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# Innovative Approach for Estimating Car Speed at the Moment of Impact with a Roadside Barrier

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**STRESZCZENIE:** Accurately determining a speed of a vehicle when it collides with a roadside barrier remains a challenge. The aim of this research is to develop a new method for estimating the vehicle's speed at the moment of impact with a roadside barrier. The proposed methodology integrates full-scale crash testing, numerical simulations, and artificial intelligence algorithms. As part of the research, a full-scale crash test was carried out, and a computational model of the w-beam barrier was developed and validated. This model was subsequently used to conduct a series of numerical simulations. Based on the obtained results, a database was created and utilized to develop artificial intelligence models for impact speed estimation. The conducted research confirmed the effectiveness of the proposed approach for estimating impact speed, enabling the reconstruction of road accidents. Additionally, the practical aspect of the research is notable, as the developed model was implemented in an online application, providing easy access and quick results. The proposed methodology and developed model can support and facilitate the process of reconstructing road accidents.

**KEYWORDS**: road traffic safety, car speed estimation, road accident reconstruction, roadside barrier, Artificial Intelligence

## 1. Introduction

Road traffic safety is a crucial aspect of social life, as traffic accidents result in around 1.3 million deaths and 50 million injuries each year [1]. This global issue affects both developing and industrialized countries.

Driving off the carriageway, often due to human error, accounts for around 20% of road accidents [2]. Roadside barriers (Fig. 1) are one measure to mitigate the severity of road accidents. Currently, finite element (FE) simulations are used to evaluate the performance of roadside barriers [2].


Fig. 1. Example of a w-beam barrier.

In a road accident, both the roadside barrier and the vehicle sustain damage. The extent of the damage is influenced by the impact conditions, i.e., vehicle speed, mass, impact angle, and the structural properties of the barrier. While vehicle mass and impact angle can often be estimated post-impact, reliably estimating vehicle speed at the moment of impact with a roadside barrier remains challenging.

The aim of this research is to propose a novel approach for estimating car speed at the moment of impact with a roadside barrier. This method integrates full-scale crash testing, FE simulations, and artificial intelligence (AI) algorithms. A practical outcome of this study will be the development of a web application designed to estimate vehicle speed at impact using data collected from accident scenes.

## 2. Method description

The flowchart of the proposed method is presented in Fig. 2. First, results from available crash test reports will be collected, and a full-scale crash test will be conducted. Next, a FE model of the roadside barrier will be developed and validated against the actual test results. Then, this validated model will be used to conduct a series of FE simulations under various impact conditions. The results from these simulations and crash tests will be used to create a database. Subsequently, this database will be utilized to create AI-based models for estimating vehicle speed at the moment of vehicle impact with the roadside barrier. Finally, an online application will be developed to provide access to the speed estimation model.

The proposed method enables the determination of the impact speed for a specific vehicle and roadside barrier system. In this study, the method was applied to a w-beam barrier and vehicles weighing between 900 and 1,800 kg. The estimated impact speeds were then validated using the results from a finite element (FE) simulation. Detailed results of the road accident reconstruction using this proposed method can be found in [3].

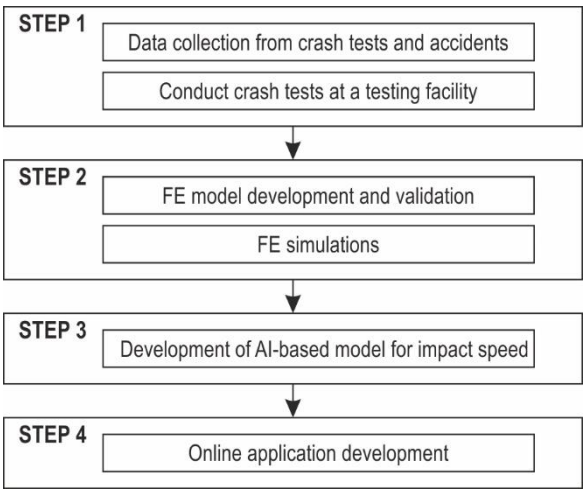


Fig. 2. Proposed method for estimating vehicle speed at the moment of impact with a roadside barrier.

