



# Safety Assessment of Road Railing on UB–Nalaikh Road

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**Abstract.** Road traffic accidents along the Nalaikh–Ulaanbaatar road have raised serious concerns regarding the adequacy of existing safety measures, particularly the effectiveness of safety railings. This research investigates the structural integrity and performance of these railings with the aim of enhancing road safety and reducing accident severity. The study employs a mixed-methods approach, including on-site assessments, consultations with local authorities and road safety experts, and an in-depth review of international safety railing standards. The evaluation reveals that while the current railings comply with certain Mongolian national standards, they fall short in effectively mitigating accident impacts due to shortcomings in design, material durability, and maintenance practices. Based on these findings, the study proposes a series of improvements, drawing on advanced international design standards and advocating for stricter maintenance protocols. These recommendations aim to improve the railings’ ability to prevent vehicles from veering off the roadway, thereby contributing to a safer commuting environment along this critical transportation corridor

**Keywords:** Road safety railing, Railing design, Railing standard.

## 1 Introduction

Road safety is a critical concern worldwide, with road traffic accidents accounting for a substantial number of fatalities, injuries, and economic losses each year. In Mongolia, this issue has become increasingly urgent along key transportation routes that support both economic and social activity. Among these, the Nalaikh–Ulaanbaatar road holds particular significance. This arterial road not only connects the capital city of Ulaanbaatar with the mineral-rich district of Nalaikh but also serves as a vital route for thousands of daily commuters and freight vehicles. Despite its importance, the road has seen a disturbing rise in traffic accidents, some of which have resulted in serious injuries and fatalities. One of the most pressing safety concerns along this road is the inadequacy of existing safety infrastructure, especially roadside safety railings. These railings are meant to prevent vehicles from veering off the road into potentially deadly hazards such as steep slopes, water bodies, or construction zones. When properly designed, installed, and maintained, safety railings significantly mitigate accident severity and protect road users from catastrophic

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outcomes. However, field observations and incident reports suggest that the safety railings along the Nalaikh–Ulaanbaatar road are frequently damaged, poorly maintained, or absent altogether. In addition, many of the existing railings appear to be outdated and may not be structurally capable of absorbing the impact from modern vehicles—particularly heavy trucks associated with mining operations in the region.

The growing rate of accidents has raised serious doubts about the effectiveness of current safety measures and highlights the need for a comprehensive reassessment of the road’s protective infrastructure. Furthermore, these railings often do not comply with modern international safety standards and fail to reflect the unique geographical and environmental conditions of the area—such as harsh winters, reduced visibility, and mixed vehicle types. The consequences of this inadequacy are not limited to human tragedy but also disrupt economic activity and contribute to increased public costs related to emergency response and road repairs.

This research aims to evaluate the current condition, performance, and design adequacy of safety railings along the Nalaikh–Ulaanbaatar road. The primary objectives include assessing the structural integrity of existing railings, identifying areas of critical deficiency, comparing the infrastructure against international best practices, and proposing realistic, context-sensitive improvements. The methodology combines on-site surveys, technical inspections, accident data analysis, and expert consultations with local authorities and road safety specialists. By addressing these issues, the study seeks to contribute to the broader goal of enhancing road safety in Mongolia. The findings and recommendations are expected to not only reduce the incidence and severity of traffic accidents along this crucial route but also provide a foundation for similar safety improvements across the national road network. This research thus aligns with both national development priorities and international commitments to promote safer, more sustainable transport systems. The significance of this study extends well beyond academic interest—it represents a critical step toward safeguarding human lives, improving infrastructure resilience, and supporting Mongolia’s economic connectivity. With the increasing demand for safer roads, particularly in regions with growing industrial activity, the results of this study will serve as a valuable reference for policymakers, engineers, and planners working to transform Mongolia’s roads into safer and more reliable arteries of development.

## 2 Literature Review

The body of research surrounding road safety railings has evolved considerably over the last century, reflecting shifts in both technological capabilities and road safety philosophies. Early railings were rudimentary, primarily serving to mark the edge of the road. Over time, and with the increase in traffic speed and vehicle weight, railing systems have been engineered to absorb impact energy and prevent vehicles from leaving the roadway, thereby reducing fatalities and serious injuries. Recent technological developments have further enhanced the functionality of safety railings. Innovations such as energy-absorbing terminals, cable barriers, and the integration of smart technologies have improved performance in diverse environments and accident conditions. These developments are aimed at increasing durability, minimizing

maintenance, and enhancing protection for road users. An essential aspect of safety railing development is the establishment and comparison of international standards. Countries such as those in the European Union and the United States (via AASHTO) have developed comprehensive guidelines for safety barrier performance. A comparative analysis reveals both universal principles and region-specific adaptations, offering a spectrum of global best practices that can inform improvements in countries with developing infrastructure like Mongolia. In the Mongolian context, studies have documented a rising trend in traffic accidents, many of which are linked to insufficient or poorly maintained road infrastructure. Empirical research and policy reviews indicate that while Mongolia has made efforts to adapt international safety standards, significant gaps remain due to economic, geographic, and administrative constraints. The lack of systematic evaluation of existing railings and limited integration of modern materials and design practices has left many roads vulnerable.

