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PRELIMINARY COMMUNICATION

Passive Road Safety Systems - Case Study Of Road Section Banja Luka - Prnjavor (M16, M16.1)

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Abstract: In this paper, the authors will show the influence of roadside objects on road safety on the Banja Luka- Prnjavor section. Roadside objects have a major impact on the weight of a traffic accident because they represent direct obstacles to the wandering vehicle, which in most cases will be stopped by a collision in one of them in the immediate vicinity of the road. Roadside objects can be of different types and constructions, concrete poles, public lighting poles, trees, inadequately installed rebound fences and unprotected petrol stations are only some of them. Therefore, the essence of this paper is to spot possible roadside objects on the observed road section, categorize them, and make suggestions for short, medium and long term improvements.

Keywords: roadside objects types – RSI analysis – proposal of the solution for the observed road accident type – short, medium and long term improvements.

INTRODUCTION

INTRODUCTION

In the world, and especially in the underdeveloped countries and developing countries, 1.3 million people per year die in traffic accidents, and more than 50 million people remain permanently immobile or suffer injuries. In this "black" statistics Bosnia and Herzegovina contributes with at least 400 dead and 11,000 injured persons per year. The traffic death rate in BiH is three times higher than in Western European countries, according to official statistics over 10 people have been killed per 100.000 inhabitants. This difference can be even bigger if you take into account accidents that have not been recorded. The actual number of people killed in traffic accidents in the Republic of Srpska is higher than the registered number in the official statistical data. About 160 persons die on roads in Republic of Srpska, while over 3.200 persons get injuries. [1]

The economy of Republic of Srpska, due to traffic accidents, loses over 174 million KM, or about 90 million euros per year, when considering the costs of treatment, material damage, the costs of judicial and administrative procedures and loss of productivity. Total losses, damages and costs amount to over 2% of Gross Domestic Product (GDP). According to reports from the Ministry of Internal Affairs (hereinafter: the MIA), in the past five years, 850 persons died in Republic of Srpska, while 16.800 persons were injured or permanently incapacitated. The economy of Republic of Srpska has lost over 880 million KM (over 430 million euros). No economy can afford to have such high losses that are repeated year after year. It is therefore necessary to undertake urgent activities to reduce losses in people and the listed economic costs. [2]

DIRECTIVE 2008/96/EC OF THE EUROPEAN PARLIAMENT

The directive 2008/96/EC of the European Parliament on road infrastructure safety, dictates four points that all member states must undertake to improve safety on existing and future roads. Therefore, under this directive, member states should introduce and implement procedures relating to road safety inspection (RSI), road safety audit (RSA), the management of road safety aspects and the control of road safety. [3]

This directive applies to roads that are part of the trans-European road network, regardless of whether these roads are only designed, built or already in use. Bosnia and Herzegovina is a member of countries that have implemented this road safety directive.

Four points of the 2008/96/EC directive [3]:

- Infrastructure assessment projects impact on road safety;
- Road Safety Audit and Inspection on road infrastructure projects;
- Ranking of shares with a large number of traffic accidents and security ranking within the network;
- Data to be entered in a traffic accident report.

The Haddon matrix

The Haddon Matrix is the most commonly used paradigm in the injury prevention field. Developed by William Haddon in 1970, the matrix looks at factors related to personal attributes, vector or agent attributes and environmental attributes; before, during and after an injury or death. By utilizing this framework, one can then think about evaluating the relative importance of different factors and design interventions. [4]

Category	Before Crash	In Crash	After Crash
Human	Information, attitude, impairment, police enforcement	Use of restraints, impairments	First-aid skills, access to medics
Vehicle	Roadworthiness, braking, lighting, speed management	Occupant restraints, crash-protective design, other safety devices	Fire risk, ease of access
Road	Road design and layout, speed limit, pedestrian facilities	Crash protective roadside objects	Rescue facilities, congestion

Figure 1. The Haddon matrix

ROAD SAFETY INSPECTION ANALYSIS (RSI)

RSI is a systematic field study conducted by qualified experts. It consits in doing a safety check on existing roads in order to identify any dangerous points, mistakes and defects that can lead to serious traffic accidents. Following the "better to prevent than treat" principle through RSI analysis, the existing road facilities and infrastructure can be improved and this can reduce the percentage of serious traffic accidents.