## 3. Crash test, FE model development and simulations

A crash test was conducted, and an FE model of the w-beam barrier was developed, as shown in Fig. 3.


Fig. 3. Comparison between the actual w-beam barrier and its FE model.

The FE model was validated against the results from the crash test in which a 1,500-kg vehicle impacted a barrier at a speed of 110 km/h at an angle of 20 degrees. A comparison of the key crash test indices, determined in accordance with the EN1317 standard [4], is presented in Tab. 1. Based on this FE model, approximately 300 FE simulations were carried out, the results of which were used to create a database. This database contains impact parameters, such as impact angle and speed, vehicle mass, and information about barrier damage, including the number of damaged posts and guardrail, and the maximum lateral displacement of the guide. This database was supplemented with data from available full-scale crash tests.

Table 1. Results from actual test and FE simulation

| index | Crash test | FE simulation |
|---|---|---|
| ASI | 0.7 | 0.8 |
| THIV | 23 km/h | 26 km/h |
| Working width | 1.0 m | 1.1 m |
| Contact length | 10.0 m | 8.6 m |

## 4. AI-based model for impact speed estimation

The created database was utilized to develop an AI-based model for impact speed estimation, selecting five input features: vehicle mass, impact angle, final guardrail displacement, number of damaged posts, and number of damaged guardrails. The initial model was introduced in a published article [3]. The current version of the model was enhanced to incorporate multiple models, including Tree Ensemble, Multilayer Perceptron, Regularized Linear Ensemble, Support Vector Ensemble, and a Final Voting Ensemble. The Final Voting Ensemble calculates a weighted average of these models, achieving a Mean Absolute Error of 3.173 km/h and an $R^2$ of 0.958 for test data estimation. This updated model is accessible through an online application [5], as depicted in Figure 4.

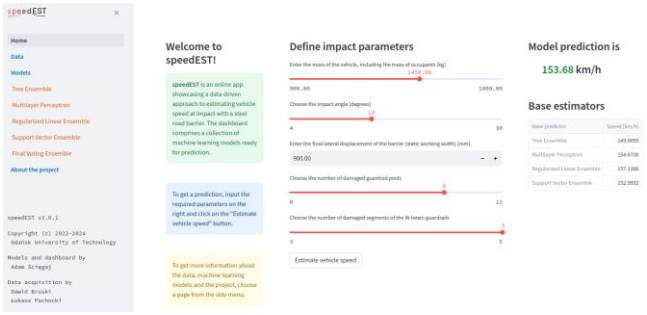


Fig. 4. Web application interface view [5].

The developed AI-based speed estimation model was used to reconstruct a road accident, as shown in Figure 5 [3].


Fig. 5. An example of a road accident reconstruction [3] (source of the photo on the right: GDDKiA)

## 5. Conclusions

The aim of the research was to develop a new method for estimating a car's speed at impact with a roadside barrier. The key findings are as follows:

1) FE simulations can be successfully used to analyze numerous crashes under various impact conditions.
2) A new method for car impact speed estimation that integrates crash testing, FE simulations, and AI algorithms was proposed.
3) Creating a new model based on the proposed methodology is time-consuming, but once developed, the model allows for quick impact speed estimation.
4) The speed estimation model and the online application can be reliable and easily accessible tools for reconstructing road accidents involving roadside barriers.

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### Literatura

[1] World Health Organization, *Global Status Report On Road Safety*, Tech. Rep. 2, 2018.
[2] Wilde K. et al., *Numerical Analysis of TB32 Crash Tests for 4-cable Guardrail Barrier System Installed on the Horizontal Convex Curves of Road*, International Journal of Nonlinear Sciences and Numerical Simulation, Vol. 21, Iss. 1., pp. 2-17, 2019.
[3] Bruski D. et al., *Speed estimation of a car at impact with a W-beam guardrail using numerical simulations and machine learning*, Advances in Engineering Software, 184, pp. 1-12, 2023.
[4] EN 1317:2010. Road restraint systems, 2010.
[5] http://www.speedest.pl/ (access on 10-July-2024).