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PRELIMINARY REPORT

The impact of passively safe poles on the consequences of A traffic accident

Danislav Drašković
Faculty of Traffic of the Pan-European University Apeiron Banja Luka, danislav.m.draskovic@apeiron-edu.eu

Demeter Prislan
ICC DEMETER PRISLAN S.P. Dobravica 44, SI-1292 Ig, Slovenia, demeter.prislan@siol.net

Zoran Injac
Faculty of Traffic of the Pan-European University Apeiron Banja Luka, zoran.dj.injac@apeiron-edu.eu

Boris Mikanović
Faculty of Traffic of the Pan-European University Apeiron Banja Luka, boris.r.mikanovic@apeiron-edu.eu

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Abstract: All EU Member States have committed to targets to reduce the consequences of road accidents in the decade to 2030. In 2023, there were 20,400 road deaths in EU countries, down just 1% from the previous year. While this is a 10% decrease compared to 2019, which is the baseline for the 2030 strategic target, we can note that the trend has remained flat in several Member States, while others have seen an increase. Statistical trends in the Western Balkans show that the number of road deaths rose to 1,261 in 2023, an increase of 15 lives lost compared to previously published data. The region continues to lag behind the EU27 in road safety, underscoring the need for more effective measures. As one of the measures to increase traffic safety, the possibility of using passivly safe infrastructure, in particular lighting poles, traffic signal supports and equipment as an alternative to existing structures with the aim of reducing the consequences of traffic accidents that occur in the last run-off of the road is presented. The presented results are consistent with previous findings published in the literature on the severity of the consequences of traffic accidents with run-off of the road in several different environments. Most importantly, the results provide evidence that passive safety poles that absorb high energy (in accordance with EN 12767) contribute to the reduction of accidents in this type of traffic accident.

Key words: Traffic safety, passively safe pole, energy absorption.

INTRODUCTION

The consequences of traffic accidents represent a global problem. According to the World Health Organization (WHO), about 1.35 million people are fatally injured in traffic accidents worldwide each year, and 20 to 50 million people are injured, some of whom become permanently disabled [1].

Furthermore, traffic-related injuries are the leading cause of death among children and young people aged 5 to 29, and the twelfth leading cause of death across all age groups.

In addition to personal tragedies, traffic accidents also impose significant costs on society, including expenses related to emergency services, medical care, insurance, and more. For most countries, these costs amount to 1–3% of their gross domestic product (GDP), while in some less developed countries they reach up to 6% of GDP. Many people lose their lives in traffic accidents during their most productive years. Approximately 69% of fatal traffic accident victims are between 18 and 59 years old, while 23% are aged 60 or older.

In 2023, the EU recorded 20,400 road fatalities, representing only a 1% decrease compared to the previous year. Although this marks a 10% reduction compared to 2019 the baseline year for the strategic objective set for 2030 it can be concluded that the downward trend has remained steady in several member states, while an increase has been observed in others.

It should also be noted that, between 2012 and 2022, the total number of fatalities in traffic accidents decreased by approximately 11%. However, the share of fatal traffic accidents involving a single vehicle, compared to all traffic accidents, increased from 30% to 35%.[4]

Running off the road—that is, the unintentional deviation of a vehicle from its intended direction of travel—occurs frequently, and the literature often addresses this type of single-vehicle incident, commonly referred to as SVROR (Single Vehicle Run-Off Road).

Not every run-off-road incident necessarily results in human casualties or severe injuries; however, it is rare for the area beyond the roadway to be arranged in such a way that a vehicle can come to a relatively safe stop without posing risks to the occupants. The area adjacent to the roadway surface—referred to in foreign literature as the "roadside"—should be designed so that no hazards are present for vehicles that may leave the road due to loss of control. The concept of "forgiving roads" emphasizes the need to remove all dangerous objects from the safety zone. If certain objects must be located near the roadway—primarily street lighting poles and traffic sign supports—they must be designed so that they do not pose a serious threat to vehicle occupants in the event of a collision. These are known as passively safe roadside structures. If such design solutions are not feasible, hazardous objects within the safety zone must be protected by vehicle restraint systems.

Statistics show that approximately 20% of traffic-related fatalities result from vehicles running off the road and colliding with fixed roadside objects. [5] Nearly half of all fatalities in crashes involving fixed objects occur at night and frequently involve drivers under the influence of alcohol. Such accidents also occur due to excessive speed, driver fatigue, inattentiveness, or poor visibility.

