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TRANSPORT SAFETY AND MODERN SCIENTIFIC-THEORETICAL APPROACHES

Kalauov Saidulla Aymakhanovich
Candidate of Technical Sciences, Professor of the Academy of the Ministry of Internal Affairs of the Republic of Uzbekistan,
Shukurov Nuritdin Rakhimovich
Candidate of Technical Sciences, Associate Professor Academy of the Ministry of Internal Affairs of the Republic of Uzbekistan
Dr.nuritdin@yandex.ru
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Abstract: This article analyzes the contemporary concept of transport safety, its theoretical and methodological foundations, as well as advanced approaches to risk management in transport systems. Transport safety is considered as a multifaceted system associated with road traffic accidents, technical failures, human factors, natural and technological hazards, information security, and the resilience of transport infrastructure. The article examines the theoretical and practical significance of a systems approach, risk management, consideration of human factors, digitalization, artificial intelligence, and intelligent transport systems. Particular attention is also given to the role of preventive monitoring, data-driven management, and the development of a safety culture in ensuring transport safety.

Key words: transport safety, transport system, hazard, risk, road traffic accident, human factor, intelligent transport systems, digitalization, artificial intelligence, monitoring, risk management.

Introduction. The transport system is a strategic infrastructure that ensures the functioning of the national economy, interregional connectivity, and the social mobility of the population. The continuity and reliability of transport services have a direct impact on the stability of economic processes. Therefore, ensuring transport safety should be considered a comprehensive task encompassing not only technical but also economic, organizational, legal, social, and informational factors.

In traditional approaches, transport safety has primarily been associated with preventing road traffic accidents, monitoring the technical condition of vehicles, and ensuring compliance with traffic regulations. Under modern conditions, however, transport systems are becoming increasingly complex, with a growing role played by digital technologies, automated control systems, sensors, telematics, and artificial intelligence technologies. As a result, the concept of safety has also expanded, requiring physical, technical, and cybersecurity elements to be considered as an integrated system.

The Theoretical Essence of Transport Safety.

Transport safety can be interpreted as the state of a transport system in which risks capable of causing harm to human life and health, property, infrastructure, and the environment are limited to an acceptable level.

The main components of transport safety include:

1. Road Traffic Safety – the safe organization of the movement of vehicles and pedestrians.

2. Technical Safety – ensuring the proper technical condition of vehicles, roads, and transport infrastructure.

3. Operational Safety – compliance with established requirements and standards during the operation and use of transport vehicles.

4. Human-Factor Safety – taking into account the qualifications, psychophysiological condition, and behavior of drivers, operators, dispatchers, and other personnel.

5. Information and Cybersecurity – protecting digital transport systems and data from unauthorized interference.

6. Environmental Safety – reducing the negative impact of transport activities on the environment.

From this perspective, transport safety is not a narrow concept aimed solely at preventing individual incidents. Rather, it is a continuous process of identifying, assessing, mitigating, and monitoring risks throughout the entire life cycle of the transport system.

A Systems Approach to Transport Safety.

A systems approach plays an important role in modern scientific research on transport safety. According to this approach, a transport incident may not be the result of a single cause but rather the outcome of interactions among the human factor, vehicle, road infrastructure, external environment, and management system.

Transport safety can conventionally be represented through the following system: Human → Vehicle → Infrastructure → External Environment → Management → Information System.

A malfunction or inconsistency in one of these elements may affect the other elements as well. For example, even if the technical condition of a vehicle is satisfactory, poor road lighting, unfavorable weather conditions, or driver fatigue may increase the level of risk.

Therefore, rather than isolating individual factors when ensuring safety, it is more effective to study their interrelationships and interactions.

Risk Management as a Key Element of the Modern Approach.

The concept of risk is of particular importance in transport safety. Risk is associated with the probability of a hazardous event occurring and its potential consequences.

In general terms, risk can be expressed as follows:

$$R = P \times C,$$

where:

R – risk level;

P – probability of occurrence of a hazardous event;

C – potential consequences of the event.

This model makes it possible to prioritize risks when making management decisions concerning transport safety. In this context, it is appropriate to allocate resources first to factors that pose the greatest risks.

