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SYSTEMIC CHARACTERISTICS AND MAIN STRUCTURAL ELEMENTS OF VEHICLE SAFETY

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 examines the concept of vehicle safety from a systemic perspective. The study considers the interrelationship between the main components that determine transport safety, including the human factor, the technical condition of vehicles, road infrastructure, and environmental conditions. Particular attention is paid to the development of active and passive vehicle safety systems, electronic control technologies, advanced driver assistance systems, and digital technologies aimed at preventing road traffic accidents and reducing their consequences. The article emphasizes the importance of a systemic approach to assessing vehicle safety and identifies the role of modern digital technologies in improving the reliability and efficiency of road transport safety systems.*
Keywords: *vehicle safety, road traffic safety, automobile, human factor, active safety, passive safety, technical condition, digital technologies, ADAS, intelligent transport systems.*

Introduction. Road transport is one of the most important components of modern economic and social infrastructure. The widespread use of automobiles provides significant opportunities for mobility and economic development while simultaneously increasing the importance of ensuring road traffic safety and reducing the risks associated with road traffic accidents.

Vehicle safety cannot be determined solely by the technical condition of an automobile. The overall level of safety is influenced by the driver's behavior, vehicle design and operating characteristics, road infrastructure, weather and road conditions, and the effectiveness of traffic management systems.

Therefore, vehicle safety should be considered not as a set of independent technical characteristics but as a complex system in which individual components interact with and influence one another.

A systemic approach considers transport safety as an integrated system consisting of several interconnected components. The principal components can be represented as follows:

– *Human factor* – drivers, passengers, pedestrians, and other road users;

– *Vehicle* – its structural, technical, and operational characteristics;

– *Road infrastructure* – roads, intersections, traffic signs, traffic signals, and traffic management systems;

– *External environment* – weather, climate, visibility, road surface conditions, and other environmental factors;

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– *Management and information systems* – traffic monitoring, communication, control, and digital technologies.

The failure or insufficient performance of any one of these elements can negatively affect the safety of the entire system. For example, even a technically advanced vehicle may become involved in a road traffic accident because of driver inattention, poor road conditions, or inadequate visibility.

Consequently, transport safety is the result of the coordinated interaction of the "human–vehicle–road–environment" system.

The primary purpose of active safety systems is to prevent road traffic accidents or reduce the probability of their occurrence.

Modern vehicles may include a wide range of active safety technologies, such as:

- braking systems;
- anti-lock braking systems (ABS);
- traction control systems;
- electronic stability control (ESC);
- tire pressure monitoring systems;
- adaptive cruise control;
- automatic emergency braking;
- lane departure warning systems;
- blind-spot monitoring systems;
- driver monitoring systems.

These technologies enable continuous monitoring of vehicle movement parameters and road conditions. When a potentially dangerous situation is detected, the system can warn the driver or, in certain circumstances, automatically intervene in vehicle control.

The development of active safety systems is closely associated with the increasing use of cameras, radar sensors, lidar technologies, electronic control units, and other digital components.

Passive safety systems are designed to reduce the severity of injuries and protect vehicle occupants when a road traffic accident has already occurred.

The main elements of passive safety include:

- seat belts;
- airbags;
- crumple zones;
- head restraints;
- child restraint systems;
- energy-absorbing structural elements;
- reinforced passenger compartments.

The effectiveness of passive safety depends on the interaction between vehicle structure, materials, restraint systems, and occupant protection technologies.

Modern vehicle design increasingly focuses on controlling and absorbing collision energy so that its impact on the passenger compartment is minimized. The structural integrity of the passenger compartment is therefore one of the fundamental elements of passive vehicle safety.

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The human factor plays a central role in the transport safety system. A driver's experience, attention, psychological and physiological condition, decision-making ability, and compliance with traffic regulations directly affect road safety.

Driver fatigue, distraction, the use of mobile devices while driving, excessive speed, and insufficient attention to road conditions can increase the probability of dangerous situations.

In this context, driver monitoring technologies are becoming increasingly important. Such systems can analyze certain behavioral and physiological indicators and provide warnings when signs of distraction or reduced attention are detected.

Thus, modern vehicle safety increasingly involves not only technical systems but also technologies designed to support the driver and compensate for certain human limitations.

Vehicle safety cannot be considered independently of road infrastructure. Road geometry, pavement quality, lighting, traffic signs, traffic signals, pedestrian crossings, and intersection design all have a direct influence on road traffic safety.

The development of modern road infrastructure increasingly involves:

- intelligent traffic signal systems;
- automated traffic monitoring;
- real-time traffic flow analysis;
- road condition monitoring;
- automated speed control;
- communication between vehicles and road infrastructure.

These technologies make it possible to improve traffic management, identify potentially hazardous road sections, and provide timely information to road users.

Digitalization is transforming the modern approach to transport safety. Sensors, artificial intelligence, big data, cloud technologies, and automated control systems are expanding the ability of vehicles to monitor their surroundings and identify potential hazards.

In particular, Advanced Driver Assistance Systems (ADAS) provide drivers with information and assistance in potentially dangerous situations. Depending on the specific system, ADAS technologies can warn the driver, assist with vehicle control, or automatically perform certain safety-related actions.

The further development of communication technologies between vehicles (V2V – Vehicle-to-Vehicle) and between vehicles and infrastructure (V2I – Vehicle-to-Infrastructure) may become an important component of future road safety systems.

Such technologies enable vehicles to exchange information about traffic conditions, potential hazards, road infrastructure, and the movement of other vehicles. This creates opportunities for earlier identification of risks and more coordinated responses to dangerous situations.

Assessment of transport safety should not be limited to the number of road traffic accidents. A comprehensive evaluation should take into account technical, human, infrastructural, environmental, and organizational factors.

The following indicators may be considered in a systemic assessment:

- technical condition of vehicles;
- operational status of active safety systems;
- availability and effectiveness of passive safety systems;

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- driver behavior;
- road and weather conditions;
- traffic flow density;
- road traffic accident statistics;
- number of hazardous road sections;
- emergency response time.

A systemic assessment makes it possible to identify causal relationships between different risk factors and develop preventive measures aimed at reducing the probability and severity of road traffic accidents.

Conclusion. Vehicle safety is a complex and multidimensional system whose effectiveness depends on the interaction of human, vehicle, road infrastructure, environmental, and technological factors. Therefore, improving road traffic safety requires a comprehensive approach rather than focusing exclusively on the technical condition of vehicles.

The development of active and passive safety systems, digital technologies, sensors, intelligent control systems, and advanced driver assistance systems is expanding the possibilities for preventing road traffic accidents and reducing their consequences.

The future development of transport safety should therefore be based on an integrated "human–vehicle–road–digital infrastructure–environment" model. Such an approach can contribute to the early identification of potential hazards, prevention of road traffic accidents, improvement of traffic management, and enhancement of the overall resilience and safety of road transport systems.

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