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Assessment and improvement of constructive safety of the Damas light passenger vehicle

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Abstract:

The article is devoted to assessing and improving the constructive safety of the Damas light passenger vehicle widely used in Uzbekistan. The study analyzes the influence of geometric parameters, vehicle stability, braking performance, and active safety systems on overall operational safety. Vehicle stability was evaluated using the Static Stability Factor (SSF), rollover resistance indicators, and braking performance calculations. The obtained results showed that the vehicle's constructive safety is significantly affected by its center of gravity position, track width, and the absence of modern active safety systems. The calculated stability indicators revealed an increased rollover risk during high-speed cornering maneuvers. A comparative analysis demonstrated that the implementation of Anti-lock Braking Systems (ABS) and Electronic Stability Control (ESC) could significantly improve vehicle stability and controllability under critical driving conditions. Based on the findings, engineering recommendations aimed at enhancing vehicle safety, reducing accident risk, and improving operational reliability were developed. The proposed measures can contribute to improving road safety and increasing the efficiency of light passenger vehicle operation under the road and climatic conditions of Uzbekistan.

Keywords:

constructive safety, vehicle stability, Damas vehicle, rollover resistance, braking performance, ABS, ESC, road safety, vehicle dynamics, operational reliability

1. Introduction

The rapid growth of the global automotive industry has significantly increased the number of vehicles operating on roads worldwide. Along with the expansion of vehicle ownership, issues related to road traffic safety have become one of the most important challenges facing modern transportation systems. According to international studies, vehicle design characteristics directly affect the severity of traffic accidents, passenger protection levels, vehicle stability, and overall operational safety [1-5]. Therefore, improving the constructive safety of motor vehicles remains a priority area of research in automotive engineering and transportation safety science.

In recent years, substantial efforts have been undertaken to improve vehicle safety through the implementation of advanced braking systems, electronic stability control technologies, traction control systems, reinforced body structures, and intelligent driver assistance systems. These technological developments have considerably reduced accident rates and injury severity in modern passenger vehicles [4,5]. However, a significant proportion of vehicles currently in operation in developing countries continue to utilize relatively outdated design solutions that do not fully satisfy contemporary safety requirements.

The Republic of Uzbekistan has experienced a steady increase in vehicle ownership during the last decade. The expansion of the national vehicle fleet has contributed positively to economic development and population mobility. At the same time, the increasing traffic intensity has led to a growing number of road traffic accidents, emphasizing the necessity of improving vehicle safety characteristics. Government programs aimed at modernizing

the transport sector and enhancing road safety have identified the improvement of vehicle operational and constructive safety as a strategic objective for sustainable transportation development [18].

Among the vehicles widely used in Uzbekistan, the Damas light passenger vehicle occupies a special position due to its affordability, maneuverability, and suitability for urban and rural transportation. The vehicle is extensively used for passenger transportation, small-scale commercial activities, and family mobility. Despite its widespread utilization, the Damas vehicle possesses several design limitations associated with its relatively narrow track width, high center of gravity, lightweight body structure, and lack of modern active safety systems such as Anti-lock Braking System (ABS), Electronic Stability Control (ESC), and Traction Control System (TCS).

Numerous studies have demonstrated that vehicle stability during braking, cornering, and emergency maneuvers is strongly influenced by geometric parameters, weight distribution, suspension characteristics, and tire-road interaction conditions. Insufficient stability may lead to skidding, rollover accidents, and loss of vehicle controllability, particularly under adverse road and weather conditions. Consequently, comprehensive assessment of constructive safety parameters is necessary to identify potential risks and develop effective engineering solutions for improving vehicle safety performance [1-3,10].

Previous investigations have mainly focused on vehicle dynamic behavior, braking efficiency, rollover resistance, and active safety technologies for modern passenger cars. However, limited attention has been paid to the constructive safety assessment of compact light passenger vehicles operating under the specific road and climatic conditions of Uzbekistan. In particular, the stability characteristics and

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safety improvement potential of the Damas vehicle remain insufficiently studied, creating a significant research gap in the existing literature.

Therefore, the objective of this study is to evaluate the constructive safety characteristics of the Damas vehicle by analyzing its stability, braking performance, and operational safety indicators, as well as to develop technically justified recommendations for improving its safety level. The obtained results may contribute to enhancing road safety, reducing accident risks, and improving the operational reliability of light passenger vehicles used under typical operating conditions in Uzbekistan.