According to the data [5], in fatal crashes the most common fixed objects struck by vehicles are trees (3,836 fatalities, 44%), roadside poles (1,027 fatalities, 12%), and safety barriers (844 fatalities, 10%).

In line with the sustainable development and road safety vision of the European Union and the United Nations, the Road Safety Strategy of the Republic of Srpska 2013–2022 identified the improvement of road safety in the Republic of Srpska as one of its key pillars, thereby directly contributing to the implementation of the United Nations 2030 Agenda for Sustainable Development (UN Agenda 2030). [6]

As a contribution to the "safe infrastructure" measure, interventions related to the pavement structure itself, as well as to the equipment installed along roadways, are taken into consideration. When examining roadside equipment, the use of passively safe poles is regarded as one of the most effective measures for improving overall traffic safety. When a vehicle collides with this type of pole, the pole is designed to yield in a controlled manner, thereby reducing injuries to vehicle occupants and other road users. As part of this measure, the gradual replacement of existing rigid poles with passively safe ones is recommended.

MATERIALS AND METHODS

This study addresses the current lack of literature concerning the safety implications of collisions with conventional roadside poles, such as metal, concrete, and wooden structures. While most previous research has focused either on general fixed-object collisions or on specific passive safety solutions, localized empirical analyses of real-world crashes involving standard, non-energy-absorbing poles remain limited. By examining the severity of real-world collisions involving these traditional pole types, the research aims to provide new insights into the consequences of outdated roadside infrastructure and to support the promotion of passively safe solutions compliant with EN 12767.

The study also analyzes the suitability of specific types of passively safe poles for particular locations, taking into account their ability to absorb impact energy, with the aim of reducing the severity of run-off-road crashes.

Currently, the Republic of Srpska does not maintain statistical records of traffic accidents in which a vehicle collided with a lighting or other utility pole. Therefore, one of the objectives of this research is to improve the traffic accident database to better understand the occurrence of vehicle-to-obstacle collisions.

Given the frequency and consequences of these incidents, the goal is to explore the potential for implementing forgiving infrastructure and remedial measures in high-risk areas to mitigate negative outcomes of the impact of vehicle–obstacle collisions mitigated through passively safe poles.

PASSIVELY SAFE POLES ACCORDING TO EN 12767:2019

General

The design of passively safe lighting columns in Europe is carried out in accordance with EN 40, while passive-safety performance is assessed according to the EN 12767:2019 standard. EN 12767:2019 defines passive-safety levels and establishes the rules for conducting and interpreting crash-test results under various impact conditions and vehicle speeds.

In the previous edition, EN 12767:2007 [8], poles were classified based on three parameters: impact speed, energy-absorption capability, and the level of occupant safety. In the revised 2019 edition, passive-safety classification is based on seven parameters:

- vehicle impact speed,
- energy-absorption capacity,
- occupant-safety level,
- backfill type of foundation for the poles,
- mode of pole failure,
- impact direction,
- impact angle,
- risk of roof indentation.

Parameters for Assessing Passive Safety

Vehicle Speed at Impact with the Pole

The speed class represents the speed of the vehicle at the moment of the experimental collision. According to the EN 12767 standard, two types of experimental crash tests are required: low-speed tests at 35 km/h, and higher-speed tests at 50, 70, or 100 km/h. A standard passenger vehicle weighing 900 kg and various types of pole foundations are used during these experimental tests. Low-speed crash tests are conducted to ensure satisfactory structural performance. High-speed crash tests enable the assessment of the pole's failure mechanism, its potential for energy absorption during impact, as well as the effects on the vehicle and its occupants.

Categories of Poles According to Their Energy-Absorption Capability

With respect to energy-absorption capacity, passively safe poles may be classified into three categories according to EN 12767:2019:

- HE poles (high energy absorbing) – poles that absorb a large amount of energy,
- LE poles (low energy absorbing) – poles that absorb a small amount of energy,
- NE poles (non-energy absorbing) – poles that do not absorb impact energy.

The behavior of the aforementioned poles during a vehicle impact is shown in Figure 1.

