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PASSIVELY SAFE INFRASTRUCTURE AND ITS APPLICATION IN EUROPEAN COUNTRIES

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Abstract: It is obvious that a constant development of technologies in all fields of human life set out also the safety of a traffic, specially the safety in road traffic. Today, the awareness that roads should be made in a way to give as much safety as possible is already noticeable compared to decades ago when the only scope of the road was to enable the movement of one's vehicle from point A to point B. Part of the road safety belongs also to the road infrastructure which can be made in accordance with the European norms for passively safe infrastructure but it can be made also disregarding these norms. How is it possible to produce, design and apply unsafe road infrastructure when we know that the society is looking for the possibilities to reduce fatalities in road traffic? While on one hand we have standards what a passively safe infrastructure is, we know how to produce it and apply, on the other hand there is no regulation on the level of European Community when, how and which passively safe infrastructure elements are to be used in certain situations. Each European country has its own regulation about the road passive safety and some of them are discussed in the article, with regard to the road furniture, searching for a common direction in developing the European guidelines for passively safe road infrastructure.

Keywords: passive safety, infrastructure, European norms

1. INTRODUCTION

“There is both a moral and a financial imperative for EU decision-makers to strive towards the highest levels of road safety and to reduce intra-EU differences in risk on the roads,” said Mr. Avenoso in the light of incoming EU Parliament elections that will take place in May, 2014 having in mind the ETSC Manifesto for the mentioned elections. Reaching the EU 2020 road safety target will depend in part also on the activities of newly elected MEPs, who must support the efforts to improve road safety, both at the national and EU level (ETSC Release, 2013, November 19th). The Road Safety Manifesto presents already on the first page a significant decrease in the number of road deaths in the period from 2001 to 2012 but setting out already huge inequalities between different Member States in terms of road safety.

The EU must strive for a policy that will provide the highest level of road safety as well as reduction in differences in safety level across the whole region. The new Parliament (2014-2019) should have a significant role in the following three areas: reaching the EU 2020 Target, reducing the socio-economic cost and reducing serious injuries in the EU, which is a new Target for 2020. Resulting from these Targets a four priorities appear related to the main causes for deaths and serious injuries:

- **Speeding**: Excessive speed is the single biggest contributory factor in road collisions resulting in death.
- **Drink and Drug driving**: Approximately 6,500 lives would have been saved in 2010 if all drivers had obeyed the prevailing drink driving laws.
- **Infrastructure Safety**: 56% of the road deaths recorded annually in the EU occur on rural roads, 7% on motorways and 37% in urban areas. On the TEN-T, motorways, rural roads and urban road networks, all EU Member States should be working towards the same high levels of infrastructure safety. The newly adopted TEN-T Guidelines and accompanying funding mechanisms assure that European funds will only be granted to infrastructure compliant with the infrastructure safety and tunnel safety Directives.
- **Vulnerable Road Users**: Road deaths among cyclists and pedestrians have not been cut at the same pace as those for other types of road users, most of the progress has been seen among vehicle occupants.

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- Another topic that future Members of European Parliament should support are **Powered two wheelers**: In the EU27 PTWs represent 17% of the total number of road deaths while accounting for only 2% of the total kilometers driven. Motorcyclists face a much higher risk of being killed than other road users. For the same distance travelled, the risk for riders of being killed in road collisions is on average 18 times the risk of car drivers.

The European Union has renewed its commitment to improving road safety by setting a target of reducing road deaths by 50% by 2020, compared to 2010 levels. To accompany this target the European Commission adopted a new road safety strategy in 2010 'The Road Safety Policy Orientations 2011-2020' including priority areas and measures for action. The EC has started to implement the plan, which is up for its mid-term review in 2015. In its White Paper on the future of transport, the European Commission committed to working towards a long-term 'zero vision' in road safety (ETSC Manifesto, 2013).