The basic principles of RSI analysis are [5]:

- Interdisciplinary detailed analysis of road and road environment;
- Identification of possible accidental risks;
- An analysis of the state of the driver's perception and the quality of driving;
- Checking the performance of roadside equipment such as rebound fences and others;
- Compliance of the local situation with norms and guidelines.

CASE STUDY (BANJA LUKA - PRNJAVOR)

This case study presentes the analysis of passive road safety. The impact of roadside objects on road safety along the road section Banja Luka - Prnjavor is showed. In February 2017, the entire research-relevant stock was recorded with a camera placed in a cockpit of a passenger car. Analyzing the snapshots, additional field research was not necessary, given that the output information from the camera, or video recording, was of very good quality and could fully represent the real state of the road. Considering that the observed section contains two categories of road in its route, passing through inhabited and uninhabited places, the number of observed roadside objects was generally quite large. Such a result, looking at the state of the road and the environment, was not surprising. The roadside object impact factor for the consequences of a traffic accident was somehow always viewed as a secondary and not so important thing. But the fact is that an adequately set front rebound fence or an adequately protected concrete pole can significantly reduce the consequences for the persons and the vehicle involved in an accident, changes significantly the thinking about this topic. One of the aims of this case study is to precisely prove this claim. The vision of the competent authorities for the safety of traffic in the Republic of Srpska has to be enlightened to the extent that investing in the safety of transport is not a cost but a profit. Why profit? Well, if we look at the annual cost of traffic accidents based on the parameter from 2012, which "Economic Institute a.d. Banja Luka" in cooperation with Swedish experts calculeted, we will come to a simple conclusion that investments in adequate equipment for the protection of roadside disturbances are far less than the total cost of traffic accidents. Adequately protected roadside disturbances reduce the consequences of traffic accidents and reduce their costs for the Republic Of Srpska's budget analogously.

The cost of a traffic accident only with pecuniary damage, based on the "readiness to pay" calculation process, which represents the minimum economic loss, is 3.258 convertible marks (hereinafter KM). If we compare this amount with the cost of a traffic accident with severely injured or dead persons we will have 66.683KM or 620.618KM. We can conclude that the difference between economic losses is enormous depending on the severity of the traffic accident. Therefore, if the consequences of traffic accidents are reduced to a greater extent, the costs of this will decrease. [2]

The starting location begins at the exit from the Banja Luka city area on the road reserved only for the traffic of motor vehicles (M16). In the town of Klašnice, the road reserved only for the traffic of motor vehicles (M16) stops and crosses to the road M16.1 Klašnice - Prnjavor. During the observing period, this section was constantly under heavy load throughout the day due to the construction of the section of the Prnjavor-Banja Luka freeway parallel to this route. This means that the percentage of heavy vehicles in the traffic flow was big. There are a lot of smaller connecting roads that only these vehicles use, the newly constructed freeway-related facilities are in no way protected from the upcoming traffic. All of these factors aditionally pose a danger to an already insufficiently safe road from the aspect of roadside disturbances.

Roadside disturbances identification

The identification of roadside disturbances was done by a detailed overview of the video material. Each roadside disturbance was marked by using the hours, minutes, and seconds on the recording. Categorization was done for easier data processing and because the number and the type of roadside disturbances was quite large. Each category of road was primarily dominated by one category of roadside disturbances with a smaller share of others.

