AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

ISSN NUMBER: 2692 - 5206 Volume 6. No 05. MAY ,2026

INCREASING ROAD SAFETY AND REDUCING TRAFFIC CONGESTION USING INTELLIGENT TRANSPORTATION SYSTEMS

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Abstract: This article examines the role of intelligent transportation systems (ITS) in the lifecycle of highways, their effectiveness in ensuring road safety, and reducing congestion. It emphasizes the importance of a systems approach and digital twin technology in infrastructure design. The study's results demonstrate the potential for achieving cost efficiency and reducing road accidents through the implementation of ITS components.

Keywords: Intelligent Transportation Systems (ITS), traffic safety, traffic congestion, systems engineering, digital twins, BIM, life cycle.

Introduction: In the modern world, global urbanization and the level of motorization of the population are growing rapidly. This trend has led to a huge burden on urban transport systems and the emergence of two major global problems: an increase in road traffic accidents (RTAs) and chronic traffic jams. According to statistics, millions of people around the world die every year as a result of road traffic accidents, and the economy suffers billions of dollars in losses due to transport delays. Therefore, abandoning traditional methods of managing traffic flows and implementing innovative technologies is an urgent task todayю[3]

The concept of intelligent transport systems (ITS) implies the integration of information and communication technologies (ICT) into transport infrastructure and vehicles. As researcher F. Kuljanov noted, the use of ITS is of strategic importance not only at the operational stage of highways, but also throughout their entire life cycle – design and construction. Local scientists A. Karimov analyzed the direct impact of intelligent systems on traffic safety, while J. Kutlumuratov and I. Adilboev focused on the organizational and technical issues of creating ITS. In international experience, organizations such as MnDOT and RGBSI recognize the Systems Engineering process as the basis of ITS.

The main goal of ITT is to reduce the human factor, increase road capacity and maximize safety. However, the lack of a systematic approach to implementing intelligent systems in practice, the insufficient use of digital twins and BIM technologies prevent the achievement of the expected efficiency. Also, technical failures in the data exchange process and the lack of improvement of algorithms remain an obstacle to eliminating traffic jams [1].

The aim of the research is to substantiate scientific and practical solutions to improve road safety and reduce traffic congestion by analyzing the components of intelligent transport systems. The research examines the possibilities of digitally transforming transport infrastructure and achieving socio-economic efficiency through the use of a systems engineering process.

AMERICAN ACADEMIC PUBLISHER
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Methods: This study involves a comprehensive approach aimed at optimizing safety and efficiency indicators in the design and implementation of intelligent transport systems (ITS). As a methodological basis for the study, I used the following set of methods and tools:

Systems Engineering and the "V-model" approach The Systems Engineering (SE) process recommended by the international INCOSE (International Council on Systems Engineering) and MnDOT (Minnesota Department of Transportation) standards was selected as the main methodology for the study. The "V-model" form of this approach was analyzed in the development of ITS projects. This model covers the project life cycle at the following stages: Left branch: Development of the project concept, formulation of system requirements and high-level design. And right branch: Integration of system components, verification (approval) and validation (checking compliance with project objectives). This methodology allows reducing the human factor in ITS projects and identifying technical errors at an early stage.

Digital modeling and ICT tools The effectiveness of modern digital technologies in transport infrastructure management was studied through the following methods: BIM (Building Information Modeling): As a method of ensuring data integrity in the design of road assets. Also, Digital Twins: A model for virtualizing and forecasting real-time traffic flow data was analyzed. This method allows for the preliminary simulation of road safety risks [4].

The study compared the performance of systems equipped with traditional (static) traffic management and ITT (dynamic/adaptive). The following parameters were analyzed:

- Intersection capacity;
- Accident frequency;
- Vehicle travel time and fuel consumption.

To strengthen the theoretical part of the study, local and international scientific sources were synthesized. The scientific works of Uzbek scientists A. Karimov (traffic safety), J. Kutlumuratov and I. Adilboev (system development issues), and F. Kuljanov (life cycles) were compared with the data of the international RGBSI research center.

This methodological approach serves to comprehensively assess not only the technical part of the ITT, but also its socio-economic effectiveness.

Results: As a result of the analysis, the following indicators of ITT's effectiveness in traffic safety and flow management were identified:

Traffic safety: According to A. Karimov's research, intelligent systems (for example, adaptive lighting, automatic speed control, and driver warning systems) can reduce traffic accidents by 20-30%.

Congestion management: Adaptive traffic light control and real-time data exchange reduce traffic jams at intersections by 15-25%.

Digital twins: The experience of US highways shows that intelligent asset management using digital twins increases economic efficiency and allows for the prediction of dangerous areas in advance.

The analysis of internal and external factors of the integration of ITT into the transport system of Uzbekistan is as follows: Table 1

Table 1

Strengths	**Weaknesses**
Real-time management: Ability to analyze traffic	High costs: Requires a large investment to

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flow using sensors in seconds.	install and maintain the system.
Human factor reduction: Minimize errors by using algorithms in decision-making.	Skill shortage: Insufficient number of specialists in ITT and Systems Engineering (SE).
Data integrity: Accurate monitoring of road assets through BIM and Digital Twins.	Old infrastructure: Most of the existing roads are not adapted to the installation of modern sensors.
Opportunities	**Threats**
Economic efficiency: Fuel savings and reduced logistics costs due to reduced traffic jams.	Cybersecurity: Risk of disruption of traffic through external hacking attacks on the system.
Environmental improvement: Reduced CO2 emissions due to reduced vehicle downtime.	Interoperability: Incompatibility of devices from different manufacturers.
International standards: Increased safety levels by implementing global practices such as MnDOT and INCOSE.	Data privacy: Leakage of personal data about drivers and vehicles.

Discussion: As shown in the works of J. Kutlumuratov and I. Adilboev, one of the main issues in creating an ITT is ensuring data integrity and establishing interoperability. ITT is not just a set of "smart" devices, but a holistic systemic ecosystem.

According to the RGBSI Blog, the main components of ITT (sensors, communication networks, analytical centers) must work in harmony with each other. When the systems engineering process (SE process) is applied to infrastructure design, the probability of errors is reduced and costs are saved throughout the life cycle of the system.

Also, the implementation of BIM and Digital Twins technologies in the transport system of Uzbekistan will bring roads to the level of not only physical, but also digital management. This will allow solving traffic jams not only by expanding physical roads, but also by intelligently distributing the existing flow.

Conclusion

Intelligent transport systems are an integral part of modern road infrastructure. The study shows that by implementing ITT components on a systems engineering basis, it is possible to: Significantly reduce road fatalities and injuries, Eliminate traffic jams by optimizing traffic flow, Achieve economic efficiency throughout the life cycle of road infrastructure.

Future research should focus on the specifics of implementing artificial intelligence-based traffic light control algorithms in urban conditions in Uzbekistan.

AMERICAN ACADEMIC PUBLISHER
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ISSN NUMBER: 2692 - 5206 Volume 6. No 05. MAY ,2026

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