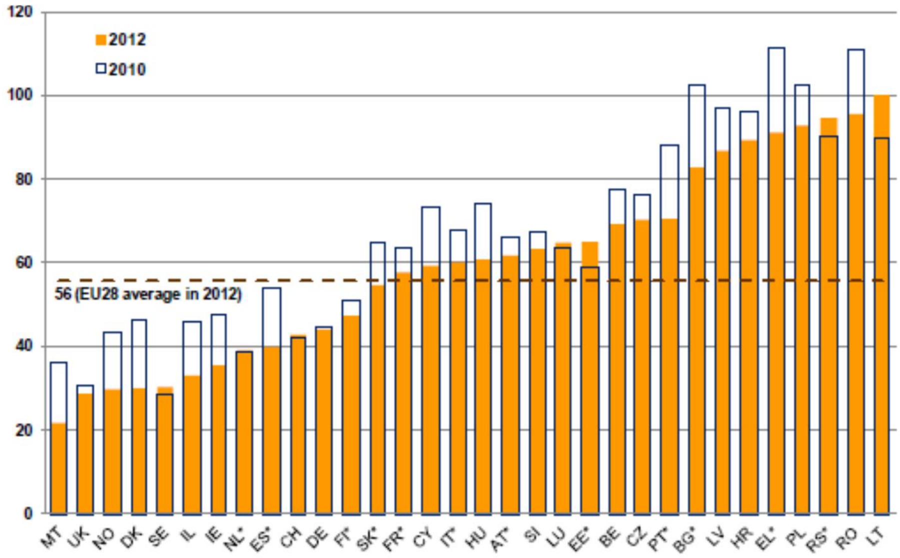

Figure 1. *Road deaths per million inhabitants in 2012 with regard to 2010 (provisional estimates used for 2012, as final figures for 2012 are not yet available).*

2. ROAD NETWORK AND STATISTICS

Mostly, when talking about road safety, making plans for new road connections, making plans for developed road network, always highways and speedways are considered but actually much more attention should be dedicated to so-called national network, which consists of main and regional roads. No matter being these roads classified as 1st or 2nd class roads we can divide them in two groups: non-urban and urban roads. Having a look at statistics we can immediately recognize that non highways or trunk roads take the biggest part in road deaths. According to the ETSC 5th PIN Report it is obvious that more than 55% of all road deaths occur on the roads outside urban areas and only approximately 5 - 10% on the highways and the rest of them in urban area, everything depending on each country's state of road network. (Jost, ETSC 5th PIN Report, 2011:55)

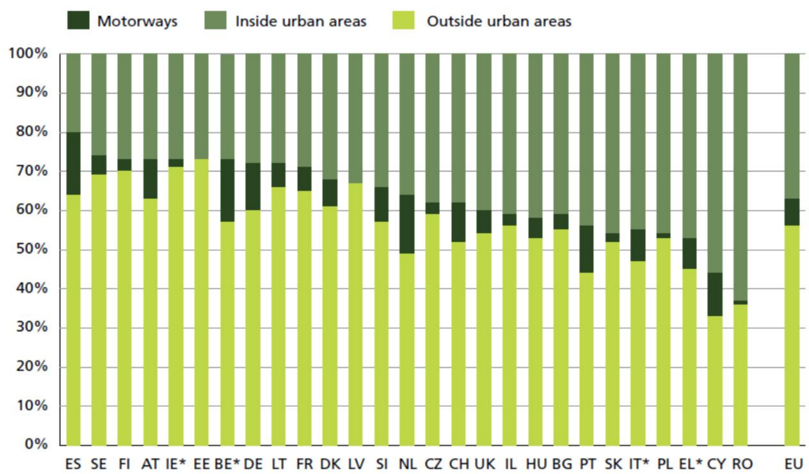

Figure 2. *Percentage share of road deaths per road type (2007-2009 average) ranked by the percentage share of road deaths on a rural roads and motorways taken together*