The risk management process generally consists of the following stages:

hazard identification → risk assessment → prioritization → risk mitigation → monitoring → reassessment of results.

Such a cyclical approach transforms transport safety from a one-time control measure into a continuous management process.

Human Factors and Safety.

The human factor is considered a separate scientific area in the study of safety problems within transport systems. A driver's attention, fatigue, experience, stress level, decision-making speed, and ability to correctly assess risks are important factors affecting transport safety.

Therefore, the modern concept of transport safety emphasizes not only disciplinary control over drivers but also the creation of a transport environment that reduces the likelihood of human error.

Examples include:

- optimizing drivers' work and rest schedules;
- regularly updating professional training;
- developing safe driving skills;
- using technologies for detecting driver fatigue;
- implementing driver-assistance systems that compensate for human errors.

Thus, the human factor should not be viewed solely as a weak point in transport safety but also as an important component of the safety system when properly managed.

Digitalization and Intelligent Transport Systems.

The digitalization of the transport sector creates new opportunities for ensuring safety. Intelligent Transport Systems (ITS) enable the collection, processing, and analysis of information about traffic flows, road conditions, and vehicles in real time.

The use of sensors, video surveillance, navigation technologies such as GPS/GLONASS, telematics, and automated control systems expands the possibilities for early detection of hazardous situations.

Artificial intelligence-based algorithms can analyze large volumes of data and be used to identify abnormal conditions in traffic flows, forecast congestion, and determine potentially hazardous road sections.

However, digitalization also creates new risks, including:

- unauthorized access to information systems;
- corruption or loss of data;
- software errors;
- excessive dependence on automated systems;
- cyberattacks.

Therefore, digital transport safety should be considered together with physical safety as an integral part of the overall transport security system.

Preventive Safety and Predictive Analytics.

Traditional safety systems often place considerable emphasis on analyzing incidents after they have occurred. The modern approach, by contrast, seeks to identify and mitigate risks before an incident takes place.

Predictive analytics makes it possible to forecast potential hazardous situations based on large volumes of data obtained from vehicles and transport infrastructure.

For example, regular analysis of information concerning a vehicle's:

- speed;
- braking performance;
- technical condition;
- direction of movement;
- fuel or energy consumption;
- service life can help identify technical malfunctions or hazardous operating conditions in advance.

In this regard, the predictive safety model is based on the following sequence:

data collection → data analysis → risk forecasting → preventive action → outcome monitoring.

Priority Areas for Improving Transport Safety.

To develop transport safety in accordance with modern requirements, it is advisable to implement the following areas comprehensively:

First, it is necessary to develop a unified system of transport safety indicators. This system should take into account not only the number of road traffic accidents that have occurred but also hazardous situations, technical failures, infrastructure conditions, and the effectiveness of preventive measures.

Second, digital monitoring systems for transport infrastructure should be expanded. This will make it possible to identify hazardous road sections and allocate resources more effectively.

Third, it is important to develop a human-factor-oriented safety policy. Driver training, retraining, and professional development systems should be improved in accordance with modern psychological and technological requirements.

Fourth, it is necessary to automate the diagnosis of vehicle technical conditions and develop predictive maintenance mechanisms.

Fifth, cybersecurity requirements in digital transport systems should be strengthened. In particular, within automated and interconnected transport systems, information security should become an integral component of the overall safety concept.

Conclusion. Transport safety under modern conditions is emerging as a multidimensional and dynamic system. Its effectiveness is determined not only by the technical condition of vehicles or compliance with traffic regulations. The interaction and integration of human factors, infrastructure, external environmental conditions, management mechanisms, digital technologies, and cybersecurity collectively shape the overall level of transport safety.

Modern scientific and theoretical approaches envisage a transition from a reactive transport safety management model to a proactive and predictive management model. In this context, early identification of risks, their qualitative and quantitative assessment, the use of digital data, and the development of preventive measures are of particular importance.

Thus, the key condition for improving transport safety is the integrated management of technical, organizational, human, and digital factors within a unified system. Intelligent Transport Systems, artificial intelligence, predictive analytics, and real-time monitoring may become important scientific and practical tools for managing transport safety in the future.

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