Tabiei (2000) used virtual crash testing to show that existing US guardrails, designed 30 years earlier, were unsuitable for SUVs/trucks and proposed modifications like post spacing, embed depth, and rail height under FHWA guidance [1]. Wu et al. (2018) employed LS-DYNA to model and optimize movable median guardrails per NCHRP350 and EN-1317. They refined segment length, friction, section shape, enhancing crash performance and occupant safety [2]. Leitlands et al. (2024) introduced glass fiber-reinforced LDPE composites for W-beam guardrails, citing advantages in corrosion resistance and durability [3]. Helaili et al. (2023) designed guardrail beams using *Stipa tenacissima* stems and pre-tensioning, showing improved energy absorption [4]. A US patent describes hollow plastic/composite structures filled with foam or liquids for enhanced energy dissipation—an early acknowledgment of composite guardrail potential [5]. AASHTO M 180 is the key US standard for corrugated steel beams, covering design, fabrication, testing, installation, and durability requirements [6]. Al Oide et al. (2025) developed an automated guardrail damage detection system using YOLOv8 computer vision integrated with GPS, enhancing inspection accuracy and reducing labor demands [7]. The National Academies detailed MASH-tested W-beam yield strength distribution, noting all met minimum thresholds (~50 ksi) with most above 60 ksi—crucial for barrier consistency [8].

### 3 Assessment of the Current Condition of Safety Railings

The condition assessment of the safety railings along the Nalaikh–Ulaanbaatar road revealed a troubling and widespread state of disrepair. Figure 1 shows the current state of the safety railings. A series of systematic field surveys conducted over multiple sections of the road documented numerous instances of visible deterioration, physical damage, and even complete absence of safety barriers in high-risk zones. These findings point to a significant degradation of this essential safety infrastructure, which could severely undermine road user protection and increase the likelihood of serious accidents. The most commonly observed issues were categorized into the following areas:

**Structural Damage:** A considerable number of railing segments exhibited extensive impact damage, likely resulting from past vehicular collisions. These damages ranged from bent and twisted steel sections to fully detached or collapsed railings. In many cases, the damaged railings were left unrepaired, thereby losing their capacity to contain or redirect errant vehicles—an essential function in preventing vehicles from leaving the roadway and crashing into surrounding hazards.

**Corrosion:** A pervasive issue identified during the assessment was the widespread corrosion affecting metallic components of the railings. Many of the barriers showed advanced rusting, particularly at the base where water accumulation and poor drainage may have accelerated degradation. The loss of metal due to rust not only weakens the railings structurally but also makes them more prone to failure upon impact, especially in the cold and humid climate conditions typical of Mongolia's harsh winters.

**Vandalism and Theft:** In several locations, parts of the safety railings appeared to have been deliberately removed, damaged, or tampered with. Reports from local authorities and visual evidence suggested instances of theft, likely driven by the resale value of metal components. Such actions significantly compromise the continuous protective function of the railings, leaving dangerous gaps that pose serious hazards to drivers, particularly at night or during poor weather conditions.

**Lack of Maintenance and Repair:** One of the overarching issues identified was the apparent lack of routine maintenance and timely repair efforts. Damaged or missing components were not replaced, and corroded sections had not been treated or reinforced. This neglect has allowed minor issues to evolve into serious structural vulnerabilities, rendering the system ineffective in many areas.

The cumulative effect of these deficiencies raises serious concerns about the safety railings' capacity to perform their intended protective functions under current traffic and environmental conditions. Without urgent intervention—through repairs, replacements, and the implementation of a robust maintenance regime—the railings along the Nalaikh–Ulaanbaatar road are unlikely to prevent accidents or mitigate their severity effectively. This situation necessitates immediate attention from transportation authorities, infrastructure planners, and policymakers to prioritize improvements in roadside safety features and to ensure long-term reliability of such critical infrastructure.