Present road design result from many decades of construction and maintenance in times when safety issues were not considered to the same extent. Today, road features on many roads no longer meet the latest safety requirements. Moreover, traffic conditions may have changed since the road was designed and built. Knowledge about safe design and effective risk management are not fully applied even in the best performing countries. Against this background, the EU adopted Directive on road infrastructure safety management which comprises the following instruments: road safety impact assessments, road safety audits, network safety management and safety inspections. These procedures already exist and are applied to varying degrees in some Member States (Jost, ETSC 5th PIN Report, 2011:59). The fact that they are applied to varying degrees means that in some countries these instruments are vegetating at their minimum possibility and in others they are at regular and general level. It actually means that the gap between so called reach economies and poor ones is getting bigger every day. It shouldn’t be so as we are tending to form a uniform region for free movement of people and goods that will ensure safe use of road network being international or local.

3. TOWARDS FORGIVING ROADSIDE

Usually the reason for low activity on the instruments for safety management is caused by savings in the state budget, relocation of funds and similar but such shortsightedness of authorities can only bring the additional burden to the state budget forming a never ending vicious circle of investment incapability. The improvement of traffic safety can be done only by awareness of road authorities as well as other institutions on the state level about the importance of the issue. For this purpose, different programmes were formed like, within the framework of ERA-NET Road, the programme Safety at the Heart of Road Design. The aim of the programme was to improve traffic safety by increasing the awareness and acceptance of road authorities to implement joint road safety solutions following the concepts of self-explaining roads and forgiving roadsides, taking human factors and human tolerance into consideration. The programme was based on three objectives: A) Development of evaluation tools, B) Assessment of forgiving road safety measures and C) Comparison and Implementation of approaches of self-explaining roads. The objectives were developed with the concepts of forgiving roadsides and self-explaining roads in mind, focusing on rural roads combined with the most substantive issues of the European road safety goals and the Vision Zero.

Five research projects were funded by the programme and started in 2009:

- **IRDES**: Improving Roadside Design to Forgive Human Errors
- **EuRSI**: European Road Safety Inspection
- **RISMET**: Road Infrastructure Safety Management Evaluation Tools
- **SPACE**: Speed Adaption Control by Self Explaining Roads
- **ERASER**: Evaluations to Realize a common Approach to Self-Explaining European Roads

The IRDES project was focused on the concept of forgiving roadsides and the main outcomes of this project are Practical Guide for the Assessment of Treatment Effectiveness and Forgiving Roadside Design Guide.

The road side features for which recommendations have been developed are:

- Barrier terminals
- Forgiving support structures for road equipment
- Shoulder rumble strips
- Shoulder width

It is frequent to hear amongst designers and road managers that obstacles in the roadside NEED to be protected with safety barriers. This is a simplistic approach that should be overcome to reach a forgiving roadsides design approach as placing a barrier (with its length of need and its terminals) is not necessarily the most “forgiving” solution and it can be extremely costly as compared to the achieved benefits.

Support structures that have been tested according to EN12767 standard are considered to be passively safe or “forgiving” but different performance classes are given in the standard and guidelines for selecting the most appropriate performance class in different situations are given as well.

Even though this type of structures have been in place for several years in several countries including most of the northern European counties (Norway, Finland, Sweden) and Iceland, sound statistical analyses of the effectiveness of using “passively safe” support structures in reducing the severity of crashes were not found. On the other hand several studies can be found that indicate that crashes against these type of structures rarely lead to severe consequences.

