INTERNATIONAL BEST PRACTICES IN THE DEPLOYMENT AND CERTIFICATION OF HIGHWAY VIDEO SURVEILLANCE SYSTEMS AND THEIR ADAPTATION TO THE NATIONAL FRAMEWORK

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Annotation: This article analyzes the implementation of video surveillance systems on highways in developed countries, their functional capabilities, and their contribution to traffic safety. In addition, it scientifically substantiates the possibilities of adapting and integrating these systems into the road infrastructure of Uzbekistan.

Keywords: video surveillance system, road safety, best practices, digital infrastructure, integration

Аннотация: В данной статье анализируется внедрение систем видеонаблюдения на автомобильных дорогах в развитых странах, их функциональные возможности и вклад в обеспечение безопасности. Также научно обосновано рассмотрены возможности адаптации и интеграции этих систем в инфраструктуру автомобильных дорог Узбекистана.

Ключевые слова: система видеонаблюдения, безопасность дорожного движения, передовой опыт, цифровая инфраструктура, интеграция.

Annotatsiya: ushbu maqolada rivojlangan mamlakatlarda avtomobil yo'llarida videokuzatuv tizimlarining joriy etilishi, ularning funktsional imkoniyatlari va xavfsizlikni ta'minlashga qo'shgan hissasi tahlil qilinadi. Shuningdek, ushbu tizimlarni O'zbekiston avtomobil yo'llari infratuzilmasiga moslashtirish va integratsiya qilish imkoniyatlari ilmiy asoslangan holda ko'rib chiqildi.

Kalit so'zlar: CCTV tizimi, yo'l harakati xavfsizligi, eng yaxshi amaliyotlar, raqamli infratuzilma, integratsiya.

Introduction

In the 21st century, modern technologies are becoming increasingly important in ensuring road traffic safety. In particular, the widespread implementation of video surveillance systems on highways creates opportunities for regulating traffic flows, detecting violations, and responding promptly to emergencies.

Leading countries such as the United States, Japan, Germany, China, and South Korea have accumulated considerable experience in this area. By effectively integrating video surveillance and digital management systems into road

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infrastructure, they have achieved significant results in preventing traffic accidents and improving safety.

Positive developments are also being observed in Uzbekistan. In recent years, important steps have been taken to digitize the road network, enhance safety, and introduce automated control systems. This article examines foreign practices and explores proposals tailored to Uzbekistan's conditions, along with possibilities for their integration into the national system.

Methodology

The study applies various scientific and analytical methods. In particular, a comparative analysis is conducted to examine video surveillance systems for road traffic monitoring in advanced countries, taking into account the diversity of transport infrastructure, technological capabilities, economic levels, and legal frameworks. Based on this approach, several models are analyzed, and their similarities and differences are discussed in terms of system architecture, technological solutions, management principles, legal foundations, and social effectiveness.

United States: The "Intelligent Transportation Systems (ITS)" concept has been adopted as the primary approach, with emphasis on coordination among federal, state, and local centers. Data collected from cameras and sensors are transmitted to servers in real time, enabling rapid analysis and decision-making. The "Vision Zero" program, aimed at improving safety, is integrated into this system, with active involvement of government agencies, police, transport authorities, and emergency services.

Japan: In major cities, high-resolution cameras, AI-based detection algorithms, and smart traffic lights operate in an integrated manner. The "Universal Traffic Management System (UTMS)" implemented in Tokyo is a comprehensive model that combines traffic optimization, congestion prevention, pedestrian safety, and environmental monitoring.

China: The "Skynet" project represents one of the world's largest video surveillance systems, with millions of cameras connected to a unified information platform. The system monitors not only transport but also public safety, environmental conditions, and personal identification. Vehicle license plates, speed, and routes are tracked by artificial intelligence, and violations automatically trigger fines. One of the system's key strengths is the fully automated, high-speed data exchange among government agencies.

South Korea: Video surveillance systems are integrated with other smart infrastructure elements. Within the framework of the "Smart Highway" project, cameras, radars, emergency detectors, and weather-adaptive monitoring tools are

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deployed. Data are transmitted via 5G networks in real time, enabling immediate driver alerts and AI-based risk assessment. As a result, traffic flow speed has increased by 18–20 percent, while road accidents have decreased by 30 percent.