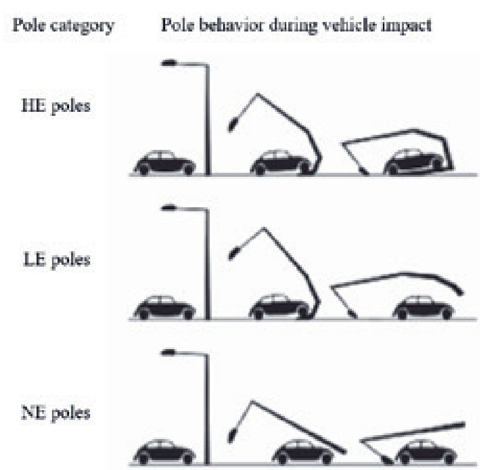

Figure 1. Categories of poles based on their energy-absorption capability

High-energy-absorbing poles (HE poles) significantly reduce the vehicle's speed after impact, and in some cases can even bring the vehicle to a complete stop. They are designed to deform in front of and beneath the vehicle upon impact, and in certain situations may even wrap around the vehicle.

Low-energy-absorbing poles (LE poles) provide only a modest reduction in vehicle speed following a collision. They are typically designed to fail in front of and beneath the vehicle before separating from their foundation.

When a vehicle collides with non-energy-absorbing poles (NE poles), the pole detaches at the foundation and is then thrown over the vehicle, ultimately falling near the base. The vehicle usually continues travelling with a certain reduction in speed and with relatively minor damage to the vehicle [9].

Some poles and supports for traffic signage offer considerable resistance when struck by a vehicle, while others provide only minimal resistance. Accordingly, there are categories of supports with high energy absorption, low energy absorption, and supports without energy absorption. This means that significant differences exist in the remaining kinetic energy of the vehicle—reflected in its post-impact speed—after striking a passively safe pole or signage support.

Table 1. Pole categories according to their energy absorption capability

Vehicle speed at impact, v_i [km/h]	50	70	100
Pole category	Vehicle speed after impact v_e [km/h]		
HE	$v_e = 0$	$0 \le v_e \le 5$	$0 \le v_e \le 50$
LE	$0 < v_e \le 5$	$5 < v_e \le 30$	$50 < v_e \le 70$
NE	$5 < v_e \le 50$	$30 < v_e \le 70$	$70 < v_e \le 100$

To determine the category of a pole with respect to its energy-absorption capability, the vehicle speed at the moment of the experimental collision (vi) and the vehicle speed after the collision (ve), measured at a specified distance from the pole, are recorded and then compared with the values provided in Table 1.

In the case of a collision at 100 km/h with a high-energy-absorbing passively safe pole (HE pole), the vehicle's post-impact speed will be at most 50 km/h, and such a support may even bring the vehicle to a complete stop.

In contrast to high-energy-absorbing passively safe poles, non-energy-absorbing poles offer significantly less resistance during a vehicle collision, leaving a relatively large amount of residual kinetic energy, which manifests in the vehicle's remaining speed. After impacting such a passively safe pole, the vehicle's speed is at least 70 km/h. The effect of deceleration on the human body in this case is minimal, with an ASI index even below 1. However, the problem lies in the fact that the vehicle continues moving at high speed. If there is another hazardous object in the stopping area, there is a high likelihood of collision with it. Numerous studies on the effects of rapid deceleration indicate that coming to a stop at a speed of 70 km/h is far from harmless.

Passenger safety level in the vehicle

The revised standard EN 12767:2019 defines five levels of occupant safety during a vehicle collision with a pole, labeled A to E, where A represents the highest level of safety. This is a change compared to the previous version of the standard EN 12767:2007, which defined four occupant safety levels, numbered 1 to 4.

Occupant safety levels are determined based on the values of two parameters: ASI (Acceleration Severity Index) and THIV (Theoretical Head Impact Velocity), obtained from the results of a large number of experimental collisions. The ASI value represents the calculated deceleration experienced by vehicle occupants during the collision.

Table 2 shows the corresponding ASI and THIV values that must be achieved during experimental collisions for each pole category according to its energy absorption capability.

Injuries from deceleration occur when a body moving at high speed is suddenly stopped, causing various types of trauma. At a speed of 50 km/h, a stop occurring within 0.1 seconds generates very high deceleration forces, potentially up to 30g, which can cause serious injuries such as shock, brain concussion, abrasions, sprains, skin lacerations, rupture of internal organs, bone fractures, respiratory and circulatory paralysis, bleeding, and organ damage.

