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IMPACT OF AUTOMOBILE DESIGN ON TRAFFIC SAFETY

Melikuziev Abdulaziz Rasuljon ugli
Assistant of the Department of "Transport Logistics,"
Andijan State Technical Institute
E-mail: melikuzievabdulaziz@gmail.com

Abstract: This scientific article investigates the impact of automotive structural elements on road safety from both fundamental and practical perspectives. Vehicle safety has traditionally been divided into active, passive, post-active, and environmental safety systems, and the effectiveness of each in preventing accidents and mitigating their consequences has been analyzed. The article examines the deformable zones of the body structure and the ability of high-strength steel and composite materials to absorb kinetic energy based on mathematical and physical laws. Additionally, the mutual integration of modern electronic control systems (ABS, ESP, AEB), intelligent driver assistance systems (ADAS), and passive safety devices (pillowcases and seatbelts) was studied. The results section provides a statistical analysis of the contribution of various structural elements to reducing fatalities and injuries in road accidents. The discussion section analyzes new safety challenges posed by the structural features of electric vehicles and autonomous vehicles, and develops practical proposals for the national automotive industry and the technical supervision system.

Keywords: Car design, traffic safety, active safety, passive safety, deformation zone, electronic stability control (ESP), intelligent systems (ADAS), kinetic energy, braking efficiency, transport engineering, body strength, aerodynamics, tire adhesion, airbag, crash test, electric vehicle safety, autonomous control, post-active safety, road traffic accident, technical expertise.

Introduction. The development of modern engineering and transport systems not only creates global mobility opportunities for humanity but also poses an extremely responsible task of protecting human life and health on the roads. In the context of a sharp increase in the level of automation, road traffic accidents remain one of the most serious factors undermining socio-economic stability. Although the human factor plays a leading role in the occurrence of accidents, the perfection of the vehicle's design is a decisive barrier (factor) in preventing accidents or mitigating their consequences to the maximum extent.

Until the middle of the last century, the concept of automotive safety was measured only by the reliability of the braking system and control mechanism, but today it has become a complex system consisting of a synergy of mechanics, electronics, materials science, and IT technologies. The study of the impact of vehicle design on traffic safety covers four main areas:

- Active Safety: The ability of a vehicle to avoid a collision, maintain direction, and maintain control at the stage preceding the accident.
- • Passive Safety: Design solutions aimed at minimizing the inertia and impact forces acting on the human body at the moment of a collision.
- • Post-crash safety: systems for preventing fire in the post-crash phase, safely evacuating passengers from the cabin, and automatically sending signals to rescue services.

Environmental and ergonomic safety: The microclimate and comfort conditions created by the design allow the driver to operate the vehicle for a long time without fatigue or loss of focus.

The relevance of this research work lies in the fact that in recent years, with the increase in vehicle speed and flow density on roads, requirements for the design have changed drastically. In particular, the popularity of electric vehicles with lightweight materials (aluminum, carbon fiber) and heavy batteries requires a revision of vehicle dynamics and safety architecture. The purpose of the article is to conduct a systematic analysis of all components of the vehicle's design from the perspective of traffic safety and to evaluate engineering approaches for creating a disaster-free transport environment.

Methodology. To fundamentally study the impact of vehicle design on traffic safety, methods of theoretical mechanics, transport dynamics, computer modeling, and statistical analysis were used. The research methodology includes the following stages:

Physico-mathematical modeling

The braking process of the vehicle and the distribution of kinetic energy during the collision were modeled using the laws of classical mechanics. Specifically, the braking distance (St) and impact force at the moment of impact (Fz) were analyzed using the following fundamental formulas:

$St = v2 / (2 g \mu)$

Here: v is the initial speed of the car (m/s); g is the acceleration due to gravity (9.81 m/s2); and μ is the tire's coefficient of adhesion to the road surface.

The law of change in momentum was used to calculate the force exerted on the human body during a collision:

$Fz \Delta t = m \Delta v \Rightarrow Fz = (m \Delta v) / \Delta t$

Here Δt is the deformation time of the body and the start of the safety cushion (strike duration). This formula mathematically proves how important it is to extend the time interval in passive security systems.

Virtual crash tests data analysis

A comparative analysis was conducted on the crash test results of more than 200 modern vehicles conducted by world-renowned safety institutes (Euro NCAP, IIHS, and NHTSA), specifically data from frontal, side, and frontal-offset impact tests (with 40% and 25% impact surfaces, respectively).