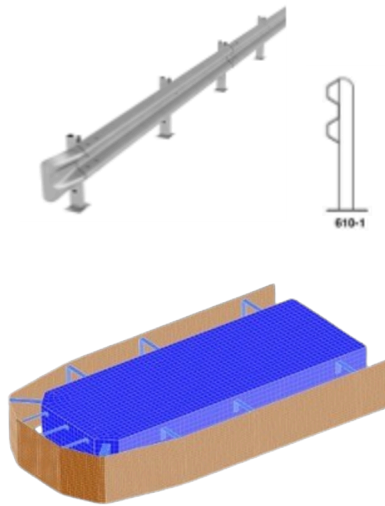
**Fig. 1.** The current condition of safety railings (guiderail) conditions.

## 4 Simulation of Safety Railing System

### 4.1 Simulation of vehicle impact

ANSYS LS-DYNA simulations were carried out to evaluate the structural integrity and impact resistance of the safety railings installed along the Nalaikh-Ulaanbaatar road. These simulations are essential for understanding the performance of the railings under various crash scenarios that replicate real-world conditions. The configuration of the current safety railing on the road between Nalaikh and Ulaanbaatar city is shown in Fig. 2. A simplified vehicle model, shown in Fig. 3, was adopted to reduce computational complexity and focus on the interaction between the vehicle mass and the guardrail structure. This approach is commonly adopted in crash analyses to evaluate barrier performance without simulating full vehicle deformation behavior. The crash test scenario involves a 2000 kg pickup truck impacting a Type T6 bridge

rail 900 mm upstream from the splice at post 11, at a speed of 99.5 km/h and an impact angle of 27.0 degrees.



**Fig. 2.** Safety railing configuration.

**Fig. 3.** The impact model of simulation vehicle.

The material used in this study for all components is an isotropic elastoplastic material modeled using the Zerilli-Armstrong plasticity formulation. This material model is applicable to components meshed with both shell and solid elements. The mechanical properties of steel for the impact model is shown in Table 1. The following equation describes the stress response during plastic deformation.

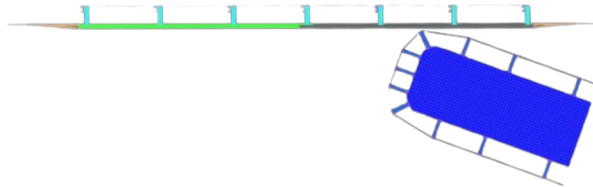
$$\sigma = C_1 + (C_2 \exp((-C_3 T + C_4 T \ln(\frac{\dot{\epsilon}}{\epsilon_0})))) + C_5 \epsilon_p^n$$

where:  $C_1$  is the plasticity yield stress,  $C_2$  is the strain rate formulation coefficient,  $C_3$  is temperature effect coefficient,  $C_4$  is temperature effect coefficient without strain rate effect,  $C_5$  is the plasticity hardening parameter,  $\epsilon_p$  is the plastic strain,  $\dot{\epsilon}$  represents the strain rate,  $T$  represents temperature, and  $n$  represents the plasticity hardening exponent, with the requirement that  $n$  must be less than 1,  $\epsilon_0$  represent reference strain rate.

**Table 1.** Mechanical properties of steel for the impact model.

Item	Input value
Initial density	$7.85 \times 10^{-6}$ kg/mm <sup>3</sup>
Poisson ratio	0.3
Hardening exponent	0.5

Hardening parameter	0.5 GPa
Failure plastic strain	0.3
Young modulus	210 GPa



**Fig. 4.** The base model for simulation.

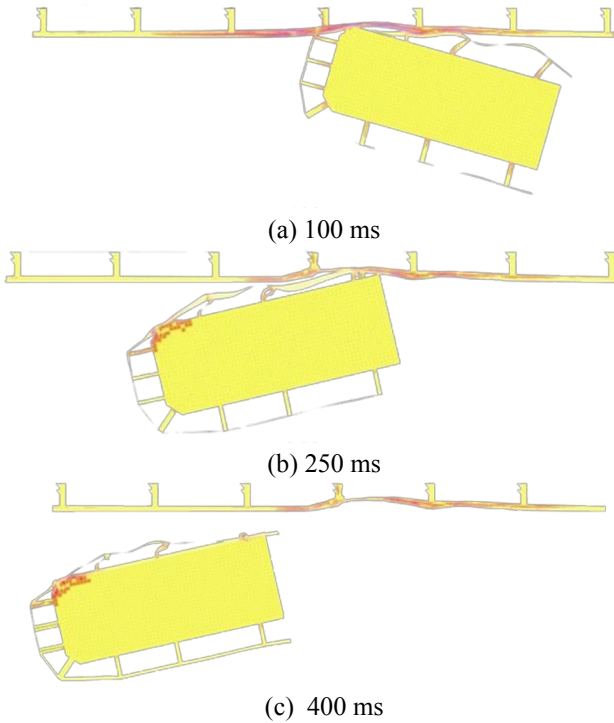
Figure 4 describes the impact simulation before colliding. The simulations modeled typical impact scenarios involving different speeds. Key parameters such as vehicle mass, impact velocity, and collision angle were defined to reflect the diverse range of accidents historically recorded on the Nalaikh-Ulaanbaatar road. In addition, environmental conditions—including road surface wetness and temperature variations—were incorporated to evaluate their influence on the performance of the safety railings.