If the stopping time is extended to 0.7 seconds, the deceleration force is significantly reduced, which can decrease the severity of injuries. However, even with longer deceleration times, injuries can still occur, though they may be less severe compared to a stop within 0.1 seconds. A collision lasting less than 0.2 seconds for a body moving at 100 km/h can be fatal. Sudden deceleration can generate substantial forces on the human body, measured in gravitational acceleration (g). If the deceleration duration is less than 0.2 seconds, the peak sustained deceleration is around 30g when the person is facing forward. Such forces can result in severe injuries, including shock, brain concussion, rupture of internal organs, and even respiratory and circulatory arrest. The human body can withstand slightly higher forces, up to 35g, if oriented with the back facing the acceleration line, but even in this case, the risk of serious injury remains high.

From the above, we can conclude that even deceleration alone can be dangerous to the human body. In the case of a collision with a conventional rigid support, there is an additional problem: the deep intrusion of the conventional equipment post into the vehicle body. The smaller the contact surface, the deeper the intrusion, assuming all other factors remain unchanged. Therefore, it is remarkable that road authorities are still debating whether to implement a passively safe post or a standard rigid road equipment post.

Figure 2. Vehicle stopping with an impact speed of 46 km/h, impact duration 0.5 seconds, deceleration 138 m/s²

Source: Test impact on a rigid pole – Španik test site, Murska Sobota, 2009

APPLICATION OF PASSIVELY SAFE POLES

General

This chapter analyzes the justification for applying specific types of passively safe poles for a given road section. When selecting the type of pole, several factors must be considered, such as the pole's failure mode, occupant safety, risks to other road users (e.g., in urban areas), the speed limit on the considered section, the presence of roadside objects such as bridges or walls, vehicle damage, and others.

Non-energy-absorbing poles (NE poles)

Non-energy-absorbing poles (NE poles) are recommended in areas where high speeds are allowed and there are no nearby objects or pedestrians. Using this type of pole achieves the highest level of safety for vehicle occupants because, after a collision, the vehicle continues to move with only moderate deceleration and minimal damage compared to other types of poles. In locations where there is no risk to other road users, this type of

Table 2. Determination of passenger safety level in the vehicle

Pole categories based on energy absorption	Passenger safety level	Speed (maximum values)			
		Mandatory low-speed crash test at 35 km/h		Crash tests at speeds of 50 km/h, 70 km/h, and 100 km/h	
		ASI	THIV km/h	ASI	THIV km/h
HE/LE/NE	E	1,0	27	1,4	44
HE/LE/NE	D	1,0	27	1,2	33
HE/LE/NE	C	1,0	27	1,0	27
HE/LE/NE	B	0,6	11	0,6	11
NE	A	Values for ASI and THIV are not specified.		No measured values for ASI and THIV.	

pole is the best choice for vehicle occupants, as the impact is usually very brief, and the vehicle continues to move after the collision. Non-energy-absorbing poles are not recommended near pedestrian zones, bicycle paths, or trees.

High-energy-absorbing poles (HE poles)

Poles capable of absorbing energy (HE and LE poles) are recommended in locations where there is a possibility of secondary collisions and risks to other road users. High-energy-absorbing poles can absorb a large amount of energy, causing plastic deformation of the pole and bending of the pole under the vehicle. Such poles significantly decelerate and stop the vehicle during a collision, reducing the risk of secondary impacts with roadside objects, trees, pedestrians, and other road users. The use of this type of pole is recommended in areas where there are no obstacles around the pole. It should be noted that after a collision with this type of pole, the vehicle may still move briefly while the pole deforms. A critical HE pole stops the vehicle completely.

Low-energy-absorbing poles (LE poles)

Low-energy-absorbing poles possess characteristics between high-energy-absorbing and non-energy-absorbing poles. They are designed so that upon collision, they fail by yielding in front of and beneath the vehicle before detaching from the foundation, unlike non-energy-absorbing poles. The speed of the vehicle striking such a pole is reduced, and vehicle damage is less than that in a collision with a high-energy-absorbing pole.

RESULTS AND DISCUSSION

A significant number of studies, based on multiple methods of data collection and analysis, have identified various factors contributing to accidents and injuries involving collisions with poles.

In Flanders (Belgium), the Flemish Road Administration has recommended the installation of HE-type passive safety poles since 2010, depending on the speed limit, distance of installation from the roadway, and the presence or absence of protective barriers. Specifically, HE-type passive safety poles are recommended in clear zones when the speed limit exceeds 50 km/h and whenever no protective barrier is present.

For roads with a speed limit of 50 km/h, these poles are recommended whenever the distance from the roadway is less than two meters and no protective barrier is present. Their installation is also recommended in areas with a high risk of vehicle collisions with lighting poles, such as sharp curves, highway exits and entrances, and roundabouts (AWV, 2010).

