass through the next intersection decreases. If the length of the group increases during the process of breaking up, then it is necessary to extend the green signal at the next intersection (which limits the rights of the opposing direction) or to pass only part of the group and stop the moving vehicles. Vehicles stopped at the stop line due to a red light at a traffic light can pass through the intersection only in the next cycle (together with the next group) [8].

A coordinated control method is also used, but the first method (extending the green signal) is used only to a limited extent to clear the stopped part of the previous

group. This ensures that the main part of the next group does not interfere with the unstoppable passage [9-11].

When the distance between intersections exceeds 800 meters, the group completely disperses and the number of stopped vehicles increases sharply. As a result, the efficiency of coordinated control decreases significantly.

Computational and graph-analytical methods of coordination programs are widespread due to their simplicity, but due to the high labor intensity of the calculation and graphic operations, they are considered effective when there are a relatively small number of traffic light objects. The essence of the method is to construct a road-time graph, which is executed in a rectangular coordinate system, if possible, on millimeter paper. The scale is chosen arbitrarily and depends on the length of the highway and the number of traffic light objects. On the horizontal axis, time is indicated in seconds, and on the vertical axis, the distance is indicated in meters.

The intersection with the largest cycle duration is considered the busiest intersection and is called the key intersection. Since the cycle duration should be the same at all intersections under coordinated control, the key intersection cycle is taken as the calculation cycle. Thus, the optimal control cycle occurs only at the key intersection, and at the other intersections this cycle is considered redundant.

It should be noted that in multi-program coordinated control, different intersections may be key for different times of the day. Accordingly, the computational cycle duration and computational speed may also differ for different programs [12].

After a single calculation cycle is determined for the highway, the durations of the main cycles for each intersection are determined in accordance with this cycle.

In the graph representation, a simplified plan of the highway is drawn to the left of the vertical axis (with the distances between intersections and the regulation modes indicated). Lines parallel to the horizontal axis are drawn through the intersection boundaries. For key intersections, cycle parameters are placed from left to right on the horizontal axis.

The left border represents the first vehicle movement in the group, and the right border represents the last vehicle movement in the group (Figure 2).

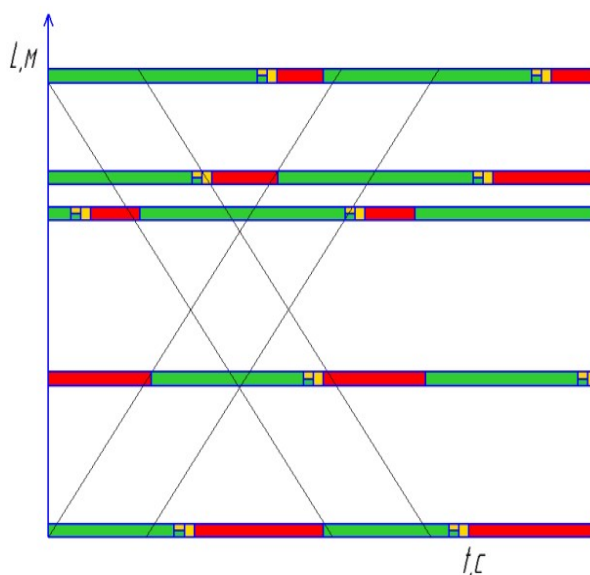


Figure 2 – Coordinated control graph.

As the cycle duration increases, the duration of the main cycles also changes proportionally. For each intersection, the duration of the main cycles and the phase shifts in the main direction are determined. The process of constructing the coordination graph is completed by constructing continuous motion tapes in both directions.

On the left, the sequence of traffic light signals along the highway: green — yellow — red — the duration of the red and yellow signals, s , is shown in a repeating sequence along the highway, observing the horizontal scale.

From the beginning of the green signals and to the right at a distance of $T_B = (0.4 \div 0.5) T_c$, oblique lines are drawn relative to the horizontal. The tangent of the angle of deviation of these lines corresponds to the calculated speed and is calculated by the following formula:

$$\operatorname{tg} \alpha = \frac{V_{kth} * M_{vm}}{3.6 * M_{rm}}; \quad \text{km/h}$$

here: V_{kth} — calculated speed for coordination, km/h;

M_{vm} — time scale, s/cm;

M_{rm} — distance scale, m/cm.

The t_n indicator determines the width of the interval, which is called the time band. If the car's traffic graph is located inside this band, it is guaranteed to move without stopping. For the opposite direction, the time band is also taken with the same width, but it has the opposite deviation, and this deviation is determined by the formula for the calculated speed of this direction [13].

The effectiveness of coordinated management is usually assessed after the system is implemented. The main indicator is the degree of reduction in the time taken by a vehicle to travel from the starting point to the end point on the highway where the coordination system is implemented. According to numerous observations, travel time is usually reduced by 15–20%.

The relative width of the timing belt (recall that its minimum width should not be less than $0.3T_{II}$) and the coefficient of non-stop passage can also be taken as efficiency indicators.

$$\beta = (N - Z) / N_0$$

Here:

N — traffic intensity passing through the intersection on this route of the highway, vehicles/hour,

N_0 — the number of vehicles stopped at this intersection in this direction, per hour.

The β coefficient is determined at each intersection, in both the forward and reverse directions, by natural observation. It is also possible to determine the average value of the β coefficient for the entire highway.

Coordinated control is considered effective if $\beta \geq 0.8$. This means that 80% of vehicles passing through the intersection pass without stopping.

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