A risk assessment of the potential effect of using passively safe lighting columns and signposts has been performed in the UK by combining the likelihood of occurrence of different events that can lead to passenger injuries. The risk associated with the use of “passively safe” o “forgiving” lighting columns resulted almost 8 times lower than the risk associated to conventional unprotected columns. The solution of protecting the column with a safety barrier is still 2 times higher than the risk associated by “passively safe” columns. (ERA-NET Final Report, 2012)

4. PASSIVELY SAFE STRUCTURES

Passive safety road equipment includes Road Restraint Systems (RRS), breakaway equipment supports, energy absorbing supports, and arrester beds. The equipment included in RRS can be divided into two groups, vehicle and pedestrian restraint systems. Vehicle restraint systems comprise safety barriers and bridge barriers (parapets), terminals for barriers, crash cushions, transitions among different RRS, and Motorcyclist Protection Devices (MPD). Pedestrian restraint systems include pedestrian parapets and guardrails for separation of pedestrians and traffic. Passive safety structures constitute, together with road markings and signing, a basic element for road safety.

Passive safety road equipment (or road equipment) is implemented at locations where there are serious consequences when a vehicle makes an uncontrolled exit from the roadway. It must be recognized that passive safety equipment represents objects that can be struck by a vehicle. However, they are constructed and tested to ensure that any collision with a passive safety structure is less severe than with a hazard located on the side of the road. The necessity of installing road equipment is made when the roadside area cannot be made safer using the safety zone concept. Some roadside hazards can be removed or made less dangerous through different countermeasures. However many situations arise where the hazard cannot be removed or when it is more economical to install road equipment. (RISER Project, 16/02/2005)

The main categories of passive safety road equipment are

- Safety Barriers
- Crash Cushions
- Terminals/End Treatments
- Transitions
- Arrester Beds
- Break-away and Energy Absorbing Structures – typically used for lighting columns, utility posts, sign posts, etc., designed so they break or deform in a controlled way when impacted by a vehicle. The EN 12767 lists testing requirements for passive safety structures like break-away and energy absorbing lighting columns. This norm defines for different speed classes different levels of safety for passengers and categorizes columns as high energy absorbing, low energy absorbing and no energy absorbing elements.

5. APPLICATION OF PASSIVE SAFE STRUCTURES

Different countries are approaching increasing of passive safety in different ways. As there are many instruments for improvement of road safety the cheapest solutions are usually the most used. Generally, they are following the RISER (Guidelines for Roadside Infrastructure on New and Existing Roads) recommendations based upon the study about the safety of the roadsides.

As part of RISER, a review of current European Design Guidelines for Roadside Infrastructure was carried out for seven countries. In this report, the main documents were reviewed with regard to safety hazard objects.

- **Trees**: In all seven RISER participating countries, trees were considered as roadside hazards in the design guidelines. However, the minimum diameter when a tree was considered hazardous varied from 0.1 m to 0.3 m.
- **Posts and Poles***:* Post and poles on the roadside of varying types were also considered as hazards in a number of the countries. In Great Britain and Finland, traffic sign supports with a minimum diameter of 0.09 m and 0.11 m respectively are considered as hazards. In Spain, trees and poles over 0.15 m diameter are hazards depending on the distance to the carriageway edge line.
- **Rock and Concrete Objects**: in guidelines across Europe specified as being hazardous.
- **Sloping Ground:** Roadside slopes and ditches of varying inclinations are considered as hazardous in all of the reviewed countries. Minimum slope gradient varies from 1:3 to 1:8 and minimum slope height from 0.5 to 6 m.
- **Other Hazard:** Many other hazards are also identified in guidelines across Europe, including:
- Water hazards (rivers, lakes, canals, reservoirs, stilling ponds) (FI, DE, GB, NL, ES, SE)
- Underpasses (pedestrian, agricultural) (GB)
- Property fences (FR, NL, ES)
- Other roads and railway lines (FI, DE, GB*, ES, SE) (*Roads <10 m from carriageway edge)
- Electricity transformers (FR, GB, NL, ES)
- Control cabinets (GB) and traffic counting stations (FR)
- Hazardous storage installations (GB)
- Road references points (FR, DE, NL, ES)
- Old barriers and barrier terminations (FI, FR, NL, ES)
- Central reserves with no safety barriers (FI, GB <10 m wide)
- Curves in road (GB - Radius <850 m (with varying roadside slope gradient and height); ES - Radius <1500 m))

Usually hazardous objects are protected by the installation of a guardrail for which already standard and technical specifications exist. Nevertheless it is worth to survey what can be done for safe roadside without barriers.

