**The Effectiveness of Introducing Coordinated Traffic Light Regulation on the Main Highways of the City of Termez**

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**Abstract.** The advantages of coordinated traffic light regulation of traffic flows on the main highways of the city of Termez are calculated and described. Under current urban development dynamics, the rapid increase in vehicle ownership and population growth in Termez has not been matched by proportional improvements in its road infrastructure. This imbalance contributes to reduced average travel speeds, frequent congestion, longer journey times, more frequent unscheduled stops, higher fuel consumption, elevated transport-related expenditures, greater risk of road incidents, and worsening environmental quality.

**Keywords:** Street and road network,road traffic, vehicles, “green wave”, coordinated traffic light control, highway capacity, traffic flow, controlled intersections, traffic safety

**INTRODUCTION**

In the context of a shortage of funds in the city budget, a relevant way to increase the efficiency of the road network (RSN) is to coordinate traffic light control at a number of controlled intersections or pedestrian crossings on the main highways of the city, which requires a minimum of monetary costs. Today, scientists [1, 2, 3, 4, 5] have convincingly proven the effectiveness of using coordinated traffic light regulation to reduce transport delays in a number of sections of the road network of various cities. The introduction of the “green wave” can significantly increase the capacity of highways, reduce fuel consumption and harmful emissions into the atmosphere by increasing the average speed of traffic, as well as reducing the number of accelerations and decelerations at signalized intersections [14].

A comparable traffic management approach may be considered for implementation in Termez, as certain primary segments of the city’s road infrastructure—particularly Hakim at-Termiziy, Ibn Sino, and Barkamol Avlod streets—appear technically suitable for the deployment of a synchronized signal progression system ("green wave"). This paper explores and substantiates the technical viability of applying coordinated signal control across these major corridors.

# **LITERATURE SURVEY**

The regulation of urban traffic through coordinated traffic light systems has been the subject of extensive academic research, particularly in rapidly growing cities where congestion poses a critical challenge. Numerous studies emphasize that traffic signal coordination plays a pivotal role in improving traffic flow efficiency, reducing vehicular delays, lowering fuel consumption, and minimizing environmental impact (Papageorgiou et al., 2003; Stevanovic, 2010). These benefits become especially evident on main arterial roads, where uncoordinated signals often lead to stop-and-go traffic patterns, increasing travel times and emissions [5, 6].

Adaptive traffic signal control strategies—such as SCOOT (Split Cycle Offset Optimization Technique) and SCATS (Sydney Coordinated Adaptive Traffic System)—have been successfully implemented in cities across Europe, Asia, and Australia. These systems dynamically adjust signal timings based on real-time traffic data (Hunt et al., 1981; Lowrie, 1990). In particular, Stevanovic et al. (2013) argue that coordinated signal control improves average travel speeds by up to 20% during peak hours, especially when signal timing plans are synchronized across intersections [7, 8, 9].

In the context of developing cities, several studies highlight the challenges and opportunities of implementing such systems. For instance, Ahmed and Hawas (2017) assessed traffic light synchronization in Doha and found that even partial coordination significantly reduced intersection delays and improved corridor-level throughput [10]. Similarly, research in Indian and African urban centers shows that the effectiveness of such interventions depends on proper data collection, accurate modeling, and regular updating of signal plans (Chien & Ding, 2002; Oke et al., 2020) [11, 12].

Regarding Uzbekistan, while studies on traffic signal coordination remain limited, recent works have explored broader urban transport optimization strategies. Rustamov et al. (2022) investigated traffic congestion patterns in Tashkent and emphasized the potential of intelligent transport systems (ITS) to modernize traffic control mechanisms [13]. However, no known study has yet addressed signal coordination effectiveness specifically in Termez, a city experiencing growing urbanization and increasing vehicle density.

Thus, this study aims to fill this research gap by evaluating the potential effectiveness of introducing coordinated traffic light systems along the main highways of Termez. Building on international experience and traffic engineering theories, the research will contribute practical insights for medium-sized urban centers in Central Asia, where localized solutions for traffic efficiency are urgently needed.

**RESEARCH METHODOLOGY**

Surveys of traffic flow in the city of Termez showed that almost 70% of vehicles move on the main highways along the streets of Hakim at-Termiziy, Ibn Sino and Barkamol avlod, connecting the main densely populated areas with new fast-growing microdistricts, social facilities, administrative, financial and large commercial centers of the city.

An analysis of the traffic management scheme on sections of the above-mentioned streets revealed a number of shortcomings in traffic management (TRA):

– excessive cycle time of traffic light objects (more than 180 s);

− recurrent halts of vehicles at signalized intersections, caused by the absence of harmonized signal coordination under conditions of relatively high-speed traffic flow along the corridor.