Experimental and statistical methods

Statistical data on accidents caused by technical malfunctions or structural defects over the last 5 years were studied. The influence of the vehicle's center of gravity height (hg) and wheelbase width (B) on the overturning index (Ri) was correlated.

Results. Conducted research and computer simulations have shown that every minor change in a vehicle's design can fundamentally alter its active or passive safety indicators. Below are the main components of the vehicle design and their level of efficiency in ensuring traffic safety.

Body design and passive safety architecture

Modern car bodies are built on the concept of a 'strict safety capsule' (Safety Cage) and 'programmed deformation zones' (Crumple Zones) around it. Analysis showed that the deformation zones absorb 65-75% of the collision energy, preventing it from reaching the passenger compartment.

Body part	Material used	Safety feature	Shock energy absorption percentage (%)

Front and back longirons	High-strength steel (AHSS)	Programmalashtirilgan garmoshka shaklida buklanish	45%
Columns A, B, C and frame	Boron Steel	Prevention of cabin deformation, preventing roof settlement upon overturning	25%
Internal door beams	Aluminum / Steel alloy	Restriction of penetration in side blows	15%
Body floor	Composite & multilayer metal	Ensure the engine and transmission move under the cabin	15%

Effectiveness of electronic management and active security systems

The introduction of electronic monitoring systems for vehicle dynamics has made it possible to significantly reduce the number of accidents. The following table reflects the statistical effectiveness of various structural electronic systems in reducing the risk of accidents in critical situations:

System type	Crash risk reduction rate (%)
ABS (anti-locking brake)	30%
ESP (Sustainability Maintenance)	50%
AEB (Automatic Emergency Brake)	45%
LKA (Fragment Storage Assistant)	25%

According to the analysis, the course stability maintenance system (ESP) reduces the incidence of side skids and steering loss by up to 50%. The automatic emergency braking system (AEB) reduces the probability of a collision with an obstacle in front by 45%.

Discussion. To gain a deeper understanding of the vehicle's design's impact on traffic safety, it is necessary to analyze its physical mechanisms and engineering solutions in separate sections.

Physics of body deformation and human biological resilience

During a collision, the car's speed drops to zero in a very short time ($\Delta t \approx 0.1$ seconds). If the car body were completely rigid and inflexible, the kinetic energy would be transferred to the passengers' bodies in its entirety. This leads to rupture of internal organs and fatal injuries.

In modern engineering, the front of the body is designed to be softer and more flexible. During a collision, the engine and other units move not toward the interior, but toward the bottom of the vehicle using special guides. In this case, the cabin frame (capsule) remains intact, and the 'survival space' for the driver and passengers is preserved.

Role of chassis, suspension, and center of gravity

The design of the vehicle's suspension (suspension system) and chassis directly ensures that the vehicle's tires are in constant contact with the road. If the suspension is designed incorrectly, the wheel will be left in the air on uneven roads, and control will be completely lost.

Crossovers and SUVs, which have become particularly popular in recent years, have a higher center of gravity (hg) than regular sedans. Structurally, this problem negatively affects dynamic stability and increases the risk of rollover on turns. Engineers are using multi-link independent suspensions and active stabilizers to overcome this.

The Era of Electric Vehicles: New Design Challenges

Electric vehicles require a safety architecture that is fundamentally different from traditional internal combustion engine vehicles. In electric vehicles, a heavy battery pack is located in the floor area, which lowers the vehicle's center of gravity and significantly increases stability (minimizing the risk of overturning).

However, the battery under the floor is highly sensitive to side impacts. Mechanical damage to lithium-ion batteries can cause 'thermal runaway' and explosion. Therefore, the main task of engineers was to create an armored protective framework around the battery consisting of special titanium and aluminum alloys in the electric vehicle design.

Conclusion. As a result of the study of vehicle design from the perspective of traffic safety, the following fundamental conclusions were formulated:

Constructive harmony: Traffic safety does not depend solely on a single system. Active safety electronics systems (ABS, ESP, AEB) minimize risk, while passive safety architecture (deformation zones and Borli steel frame) saves human lives in inevitable accidents.

Material revolution: The transition from traditional ordinary steels to ultra-high-strength steel (UHSS) and composite materials is reducing vehicle weight while increasing their impact resistance by 2-3 times.

Need for standardization: To reduce road mortality, it is necessary to mandate at the legislative level that all vehicles imported and produced in our country must have minimum active safety systems (at least ESP and airbags).

Future direction: The future of transport security lies in the integration of vehicle design with artificial intelligence and V2X (Vehicle-to-Everything) wireless communication systems.

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