In **Norway** passively safe support structures shall be used in following cases:

- Within the safety zone when the speed limit is 60 km/h or higher (alternatively the supports shall be secured by safety barriers or otherwise positioned in a way that they cannot be impacted)
- Within the safety zone on roads and streets with speed limit 50 km/h, if the speed level in an 50% percentile is higher than 50 km/h and the supports are not protected with other structures
- If the mast is placed behind a safety barriers, but within the safety barrier dynamic deformation

It is not necessary to use passive safe supports on urban roads if the support is placed in front of a building wall or other rigid device.

HE-supports shall be used to limit consequential or secondary accidents after they are impacted if:

- it is important to retain the vehicles preventing them to run in a dangerous roadside area or rock cutting with protruding parts
- it is important retain the vehicles preventing them to run into pedestrians and cyclists paths that are close to the carriageway

HE-supports should not be used as a substitute for safety barriers.

Using HE-supports at medians, the smallest median width should be of 3 m in order to avoid that an impacted support fall on the carriageway becoming a danger for other vehicles. In presence of variable side terrain with the need for HE-supports, these can be used consistently (in different heights) to obtain a better appearance.

In **Finland,** more than 90% of new lighting columns installed for Finnra are breakaway. Most of them are wooden poles or yielding steel constructions, not many slip-base columns. Break-away lighting columns are only slightly more expensive than columns with no passive safety.

Energy absorbing columns are preferred on major roads when there is an actively used pedestrian way or trees behind a narrow ditch. In urban roads and streets with a speed limit 50 to 70 km/h, yielding lightweight columns (HE, LE or NE) which bend under the car impact should be used. Other kind of columns may sometimes fall on the roof of the impacting car. The risk is higher at low speeds but even than rather low. Overhead cables reduce the risk caused by a falling column.

In **Sweden** road equipment placed within the clear zone and not being protected by guardrails shall be passively safe and must not be penetrating. Delineator posts shall be ”harmless” from a traffic safety point of view.

A product that meets the requirements of a speed class for a certain type of energy absorption, e.g. 100NE, is also considered to meet the requirements of lower speed classes with the same energy absorbing function e.g. 70NE. Energy absorbing poles that meet the requirements for any HE-Class is also considered to meet the requirements for the LE of the same or a lower speed grade, refer to EN 12767:2000 Table 7.

The possibility to hit a post/column from behind should be taken into account, e g at two lane roads. When placing in intersections, posts/columns that are multidirectional, passively safe should be chosen. Posts/columns with slip base should not be used where it is likely that an errant vehicle hits a post/column on a higher level than what it is developed for, else it is likely that the slip base will not function in the correct way. All posts/columns, even passively safe ones, within a guardrails working width can disturb the functioning of the guardrail. Post/column at such location should not be of the slip base type. Posts/columns fulfilling demands for speed class 100 can be used on all kind of roads. Posts/columns fulfilling demands for speed class 70 can be used on roads with speed limit 70 or lower. Energy absorbing poles (HE and LE) can be used without restrictions.

Energy absorbing poles should be used where it is especially important to capture accident vehicles to reduce the risk of secondary collisions with other objects within the roadside area, e.g. trees, rock cuts, concrete foundations, and collisions with other vehicles. Non-energy absorbing columns (NE) can be used in other places, preferably not behind a guardrail.