LITERATURE REVIEW

Vehicle safety has become one of the most actively developing research areas in modern automotive engineering. The increasing number of vehicles worldwide has led researchers to focus on improving both active and passive safety systems in order to reduce road traffic accidents and their consequences. Active safety systems are designed to prevent accidents, while passive safety systems aim to minimize injuries when accidents occur.

Numerous studies have confirmed that vehicle stability is one of the key indicators of constructive safety. According to the research conducted by Thomas D. Gillespie, the stability of a vehicle depends on its geometric dimensions, center of gravity position, wheelbase, track width, suspension characteristics, and tire-road interaction conditions [1]. Vehicles with a high center of gravity and narrow track width are generally more susceptible to rollover and loss of control during cornering maneuvers. These findings are particularly relevant for compact passenger vehicles widely used in urban transportation systems.

Considerable attention has been devoted to the development and implementation of modern active safety technologies. Studies carried out by the National Highway Traffic Safety Administration demonstrated that Anti-lock Braking Systems (ABS) significantly improve vehicle controllability during emergency braking by preventing wheel lock-up. The introduction of ABS technology has reduced braking-related accidents and improved vehicle stability on slippery road surfaces [4].

Further advancements in vehicle safety were achieved through the implementation of Electronic Stability Control (ESC). Research conducted by European New Car Assessment Programme indicated that ESC systems can reduce the risk of rollover accidents by approximately 30–50% and significantly improve directional stability during critical driving situations [5]. These systems continuously monitor vehicle motion parameters and automatically apply braking forces to individual wheels when instability is detected.

Vehicle rollover resistance has also been extensively investigated by many researchers. Studies by Rajesh Rajamani emphasized that rollover accidents are strongly associated with the relationship between vehicle track width and center of gravity height [2]. The Static Stability Factor (SSF) is commonly used as an indicator for evaluating rollover propensity. Vehicles with higher SSF values generally demonstrate better resistance to rollover under dynamic driving conditions.

Recent investigations have focused on improving vehicle safety through computer-aided simulation and mathematical modeling. Finite Element Analysis (FEA), multibody dynamic simulation, and virtual crash testing have become standard engineering tools for evaluating

vehicle behavior before physical prototype manufacturing [3,10,13]. Such approaches reduce development costs while increasing the reliability of safety assessments.

Researchers in Uzbekistan have mainly concentrated on vehicle operational reliability, technical diagnostics, traffic safety, and transportation efficiency. The works of Hamraqulov, Fayzullayev, Sidiqazarov and other scholars have contributed significantly to understanding vehicle operation under local road and climatic conditions. However, most studies have focused on technical operation and maintenance issues rather than constructive safety assessment of light passenger vehicles [6-8].

Despite the considerable progress achieved in vehicle safety research, the constructive safety characteristics of compact light passenger vehicles operating under the specific conditions of Uzbekistan remain insufficiently investigated. In particular, there is limited scientific information regarding the stability, braking performance, rollover resistance, and safety improvement potential of the Damas vehicle. This gap in the existing literature highlights the necessity of conducting comprehensive research aimed at evaluating its constructive safety parameters and developing practical recommendations for their improvement.

Therefore, the present study focuses on assessing the constructive safety of the Damas vehicle through analysis of stability indicators, braking characteristics, and potential engineering measures intended to enhance operational safety under real operating conditions.

2. Methodology

Research Object. The object of this study is the Damas light passenger vehicle, which is widely used in Uzbekistan for urban and suburban transportation. Due to its compact dimensions, low fuel consumption, and economic affordability, the Damas vehicle occupies an important position in the national transport system. However, compared with modern passenger vehicles, its constructive safety characteristics require further investigation.

The main technical specifications of the investigated vehicle are presented in Table 1.

Table 1

Main technical parameters of the Damas vehicle

Parameter	Value
Vehicle type	Light passenger vehicle
Engine displacement	0.8 L
Vehicle mass	850 kg
Wheelbase	1840 mm
Overall length	3485 mm
Overall width	1400 mm
Overall height	1920 mm
Ground clearance	160 mm
Seating capacity	7 persons



The technical characteristics were obtained from the manufacturer's specifications and vehicle operation manuals [19].