To increase the capacity of sections of the city's main arterial streets, reduce transport delays and improve traffic safety, the following measures must be taken:

1. Calculate the algorithm for the operation of traffic light objects on the main highways of the city.
2. Coordinate the cycles of operation of traffic light facilities at the entrances and exits to these highways from adjacent streets.
3. Install the required number of road signs in the road network of these main streets.
4. Apply the necessary markings at intersections and pedestrian crossings on these streets.

To enhance the effectiveness of signalized traffic regulation systems, coordinated signal progression is applied across multiple intersections. This method aims to minimize vehicular travel time within a designated corridor. It is based on the principle of synchronized control, commonly referred to as the “green wave,” wherein vehicles moving along a planned route encounter successive green lights at intersections, provided they maintain a specified travel speed and direction.

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

a) the presence of at least two lanes in each direction;

b) the same or multiple regulation cycle at all intersections included in the coordination system;

c) flow transit rate of at least 70%;

d) the distance between adjacent intersections should not exceed 800 m.

**EQUATIONS, FORMULAS, SYMBOLS, UNITS**

With coordinated traffic control under the stretch alongA section of the main street limited by two stop lines at adjacent traffic light facilities is removed. Since the stages are always limited by stop lines on the approaches to existing neighboring traffic light objects (controlled intersectioncontrolled pedestrian crossing), in the case under consideration, the length of the stretches in the forward and reverse directions differs slightly (Table 1).

TABLE 1. Length of hauls on Barkamol avlod street

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Direction | Length of hauls across the Uzunliga, m | | | | | | Total, m |
| 1 | 2 | 3 | 4 | 5 | 6 |
| Direct | 112 | 295 | 574 | 143 | 275 | 331 | 1730 |
| Reverse | 112 | 295 | 574 | 143 | 275 | 331 | 1730 |
| Difference Between Forward and Reverse Direction | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

During the planning of coordinated signal control along a segment of a primary street, the large-scale schematic layout considers the precise positioning of stop lines at each traffic signal point, which represent directional limits for that specific section. Field measurements show that the segment lengths across all three phases range between 200 and 400 meters. As a result, the vehicular platoon length along the corridor expands by approximately 1.5 to 2 times compared to the initial queue. This setup yields a moderately high level of coordination performance, supporting the feasibility of implementing a “green wave” system along the arterial road section in question [12].

Significant turning movements onto and from the main corridor tend to diminish the efficiency of coordinated signal operations. In this context, through movements are defined as those vehicles that have already passed the upstream signalized intersection along the principal route. Consequently, the continuity of flow is largely influenced by the volume of turning maneuvers at junctions where secondary roads intersect the primary arterial. A high proportion of through traffic is indicative of dominant straight-line movements along the main route. In estimating the share of through traffic at signalized intersections within the study segment, the analysis utilized adjusted traffic volumes observed during peak hours. (Table II).

The calculated speed when constructing a coordinated control schedule determines the amount of shift in the activation of green signals at neighboring traffic light objects. In this regard, the correct choice of design speed has a decisive influence on the efficiency of coordinated control. The primary task when constructing a coordinated control schedule on sections of main streets is to determine data on the distribution of traffic speeds on individual stretches.

Technical speed is understood as the average speed of a vehicle moving along a section of the road network between two points (for example, along a stretch), taking into account delays associated with traffic regulation and interference that arise when moving in traffic. The design speed can be used as a single speed of groups of vehicles moving along a section of the highway, as well as individual design speed values ​​determined by specific traffic conditions. Moreover, in each of these cases, to selectThe following principles are used for the design speed along the entire length of the highway section or on its individual sections:

1. The assumed design speed corresponds to the mean travel speed of vehicle platoons observed either across the entire stretch of the arterial road or within selected segments of it;
2. The calculated speed is chosen to be a speed that does not exceed 85% of vehicles moving in groups along the entire length of the highway section or on its individual sections.

If the reference speed for coordination is based on the mean velocity observed along the segment, a time gap may occur wherein the lead vehicles experience a delay. This can disrupt the continuity of the vehicle platoon, as subsequent units may reach the signalized intersection prematurely—prior to the activation of the green phase intended for the designated movement direction. Therefore, usually the design speed on a section when developing coordination programs is taken equal to the technical speed, not exceeding 85% of the cars in the group.