In **Belgium,** they identify poles to passive safe if energy absorbing lighting poles are columns that yield around a car by their yielding concept during a crash, which makes that the passenger space stays fairly intact and that the impact is limited for the passengers. Installation criteria are specified for energy absorbing lighting poles type 100HE3, called also “kreukelpalen” (ZIP pole). These poles will **always** be installed:

- on roads where the allowed speed is >50 km/h and where there are no guardrails in front of the lighting poles
- on roads where the allowed speed is <50 km/h and where poles have to be closer than 2m to the side of the road and where there are no guardrails in front of the lighting poles
- on roundabouts except for areas where the allowed speed is 30 km/h
- at places where the risk of hitting a lighting pole is the biggest: roads towards and between roundabouts, in sharp curved roads, on a sharp junction between two roads, etc.

On other locations, the choice should be made according to the local circumstances. ZIP poles are preferred in comparison to classical poles in combination with guardrails, which are there to prevent from hitting the column. These guidelines are not obligated in designs of module 4 (public lighting adjusted to the city center, installed by the local government).

In **Netherlands,** lighting poles that are located in the obstacle free zone should be passive safe according EN12767:

- 100NE3 poles will be installed if there is no other risk in a zone of 40m width and 50m length, parallel to the road
- 100HE3 poles will be installed if there is another risk in a zone of 40m width and 50m length, parallel to the road

The **United Kingdom** has already a long experience in the use of passive safe structures and the application is defined in a National Annex to the BS EN 12767:2007 Recommendations for passively safe support structures for road equipment.

For non-built up all-purpose roads and motorways with speed limits over 60 km/h generally in verges of motorways, dual carriageways and single carriageway roads the 100NE 1-3 columns for lighting columns and sign or signal support should be used. Where significant volume of non-motorized users is involved at the times when impact occurs and where major risk of items on the other carriageways exist the 100 HE 1-3 columns should be used.

For built up roads and other roads with speed limits 60 km/h on all locations the class 70 or 100 HE and LE 1-3 safety level columns should be used.

In **Slovenia,** no special guidelines are made for lighting columns but indirectly through the technical specification for guardrails, the use of passive safe columns is accepted by possible omitting the guardrail if it is used only to protect against the possible impact of a vehicle (Willems, Caroline, 2013).

6. CONCLUSION

Passive safety of the road traffic is a complex issue and the road infrastructure is just a part of it. It happens quite often that the local community is treated with a secondary importance by the state authorities as if there were more important matters on the state level. In the case of the road safety, it is not the right way because we can see according to statistical data (chapter 1 and 2 of this article) that the **majority of fatal incidents happen on roads that are not categorized as highway,**

freeway or trunk road (yet mostly on such roads, elements of passive safety are used). Based on this fact we can conclude that much more need to be done for increase of road safety in local community with regard to the elements of passive safe infrastructure. Introduction of passive safe infrastructure into the local community can often be difficult. On one hand because of the shortage of finances (often local communities are happy to succeed asphalting a road that had been decades in macadam and they cannot pay for passive safe road equipment), while on the other hand because of the non-existence of direct effect of road accident prevention (saved money from road accident prevention does not belong to the local community but stays on the state level, in most cases in the ministries that are not directly involved in the infrastructure). The state should act stimulatingly in a way that the local community would have beside the moral satisfaction also the financial interest by introduction the passive safe infrastructure. Finally, in such contexts are developing new tendencies in the EU, means that from the European financial sources only those projects will be financed that will comply with the Directives for infrastructure safety and tunnels. We should be aware that local community does not mean only local roads. Roads network and local community are integrated with each other, so state roads are passing cities and villages which leads to the interaction of local and state authorities responsible for the road safety, means also for the use of passive safe road infrastructure. By implementing the passive safe infrastructure, much had been done on protection of hazardous objects with different types of barriers while the field of support structures remains less developed with exception of north European countries. There are huge possibilities for a successful implementation of passive safe support structures simply following guidelines that were made by the IRDES project (chapter 3) and which are giving a complex approach for design and arrangement of forgiving roadsides. True, there are no laws imposing the obligatory use of passive safe road elements but there are norms defining what passive safe structure is and there are guidelines that help us to design safer roads and roadside. Shouldn't we implement also our consciousness?

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