Method for Evaluating Vehicle Stability. Vehicle stability was assessed using geometric parameters affecting rollover resistance and lateral stability.

One of the most important indicators of constructive safety is the Static Stability Factor (SSF), which can be determined using the following equation:

$$SSF = \frac{T}{2H}$$

where:

T – vehicle track width, m;

H – height of the center of gravity, m.

The Static Stability Factor characterizes the resistance of the vehicle to rollover during cornering maneuvers. Higher SSF values indicate greater vehicle stability [1,2].

To determine the critical rollover speed, the following relationship was used:

$$V_r = \sqrt{gR \frac{T}{2H}}, [2,10]$$

where:

V_r – rollover speed, m/s;

g – gravitational acceleration (9.81 m/s²);

R – turning radius, m;

T – track width, m;

H – center of gravity height, m.

This equation allows estimation of the vehicle speed at which rollover becomes theoretically possible during cornering [21].

Braking Performance Assessment. Vehicle braking efficiency was evaluated by determining braking distance under dry asphalt road conditions.

The braking distance was calculated according to:

$$S_b = \frac{V^2}{2g\varphi}, [11,15]$$

where:

S_b – braking distance, m;

V – initial vehicle speed, m/s;

g – gravitational acceleration, m/s²;

φ – tire-road adhesion coefficient.

To account for driver reaction time, total stopping distance was determined using:

$$S_t = S_r + S_b$$

where:

S_t – total stopping distance, m;

S_r – reaction distance, m;

S_b – braking distance, m.

These indicators are widely used in vehicle safety analysis and transportation engineering studies [22].

Safety Improvement Assessment. To improve the constructive safety of the Damas vehicle, several engineering measures were analyzed:

- installation of an Anti-lock Braking System (ABS);
- implementation of an Electronic Stability Control (ESC) system;
- optimization of vehicle mass distribution;
- reduction of the center of gravity height;
- improvement of suspension stiffness characteristics.

The effectiveness of these measures was evaluated through comparative analysis of stability and braking

indicators before and after implementation. The expected improvement level was estimated using published safety-performance data reported in previous international studies [12,13,16].

Data Processing and Analysis. All calculations were performed using analytical methods commonly applied in vehicle dynamics and transportation engineering. The obtained results were processed and compared with safety requirements established in international vehicle safety standards and recommendations.

The calculated stability coefficient, rollover resistance parameters, and braking characteristics were used as the main criteria for evaluating the constructive safety level of the Damas vehicle under operating conditions typical of Uzbekistan.

3. Results

Evaluation of Vehicle Stability Characteristics. The constructive safety of the Damas vehicle was evaluated based on its geometric dimensions, weight distribution, and stability indicators. Particular attention was given to rollover resistance, as compact passenger vehicles with relatively high body structures are more susceptible to instability during cornering maneuvers.

Using the geometric parameters of the Damas vehicle, the Static Stability Factor (SSF) was calculated according to Equation (1). The vehicle track width was assumed to be 1.22 m, while the estimated center of gravity height was 0.75 m.

$$SSF = \frac{1,22}{2 \times 0,75} = 0,81$$

The obtained SSF value indicates a moderate level of rollover resistance. According to international vehicle safety studies, passenger vehicles with SSF values below 1.0 require additional attention regarding stability improvement measures [2,4,5].

To estimate rollover resistance under operating conditions, the critical rollover speed was determined for a turning radius of 50 m:

$$V_r = \sqrt{9,81 \times 50 \times 0,81}$$

$$V_r = 19,91 \text{ m/s}$$

$$V_r = 71,8 \text{ km/h}$$

The results show that the Damas vehicle may approach rollover conditions when negotiating relatively sharp curves at speeds exceeding approximately 72 km/h. This value is lower than that of many modern passenger vehicles equipped with advanced stability control systems.

Table 2

Calculated stability indicators of the Damas vehicle

Parameter	Value
Track width (m)	1.22
Center of gravity height (m)	0.75
Static Stability Factor (SSF)	0.81



Turning radius (m)	50
Critical rollover speed (km/h)	71.8

The obtained results indicate that vehicle stability can be significantly influenced by speed selection, road geometry, and loading conditions.

Braking Performance Analysis

Vehicle braking performance was assessed under dry asphalt road conditions with an adhesion coefficient of 0.75. Calculations were performed for a vehicle speed of 60 km/h.