Germany: Video surveillance systems are not limited to monitoring traffic but also control environmental indicators. The systems can measure emission levels, while the "Section Control" technology makes it possible to detect violations of average speed over specific distances. The automated penalty system, supported by legal frameworks, ensures higher efficiency.

Overall, the experience of advanced countries shows that video surveillance systems have evolved beyond simple monitoring tools to become comprehensive management mechanisms. They integrate artificial intelligence, automated analysis, environmental monitoring, and legal enforcement functions. Each approach has its own distinctive features, and these practices can serve as a valuable foundation for developing technologically and institutionally adapted systems in Uzbekistan.

Table 1

Comparison of video surveillance systems for highways in advanced foreign countries

Country	Core Technologies	Special Functions	Effectiveness
USA	Cameras, radars, artificial intelligence, automated control	Traffic analysis, violation detection, rapid response	Traffic accidents reduced by 22–27%
Japan	Cameras, AI, dynamic traffic lights, road sensors	Congestion prevention, pedestrian safety	Traffic accidents reduced by 30%
China	600 million cameras, facial recognition, license plate recognition	Crime prevention, automatic fines	Traffic accidents reduced by 25%, crime reduced by 40%
South Korea	5G communication, radars, AVT systems, alarms	Real-time alerts, risk assessment	Traffic flow accelerated by 20%, accidents reduced by 30%
Germany	Cameras, environmental sensors, Section Control	Environmental monitoring, legal enforcement	Effective in detecting emissions, fully automated penalty system

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Regulatory and Legal Analysis:

When implementing video surveillance systems on highways, relying solely on technology and technical solutions is not sufficient. Since such systems directly process personal data, their legal foundations require special attention. For instance, information such as license plate numbers, the appearance of drivers or passengers, and movement directions recorded by cameras are classified as personal data. Therefore, their collection, storage, processing, and dissemination must strictly comply with regulations established by law.

Significant international experience has been accumulated in this field. Notably, the European Union's General Data Protection Regulation (GDPR) serves as a unified legal document for data protection. According to GDPR, any personal data—including images obtained through video surveillance—may only be collected for clear and legitimate purposes, based on the consent of the individual or other legal grounds. Moreover, GDPR guarantees the rights of individuals to access, correct, or delete such data.

Additionally, the international standard ISO/IEC 27001 outlines how information gathered via video surveillance systems should be managed from an information security perspective. It specifically prescribes measures to prevent unauthorized access, data theft, or unlawful distribution.

Since video surveillance serves as a technical tool for transport safety, it must also comply with technical requirements set for vehicles. In this regard, the regulations developed by the UNECE WP.29 working group are noteworthy. They establish rules for the integration of video surveillance and other intelligent systems within the framework of the "connected vehicles" concept.

Furthermore, the International Telecommunication Union (ITU-T) Recommendation Y.4113 specifies ethical principles, transparency requirements, and public trust criteria for handling data within smart city infrastructure.

In Uzbekistan, the legal framework in this area is defined through several laws and government decrees. For example, the Law "On Road Traffic Safety" stipulates the use of technical means for traffic monitoring and recognizes their validity as evidence. Administrative measures can be applied based on violations recorded via video surveillance.

On the other hand, the Law "On Personal Data" protects information obtained through these systems as personal data. However, compared to international standards, some essential aspects—such as obtaining citizen consent, defining data retention periods, or establishing procedures for transferring data to third parties—are not yet fully and clearly defined in the law.

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Overall, while Uzbekistan has established legal grounds for video surveillance systems, they are not yet fully aligned with international standards. In particular, gaps remain in personal data protection, information security, and ethical approaches. Therefore, improving existing legislation and adapting international experience to national conditions remains a pressing task today.