High-energy absorbing poles (HE) should not be used on roads where vehicles travel at 30 km/h, in coastal areas with frequent storms, or for public lighting fixtures that need to be installed at heights exceeding 12.5 m (the maximum height for high-energy poles), as highlighted in the recommendations of the Flemish Road and Traffic Agency (AWV, 2010). For speeds of 30 km/h or lower, passive safety poles are not recommended because, for traditional poles, material costs in low-speed collisions are lower, and the risk of injury is considered sufficiently low (AWV, 2014).

Our efforts support the current Flemish policy regarding passively safe infrastructure, including the installation of lighting poles and traffic signal supports, through the concept of “forgiving road safety” to mitigate the severity of run-off-road (ROR) crashes on Belgian roads. Further development of road inventory systems should provide additional and improved data on road characteristics and traffic accidents. This data would create a foundation for further research, leading to more precise recommendations for the most effective enhancement of road safety.

Finally, the study by Albuquerque and Awadalla [10] aimed to quantify the probability of fatal injuries in single-vehicle run-off-road (SVROR) crashes using multivariate logistic regression models. According to the results, crashes involving W-beam guardrails showed the lowest probability of driver fatality compared to other crashes with fixed objects (trees, poles, and concrete barriers).

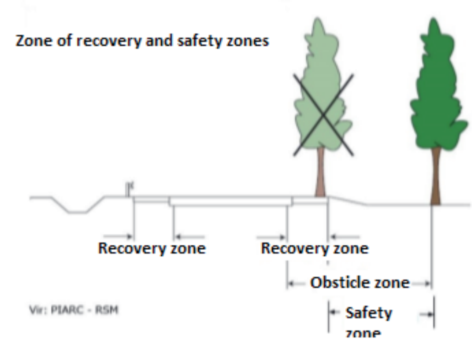

Figure 3. Safe road principle – the width and length of the safety zone depend on the type of roadway and vary from country to country

CONCLUSION

The prevention of traffic accidents and the reduction of their consequences are key objectives in the field of road safety. One way to mitigate the consequences of such accidents is the implementation of passively safe infrastructure along roads, particularly lighting poles and traffic signal supports, with appropriate energy-absorbing properties upon vehicle impact, as a contribution to the measure of safe infrastructure.

Input data represent a major limiting factor in efforts to study the contribution of roadside objects to the outcome of collisions, especially when dealing with minor injuries or cases where no injury occurs. This limitation implies that results must be carefully interpreted, and further work is needed to collect data on impacts with passively safe poles where only material damage occurs, in order to develop a more flexible and comprehensive specification model. It is essential to emphasize the need for continued data collection on impacts as well as on road equipment, with the aim of expanding the database for further research that will provide updated recommendations for the most effective enhancement of passive road safety. The selection of passively safe poles may not prevent a traffic accident, but it can reduce its consequences, help save lives, and lower material costs.

Additionally, the selection of the type of passively safe poles for a particular road section depends on several factors, such as the manner in which the poles fail, the safety of vehicle occupants, risks to other road users, the speed limit on the section under consideration, the presence of roadside objects, vehicle damage, and other factors.

Non-energy-absorbing poles (NE poles) are recommended in areas where high speeds are permitted and where there are no nearby objects or pedestrians. Using this type of pole provides the highest level of safety for vehicles and results in the least damage to the vehicle compared to other types of poles. However, these poles are not recommended near pedestrian zones, bicycle paths, or trees. Energy-absorbing poles (HE and LE poles) are recommended in locations where there is a risk of secondary collisions and potential danger to other road users.

The classification of passively safe poles according to the revised 2019 standard is based on seven parameters; therefore, pole labeling is more detailed than before, enabling a better selection of the appropriate pole type for a specific road section.

Considering that, in the Republic of Srpska, official statistics only track road accidents classified as "vehicle collision with roadside object", it would be beneficial to also monitor accidents involving collisions with roadside poles, trees, and other objects. Currently, existing accident databases do not specify the type of object involved in the collision (such as a guardrail, lighting pole, tree, or other solid object), unlike practices in databases of other countries where the exact type of object struck by the vehicle is recorded. We believe that, by utilizing today's IT technology, existing databases can be improved within a reasonable timeframe, resulting not only in more accurate records but also in a solid foundation for implementing measures to enhance road safety.

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