The braking distance was determined using Equation (3):

$$S_b = \frac{v^2}{2g\phi} = \frac{16,67^2}{2 \times 9,81 \times 0,75} = 18,9 \text{ m}$$

Considering an average driver reaction time of 1 second, the reaction distance becomes:

$$S_r = 16,67 \times 1 = 16,67 \text{ m}$$

The total stopping distance is therefore:

$$S_t = 16,67 + 18,9 = 35,57 \text{ m}$$

Table 3

Braking performance indicators

Parameter	Value
Vehicle speed (km/h)	60
Adhesion coefficient	0.75
Braking distance (m)	18.9
Reaction distance (m)	16.7
Total stopping distance (m)	35.6

The analysis demonstrates that more than 45% of the total stopping distance is associated with driver reaction time. Consequently, driver awareness and active safety systems play an important role in accident prevention.

Comparative Analysis of Safety Systems

A comparison was conducted between the Damas vehicle and a modern passenger vehicle equipped with advanced active safety systems. The comparison focused on safety-related equipment influencing vehicle stability and braking efficiency.

Table 4

Comparison of safety-related features

Safety Parameter	Damas	Modern Passenger Vehicle
ABS	No	Yes
ESC	No	Yes
Traction Control System	No	Yes
Brake Assist	No	Yes
Rollover Stability Control	No	Yes

The comparison reveals that the Damas vehicle lacks several active safety technologies commonly used in modern automotive design. The absence of these systems may increase the probability of skidding, wheel lock-up, and rollover during emergency maneuvers.

Proposed Safety Improvements. Based on the obtained results, several engineering measures were proposed to improve the constructive safety of the Damas vehicle:

1. Installation of an Anti-lock Braking System (ABS);
2. Introduction of Electronic Stability Control (ESC);
3. Optimization of suspension parameters;
4. Reduction of the center of gravity height;
5. Improvement of tire-road adhesion characteristics.

Previous studies indicate that ABS implementation may reduce braking-related accidents by approximately 20–25%, while ESC systems can decrease rollover risk by up to 40% [5,12].

Table 5

Expected safety improvement after implementation of proposed measures

Improvement Measure	Expected Safety Improvement
ABS installation	20–25%
ESC implementation	30–40%
Suspension optimization	10–15%
Lower center of gravity	12–18%
Improved tire performance	5–10%

The implementation of these measures would significantly increase vehicle stability and reduce accidents under typical operating conditions in Uzbekistan.

Discussion. The obtained results demonstrate that the constructive safety level of the Damas vehicle is largely determined by its geometric configuration and the absence of modern active safety technologies. The calculated Static Stability Factor of 0.81 indicates acceptable stability for normal operating conditions; however, rollover risk increases considerably at higher speeds and during sudden steering maneuvers.

Braking analysis revealed that stopping distance remains within acceptable limits under dry road conditions. Nevertheless, the absence of ABS may negatively affect vehicle controllability during emergency braking, especially on wet or low-adhesion road surfaces.

Comparative analysis showed that the implementation of modern active safety systems could substantially improve vehicle stability and accident prevention capabilities. Therefore, modernization of the braking and stability control systems should be considered one of the most effective approaches to enhancing the constructive safety of light passenger vehicles operating in Uzbekistan [12,13,20–23].

4. Conclusion

The study evaluated the constructive safety characteristics of the Damas light passenger vehicle based



on stability and braking performance indicators. The obtained results showed that the vehicle's safety level is significantly influenced by its geometric parameters, center of gravity position, and the absence of modern active safety systems.

The calculated Static Stability Factor (SSF) of 0.81 and the critical rollover speed of 71.8 km/h indicate that vehicle stability may decrease during high-speed cornering and emergency maneuvers. Braking analysis demonstrated that the total stopping distance at 60 km/h is approximately 35.6 m under dry road conditions.

The research also revealed that the implementation of modern safety technologies such as ABS and ESC can significantly improve vehicle stability, braking efficiency, and rollover resistance. Therefore, introducing active safety systems, optimizing suspension parameters, and improving weight distribution are recommended as effective measures for enhancing the constructive safety of the Damas vehicle.

The proposed recommendations can contribute to improving road safety and increasing the operational reliability of light passenger vehicles under the operating conditions of Uzbekistan.

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