This crash analysis investigates the guardrail system under two distinct impact scenarios. The first scenario evaluates the guardrail in its existing configuration as deployed in current road safety practices. The second scenario considers a modified version with enhanced geometric features. The impact location was set approximately 2300 mm from the start of the W-beam guardrail. For both cases, a standard TYPE 7 interface was applied for contact modeling, using a Coulomb friction coefficient of 0.2.

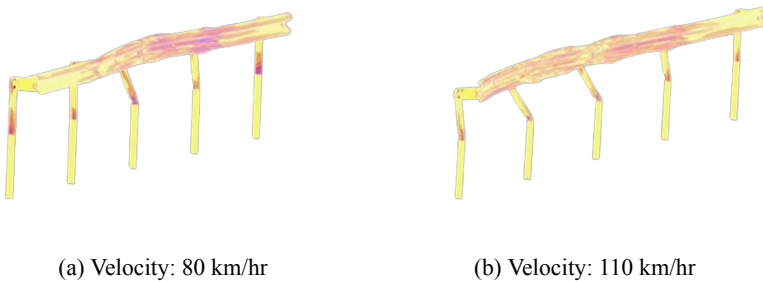
## 4.2 Simulation results

Figure 5 shows the simulation results with the car speed of 80 km/hr. The deformed shape of the safety railing after impact by the two different car speed of 80 km/hr and 100 km/hr are shown in Fig. 6. First case simulation results can be observed the behavior of the guardrail and impactor at 80 km/h initial velocity of the impactor, at three-time phases of 100 milliseconds, 250 milliseconds, and 400 milliseconds. The maximum value of the von Misses stress is 612.3 MPa. The kinetic energy curve begins at an initial value of 370,726 joules and remains constant for the first 5.5 milliseconds, corresponding to the moment before the impactor contacts the guardrail. Following this point, the kinetic energy steadily decreases until approximately 145 milliseconds, during which the impactor and the W-beam undergo deformation due to the collision. After 145 milliseconds, the kinetic energy curve exhibits a gradual decline, reaching 119,054 joules at 307 milliseconds. The crash simulation concludes at 400 milliseconds, by which time the safety barrier successfully deflects the impactor back toward the roadside.

Simulation results indicate that the existing guardrail design provides sufficient resistance under standard impact conditions. However, during high-speed collisions, the railings often fail to prevent vehicle override or penetration. Simulations incorporating enhanced material properties demonstrated notable improvements in performance, effectively reducing the risk of severe accidents.



**Fig. 5.** Simulation results: velocity of 80km/hr (22.23 m/s)



**Fig. 6.** Railings deformation by simulation.

## 5 Conclusion

This study evaluated the structural performance and impact resistance of safety railings along the Nalaikh-Ulaanbaatar road using advanced simulation tool, such as ANSYS LS-DYNA. The simulations replicated a variety of crash scenarios, accounting for vehicle type, speed, impact angle, and environmental factors. The results provide valuable insights into the failure mechanisms of current railing designs and highlight areas for safety enhancement. Findings from this research align with previous studies emphasizing the benefits of improved materials and design in road safety infrastructure. Notably, the performance of the existing railings was found to be adequate under standard impact conditions but insufficient in high-speed or oblique-angle collisions, where vehicle override or penetration occurred. Simulation results incorporating enhanced material properties demonstrated significant potential to reduce these risks.

The implications of this work are far-reaching for road safety management in Mongolia. Key recommendations include the adoption of more durable materials suited to local environmental conditions, the implementation of systematic maintenance protocols, and the exploration of sensor technologies for real-time condition monitoring. Additionally, targeted educational campaigns and policy reforms mandating certified construction standards could further enhance road safety. By implementing these strategies, Mongolia has the opportunity to modernize its safety infrastructure, reduce traffic-related injuries and fatalities, and align with international best practices. Although the majority of simulation results were consistent with theoretical predictions and empirical data, certain deviations—particularly in high-angle impact scenarios—suggest that further refinement of current modeling approaches is necessary to fully capture the complexity of real-world crash dynamics.

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