

**СОВРЕМЕННЫЕ ПОДХОДЫ И ТЕОРЕТИЧЕСКИЕ ОСНОВЫ  
СВЕТОФОРНОГО УПРАВЛЕНИЯ ПРИ РЕГУЛИРОВАНИИ  
ТРАНСПОРТНЫХ ПОТОКОВ**

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**Аннотация.** В данной статье анализируются научные основы, этапы развития и современные подходы светофорного регулирования в организации дорожного движения. Рассматривается роль светофорных систем в управлении транспортными потоками, снижении заторов и обеспечении безопасности дорожного движения. Также изучается внедрение интеллектуальных транспортных систем и технологий адаптивного управления светофорами. Результаты исследования показывают, что оптимизация фаз светофорного регулирования и применение современных систем управления значительно повышают эффективность транспортного движения.

**Ключевые слова.** *светофорное регулирование, транспортный поток, интеллектуальные транспортные системы, адаптивное управление, заторы, безопасность дорожного движения, PTV VISSIM, пропускная способность.*

**MODERN APPROACHES AND THEORETICAL FOUNDATIONS OF  
TRAFFIC SIGNAL CONTROL IN TRAFFIC FLOW REGULATION**

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**Abstract.** This article analyzes the scientific foundations, development stages, and modern approaches of traffic signal control in road traffic management. The role of traffic signal systems in regulating traffic flow, reducing congestion, and ensuring road safety is discussed. The study also examines the implementation of intelligent transport systems and adaptive traffic signal control technologies. The results indicate

that optimizing signal phases and applying modern control systems significantly improve overall traffic efficiency.

**Keywords.** *traffic signal control, traffic flow, intelligent transport systems, adaptive signal control, congestion, road safety, PTV VISSIM, capacity.*

**Introduction.** Traffic signal control is considered one of the most important tools in the organization and management of road traffic. Traffic lights ensure the safe and conflict-free movement of vehicles traveling in different directions, as well as pedestrians crossing roadways. They regulate the sequence and priority of traffic participants by allocating specific time intervals for each traffic flow, thereby enabling orderly movement through intersections. As a result, overall traffic is better organized, while congestion levels and the number of road traffic accidents are significantly reduced.

Traffic signal systems have been used in global practice for more than a century, and their importance continues to grow in modern urban transport systems due to increasing traffic volumes and the complexity of road networks.

**The Main Part.** The scientific foundations of traffic signal control are aimed at the effective regulation of traffic flows, minimizing delays, and improving road traffic safety. Early theoretical approaches emphasized the need to divide traffic signals into cycles and phases, as well as to determine optimal time allocations for each movement direction based on scientific principles. This approach ensures a balanced distribution of traffic flows and helps reduce conflict situations at intersections.

In this process, the accurate assessment of key traffic flow parameters plays a crucial role. In particular, flow intensity, vehicle speed, traffic composition (share of passenger cars, freight transport, and public transport), and roadway capacity are considered fundamental indicators. For example, the maximum number of vehicles that can pass continuously through a single lane within a unit of time is defined as the “saturation flow,” typically assumed to be in the range of 1800–2000 vehicles per hour.

In addition, the efficiency of the traffic signal cycle is evaluated by accounting for lost time, including stopping delays during red-to-green transitions and the time required for vehicles to restart and resume movement. These losses significantly affect overall intersection delay.

Therefore, a scientifically justified signal cycle and optimal phase distribution play a crucial role in ensuring traffic flow continuity, reducing queues at intersections, and improving overall traffic efficiency.

### Scientific Research.

In the modern stage of traffic signal control development, intelligent transport systems (ITS) play a crucial role. Currently, adaptive systems are being developed that measure traffic flow in real time and automatically manage traffic signal phases.

In such systems, signal cycles are dynamically adjusted based on data collected through sensors and cameras. Simulation tools such as PTV VISSIM provide the opportunity to scientifically analyze these processes.

In addition, through centralized traffic management systems (ATMS), intersections are coordinated with each other, ensuring uninterrupted traffic flow along main roads.