Data on the length of the stretch were obtained earlier. The main difficulty is determining the time it takes for vehicles to travel over a stretch of known length. The measurement requires the presence of two observers located at opposite ends of the stretch and filming video independently of each other. When simultaneously turning on video cameras installed at the beginning and end of a stretch of known length Slane, m, time passingthe passage of the vehicle will be determined by the time delay between the passage of the transport mediastop line at the beginning of the stretch t1 and at the end t2:

t= t1 - t2 (1)

To obtain a sample of t valuesivolume N, it is required to record time values t using synchronous video recording from two points (beginning and end of the stage) 1i, t2i, determined by the momentpassing through the cross section of the corresponding stop lines N of vehicles. Development of a main traffic light control system on the section of Alisher Navoi Street using graphic-analytical method [14].

The graphical representation of synchronized signal operations along a primary urban corridor is typically illustrated using a “distance–time” diagram constructed within a rectangular coordinate framework. Owing to its clarity and practical applicability, the graphical-analytical approach is widely adopted for designing coordination schedules, particularly in cases where the number of signalized intersections is limited. In this study, signal cycle lengths were previously computed for four junctions based on prevailing traffic demand. To enable coordinated control, identical signal cycles of 84 seconds were applied at each intersection.

The coordination schedule is built in the following order [8]. To the left of the vertical axis of the “path-time” graph, observing its vertical scale, a schematic plan of the highway in question is drawn, indicating the distances between traffic light objects. To the right through the boundaries of traffic light objects is carried outXia lines parallel to the horizontalaxes. On the horizontal strip corresponding to the first intersection, a schematic representation of the regulation mode is drawn from left to right in compliance with the horizontal scale - a repeating sequence of traffic light signals for flows moving along the highway in the transit direction [14].

In the problem under consideration, the width of the time tape is assumed to be equal to tl= 21 s; tl/Tts= 21/84 ≈ 0.25 (within acceptable range). The time tape for the opposite direction is taken of the same width, but has a reverse slope. By adjusting the alignment of the time–distance diagram, efforts are made to ensure that the offset lines corresponding to other signalized intersections remain fully contained within the active green interval of each respective phase. The horizontal positioning of points reflecting the green phase initiation times across intersections defines their temporal offsets relative to one another and to a selected reference time mark—corresponding to the activation of the green signal at the main (base) intersection. Based on calculations, the time offsets for green signal onset between the first and second intersections is 14 seconds, between the first and third – 63 seconds, and between the first and fifth – 48 seconds. The final coordinated signal timing plans for the section of Ibn Sino, Hakim at-Termiziy, and Barkamol Avlod streets are summarized in Table II, reflecting the design framework established under the “green wave” progression strategy.

**TABLE 2.** Changing the speed of vehicles using traffic light regulation according to the “Green Wave” principle

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Main highways | Stage length, m | Existing technical speed (km/h) | Technical speed after the Green Wave (km/h) | Changes  (-,+) |
| 1 | Ibn Sino | 2167 | 29.8 | 36.9 | **+18.1** |
| 2 | Hakim at-Termiziy | 2681 | 27.3 | 33.1 | **+17.5** |
| 3 | Barkamol avlod | 1730 | 30.6 | 37.4 | **+18.2** |

The finalized signal timing configurations for intersections along Ibn Sino, Hakim at-Termiziy, and Barkamol Avlod streets—as part of the proposed coordinated signal management framework—are designed based on the “green wave” progression concept and are detailed in Table 2.

**CONCLUSION**

Implementing synchronized traffic signal management along selected segments of Termez’s central road network, coupled with supplementary traffic organization strategies, is projected to enhance intersection capacity and decrease overall vehicle delay times by over 10%. Emissions of harmful substances into the atmosphere will also be reduced, and the average speed of vehicles will increase by 17-18 km/h. This study evaluated the potential effectiveness of implementing coordinated traffic light regulation along the main highways of Termez, a city facing increasing urbanization and growing transport demand. The literature review demonstrated that coordinated signal systems significantly enhance traffic flow efficiency, reduce vehicle delays, and lower emissions in urban corridors. Despite their proven impact in developed urban centers, such systems remain largely underutilized in secondary cities like Termez.

By analyzing international practices and the core principles of traffic signal synchronization, the study highlighted the critical prerequisites for successful implementation, including accurate traffic flow data, real-time adaptive control technologies, and institutional readiness. Findings suggest that even basic coordination of existing signals could lead to measurable improvements in travel time and vehicle throughput in the city’s most congested corridors.

This research fills an important gap by contextualizing global experience within the specific urban dynamics of Termez. It provides evidence-based recommendations for local authorities, including the phased deployment of low-cost coordination strategies and integration with future intelligent transport systems (ITS). The study also paves the way for further empirical investigations through simulation modeling or pilot projects to validate theoretical projections.

In conclusion, introducing coordinated traffic light regulation in Termez is not only feasible but also a necessary step toward modernizing the city’s traffic management system. Strategic implementation can contribute to more sustainable urban mobility, enhance road user satisfaction, and support broader smart city development goals in the region.

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