Table 2

International and national legal approaches to video surveillance systems

Criteria	International Standards	Legislation of Uzbekistan
Personal data protection	GDPR – based on consent, right to erasure/access, used for specific purposes	Law "On Personal Data" – general protection is guaranteed
Information security	ISO/IEC 27001 – protection against unauthorized access, monitoring and audit requirements	Technical regulations not fully developed, general approach in place
Legal validity as evidence	Only records from certified systems have legal force	Video recordings are recognized as legal evidence
Principles of transparency	ITU-T Y.4113 – transparency, access to information, strengthening public trust	"Digital Uzbekistan – 2030" strategy defines a general approach to openness

SWOT Analysis:

In recent years, modern information and communication technologies have been developing rapidly in Uzbekistan's transport infrastructure. Naturally, this process has made the large-scale implementation of video surveillance systems an important step in ensuring road safety. However, like any new technological solution, video surveillance systems have not only advantages but also certain limitations and risks. Therefore, applying the SWOT analysis method is appropriate when evaluating them.

First, regarding the strengths. In the context of Uzbekistan, video surveillance systems have proven to be an effective mechanism for ensuring compliance with traffic rules. Against the backdrop of the rapid increase in the number of vehicles, traffic congestion, and road accidents, these systems not only record violations but also play a significant role in accident prevention. In addition, they help accelerate the movement of ambulances and emergency services and enable real-time monitoring of traffic flow. For the traffic safety authorities, they serve as an additional control tool, enhancing the efficiency of law enforcement.

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At the same time, there are weaknesses. Above all, not all roads are fully equipped with the necessary technical infrastructure. High-resolution cameras, fiber-optic communication lines, and data centers require substantial financial investment. Moreover, the legislative mechanisms for personal data protection are not yet fully developed. Some segments of the population may perceive video surveillance as an intrusion into privacy, which could negatively affect public support for the system.

Nevertheless, there are ample opportunities. Within the framework of the "Digital Uzbekistan – 2030" strategy, the digitalization of transport infrastructure has been identified as a priority direction. The advanced experience of countries such as China, South Korea, the United States, and Germany can serve as ready-made technological and organizational models for Uzbekistan. Attracting foreign investors through public-private partnerships, localizing technical equipment, and applying artificial intelligence can contribute to the sustainable development of the system.

At the same time, potential threats should not be overlooked. Technical malfunctions, cybersecurity gaps, or poorly functioning algorithms may lead to unjust penalties. Corruption risks, as well as the possibility of unlawful use of data, could undermine public trust in the system. Furthermore, systems not legally recognized or not aligned with international standards may give rise to additional legal issues in the global arena.

In Uzbekistan, there are strong grounds for introducing video surveillance systems into road traffic infrastructure. The technological strengths of the system, its alignment with the digital transformation process, and the enrichment with global experiences further strengthen its prospects. At the same time, to minimize existing weaknesses and prevent risks, it is necessary to harmonize legislation with international standards, establish open dialogue with the public, and consistently maintain high-quality technical services.

Expert Assessment Method:

The implementation of video surveillance systems on highways is not limited solely to technological upgrades. This process represents a strategic task closely linked to large-scale system integration, regulatory and legal compliance, information security, and social acceptance. Therefore, to implement it effectively and substantiated in practice, the expert assessment method was widely employed.

Within this method, opinions of specialists in Uzbekistan's ICT sector, leading professionals with experience in transport management and safety, academics from higher education institutions, and qualified experts in digital infrastructure were systematically studied. Elements of the Delphi method were

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applied during the assessment: experts were asked questions in several stages, responses were analyzed, and a consensus was reached in the final evaluation.

The analysis showed that experts emphasize several critical factors when integrating video surveillance systems into the national infrastructure. These include the readiness level of existing ICT infrastructure, legal and regulatory flexibility, quality of technical maintenance, staff qualifications, stability of financial resources, and public trust in the system.

According to the experts, the most optimal solution for Uzbekistan is to implement a centralized, modular, and multi-level management system. In such a model, all monitoring points are connected to a single central server, information flows are processed automatically, and various levels of users — traffic safety authorities, emergency services, and local administrations — are provided with separate functional interfaces. As a result, a highly automated and stable system is established.

Most experts considered a phased integration approach to be appropriate. Initially, it was proposed to implement pilot projects on the main arterial roads of the capital and major cities, as well as at points with high accident risk. Additionally, involving local manufacturers and IT companies would allow nationalization of system components, reduce maintenance costs, and accelerate staff training.