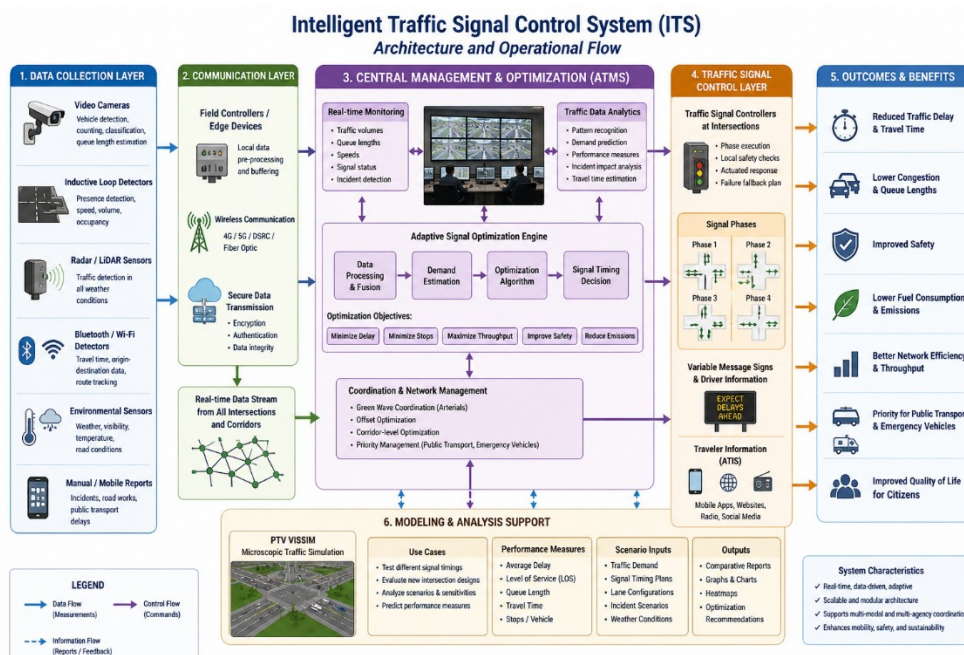


Fig.1. Adaptive Traffic Signal Control within Intelligent Transport Systems (ITS): Data Flow and System Architecture

In Uzbekistan as well, efforts are being made to modernize traffic signal systems. In Tashkent, traffic lights are remotely controlled and optimized in real time through the automated “Traffic Management Center.” In Namangan city, modern, energy-efficient, and safety-enhancing innovative traffic signals have also been implemented.

**Results.** The analysis and simulation results demonstrate that traffic signal control strategies significantly influence traffic performance indicators such as delay, queue length, and intersection capacity. The study compared three control scenarios: static control (S1), actuated control (S2), and adaptive ITS-based control (S3).

Table 1. Comparison of traffic performance indicators under different control scenarios

Scenario	Average Delay (s)	Average Queue Length (m)	Capacity Utilization (%)	Level of Service (LOS)
S1 – Static control	78	210	62	E
S2 – Actuated control	61	160	74	D
S3 – Adaptive ITS control	52	110	85	C

The results clearly indicate that adaptive traffic signal control (S3) provides the best performance among the tested scenarios. Compared to static control, average delay decreased by approximately 33.3%, while intersection capacity utilization increased by 23%.

Table 2. VISSIM simulation output for traffic performance indicators:

Indicator	S1 (Fixed-time)	S2 (Actuated)	S3 (Adaptive ITS)
Average delay (s/veh)	78.4	61.2	52.1
Average queue length (m)	212	158	112

Average speed (km/h)	18.5	22.3	26.8
Throughput (veh/h)	1680	1920	2145
Level of Service (LOS)	E	D	C

The simulation results indicate a clear improvement in traffic performance under adaptive signal control. Compared to fixed-time control (S1), the adaptive system (S3) reduced average vehicle delay by approximately 33.5% and queue length by 47.2%. At the same time, throughput increased by about 27.7%, demonstrating higher intersection efficiency.

**Conclusion.** Traffic signal control is one of the key elements of modern urban transport systems, playing a crucial role in ensuring safety and regulating traffic flow.

Improperly designed signal cycles lead to increased congestion and delays, whereas optimized phase design improves intersection capacity.

Adaptive systems and ITS technologies enhance flow stability and reduce delays through real-time control. The implementation of ATMS and the “green wave” concept ensures smoother traffic flow and environmental benefits.

In conclusion, the modernization of traffic signal systems and the widespread implementation of adaptive algorithms are essential for the sustainable development of urban transport infrastructure. In the future, the integration of AI and Big Data technologies will further increase system efficiency.

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