Legal experts recommended particular caution in this area. They noted that the current “Law on Personal Data” should be updated to include clear provisions on the legal status of video surveillance data, retention periods, and procedures for providing data to third parties. Such measures would ensure citizens’ privacy while simultaneously strengthening public trust in the system.

Table 3

Expert assessment results on the implementation of video surveillance systems

Direction	Expert Group	Key Opinions and Recommendations
ICT Infrastructure	ICT Specialists	Technical readiness exists, but optical communication and server resources are limited; a centralized, modular system is recommended.
Transport and Safety Management	Traffic Safety (YHXX) and Emergency Services (FVV) Representatives	The system must ensure real-time response and increase efficiency in emergency situations.

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Legal Compliance	Legal Experts	The "Law on Personal Data" should include specific provisions regarding video data (legal status, retention period, and transfer procedures).
Social Acceptance	Sociologists and Communication Specialists	Public awareness campaigns, transparency, and trust-building are necessary; misconceptions hinder system effectiveness.
Technical Maintenance and Personnel	Technologists and Higher Education Academics	Involve local IT companies, nationalize technical maintenance, and systematize personnel training.
Project Phases	Consensus of All Experts	Pilot projects should initially be implemented in the capital and major cities, with gradual phased expansion thereafter.

Results:

The primary strategy of developed countries is to implement video surveillance systems on roads not merely as technical monitoring tools, but as integrated systems that convert collected data into digital management mechanisms. Advanced experiences show that merely installing cameras is insufficient; it is crucial to process the captured data in real time, transmit it to automated decision-making systems, and transform it into practical management actions.

For example, the ITS model implemented in the United States not only monitors traffic flow but is also synchronized with adaptive control mechanisms. Through this system, smart traffic lights and adaptive signals are automatically managed based on traffic density, and resources are directed to high-risk accident areas. In this context, video surveillance functions as an integral module of the traffic management system.

In South Korea and China, the extensive use of artificial intelligence and machine learning algorithms has transformed video surveillance systems from passive observation tools into active analytical systems. In China, for instance, historical data on each vehicle is collected to form risk profiles for drivers. This approach reduces human errors and allows rapid and precise interventions.

In European countries, particularly Germany, video surveillance systems are closely linked to transport policy and environmental monitoring. Here, data from video surveillance is used not only for traffic safety but also to reduce

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environmental impact. For example, vehicles that contribute significantly to pollution may face movement restrictions in certain areas.

Overall, the experience of advanced countries indicates that the effectiveness of video surveillance systems depends directly on their integration with other management systems, analysis of collected data, and automation of response measures. Their approach is not merely technical but systematic and managerial. In Uzbekistan, it is also possible to adapt this conceptual model.

The opportunities for implementing video surveillance systems in Uzbekistan are influenced not only by technical and political factors but also by social, economic, and institutional resources. Widespread use of mobile devices, rapid development of the internet, modernization of intercity highways, and the elevation of digital governance to the level of state policy create favorable conditions for large-scale deployment of such systems.

Additionally, electronic government platforms in Uzbekistan are gradually expanding. Platforms such as “my.gov.uz,” “avtotest.uz,” and the Agency for Public Services enable rapid notification of citizens regarding violations recorded by video surveillance systems and automatic processing of fines. This allows the system to function not merely as a monitoring tool but as part of state service delivery.

Another important factor is the growing interest of Uzbek youth in digital technologies and the development of a startup ecosystem. This creates opportunities to develop software solutions for video surveillance systems—such as facial recognition and traffic flow analysis—within national projects, increasing technological independence and reducing reliance on external sources for technical maintenance.

International cooperation opportunities are also significant. Organizations like the Asian Development Bank, the World Bank, and the European Union are ready to support infrastructure projects in Uzbekistan. Their technical assistance and grants can serve as initial funding sources for piloting video surveillance systems.

Moreover, ongoing digital reforms in the country—such as GPS monitoring, automated traffic lights, and the implementation of speed measurement devices—lay the foundation for a unified management system integrated with video surveillance. Therefore, to utilize existing opportunities effectively, it is crucial to implement technologies not separately but based on comprehensive integration.

Discussion:

The implementation of video surveillance systems on Uzbekistan’s roads should be viewed not only as a technological task but also as a multifaceted process

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with institutional and social dimensions. International experience shows that the effectiveness of such systems is not determined solely by the installation of cameras. The key outcome depends on their integration with existing management structures, legal frameworks, and the public's information culture.

Although the digital transformation process in Uzbekistan is developing rapidly, a systematic plan for adapting video surveillance systems to the national infrastructure has not yet been fully formed. Existing traffic management systems and information and communication technologies are not equally developed across regions; therefore, a phased implementation that considers regional characteristics is necessary. From this perspective, piloting high-resolution, AI-integrated video surveillance modules on the capital's main roads and major highways is considered appropriate.

From a legal standpoint, the protection of personal data remains one of the most debated issues among the public. Thus, during implementation, the system's transparency, data retention periods, and the rights of authorities to access and use information must be clearly defined by law. Considering that user-consent-based models are effective in European Union countries, it is important to adapt this experience in Uzbekistan according to local mentality and legal culture.

Another critical aspect is ensuring the uninterrupted operation of the system and the availability of maintenance mechanisms. Video surveillance systems are highly technological, and any failures or software interruptions can negatively affect overall management efficiency. Therefore, establishing regional technical service centers, involving local manufacturers, and guaranteeing the continuity of spare parts and software are necessary.

Foreign experiences indicate that video surveillance systems are most effective when integrated with other digital management and information systems. For example, real-time data exchange between city management centers, traffic safety authorities, and emergency and rescue services transforms the system from a simple monitoring tool into a strategic management mechanism. This approach not only detects violations but also prevents accidents, allocates resources efficiently, and ensures interoperability among state services.

Building public trust also requires special attention. Any security technology directly affects citizens' privacy; therefore, regular public awareness campaigns, transparency policies through media and social networks, and clear communication about system principles, objectives, and capabilities are essential. Citizens' trust in the system is directly linked to its effectiveness.

In Uzbekistan, the implementation of video surveillance systems on roads requires a strategic, multi-stage approach rather than merely a technological

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solution. The factors discussed in this section—from legal frameworks to technical stability, infrastructure compatibility, and social acceptance—are interrelated elements. Their coordinated application can transform video surveillance systems from a simple monitoring mechanism into a modern tool for management, safety, and public trust assurance.

Conclusion:

The studied international experiences and analyses conducted in Uzbekistan demonstrate that video surveillance systems are now strategically important not only for enhancing road safety or regulating traffic flow but also for rapid response to emergencies, strengthening digital governance, and forming an integral part of modern infrastructure. In developed countries, such systems are implemented as integrated technological complexes based on artificial intelligence, allowing in-depth data analysis, automated management decisions, and real-time safety monitoring.

For Uzbekistan, the necessary technical, institutional, and legal foundations for development in this direction are being established. In particular, the expansion of communication and ICT networks, increased traffic on intercity roads, the promotion of digital governance concepts at the state policy level, and legislative attention to personal data protection and information security create favorable conditions for large-scale implementation of video surveillance systems.

Ensuring the effective operation, reliability, and stability of such systems requires certification. The certification process evaluates not only technical specifications and software security but also accuracy, operational stability, and integration with existing information systems. It also assesses the qualifications of service organizations, quality of maintenance, and compliance with national and international requirements for data security.

When implementing video surveillance systems on a large scale, priority should be given to: compliance of technical equipment with national standards, clarity and consistency of legal regulations, effective integration with existing services, training qualified personnel, regular public information campaigns, and phased preparation of AI-based analytical modules and algorithms for certification.

In the next stages, the following priority measures should be implemented:

Pilot testing of video surveillance systems on intercity routes with high traffic loads and development of practical certification mechanisms;

Creation of AI modules to expand digital analysis and automated management capabilities, preparing them for metrological and functional evaluation;

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Mobilization of financial resources through public-private partnerships and optimization of certification costs;

Continuous monitoring of system effectiveness and safety, defining the validity period of certificates, and updating them as needed.

The introduction and systematic certification of video surveillance systems on Uzbekistan's roads will contribute not only to enhanced road safety but also to deeper digital reforms in public administration, improved citizen safety, and higher quality of state services. Therefore, phased implementation, based on thorough planning and mandatory certification practices, represents a critical strategic direction for Uzbekistan.

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