Accordingly to that, lateral disturbances were categorized in:

- Concrete and iron poles of electricity distribution and public lighting;
- Open beginnings of the frontal rebound barriers;
- Approaches and fences on the bridges;
- New Jersey barriers;
- Unprotected approaches to the petrol stations.

Concrete and iron poles of electricity distribution and public lighting pose a problem to the greatest extent. The present poles, in most cases, are located in the immediate vicinity of the edge of the driveway, where they pose a serious threat to road users if a wandering vehicle hits one of them.

Observing the our case, especially on the main road M16.1 Klašnice - Prnjavor, the distance of roadside disturbances is roughly 2m from the edge of the driveway. In some segments of this road, the poles are located at a distant distance, somewhere even on a smaller one. The point is that these poles are not adequately protected in any way and pose a direct danger to traffic participants in case a wandering vehicle hits some of them.

In Figure 3. we can see an example from a real life situation. That even if the speed limit is 80km/h the poles are located very close to the edge of the driveway and extend on the right and left side of the road to the entire length of the segment of the specified speed limit. [7]

Figure 2. Iron poles in the speed limit zone of 80km/h (M16.1).

It should be noted that in such cases even if the speed limit is 80km/h the speed of the vehicles is predominantly higher than permitted for as much as 30km/h in some cases. For such segments of the road, it is necessary to protect the roadside disturbance (poles) by the setting of the rebound fences, so that the poles are not in the working width of the same fence or completely replace the existing poles with passive safety poles where this is possible.

On the road reserved only for the traffic of motor vehicles M16 Banja Luka - Klašnice, the poles of electricity distribution and pubblic lighting are adequately protected by a rebound fence. But there are some places on the exit ramps as in Figure 4. where the poles are completely exposed to the external traffic impact.

Figure 3. Pole exposure (M16)

In this road section, vehicle speeds exceed 100km/h, making this a relevant hazard. And if so far there have been no cases that a vehicle hit that unprotected pole, that does not mean that tomorrow will not happen. Therefore, it is necessary to react preventively and not wait for a serious traffic accident to happen, and then only apply certain measures that will be corrective in this case.

The frontal open beginnings of rebound fences pose a major problem in the entire observed section. The example from Figure 5. shows the open start of the rebound fence on the road section Klašnice - Prnjavor (M16.1).

Figure 4. Open start of the rebound fence (M16.1)

The open start of the rebound fence acts as a kind of blade when the vehicle in motion hits it, so we have an opposite effect of the fence here. Instead of turning away the wandering vehicle that hits the fence back on the driveway or in an another case safely stopping it along the length of the fence, the vehicle hits directly the metal structure which, at that speed, becomes a "blade" that breaks through the chassis of the vehicle. In addition to the open beginnings and endings of the rebound fences, they're mostly in a bad state. Primarily because of previous vehicle accidents and insufficient fixing after accidents. In some places the fences are not placed at the appropriate height and are not connected in an adequate way with the attachments of other fences. The explanation for this situation lies in the fact that these fences when first placed were adequately furnished. But because of insufficient maintenance of infrastructure and poor remediation after traffic accidents they've lost all their functional aspects in time and now they have almost no effect on reducing the consequences of a traffic accident. In some cases they can act contrary to what they are intended for and increase the consequences for passengers in the vehicle and for the vehicle itself.

Figure 5. Poor maintenance (M16.1)

The approaches and the fences on the bridges are also one of the critical points on the observed section. There are openings between the protective fences on the bridges and the frontal rebound fences. And in this case, the ending of the rebound fence is in most cases open. As far as the protective fences on the bridge are concerned, they are mostly in poor condition or not present on one or both sides. The approaches to the zones of the bridges are not adequately protected. The rebound fences, if any, do not protect vehicles from possible landings in slopes in the zone from 20 to 50 meters before the bridge. They are placed before the beginning of the bridge or are not at all positioned.

As can be seen in Figure 8, this frequency of the defective fence barrier before the bridge is quite constant throughout the observed section.

Figure 6. Unprotected approaches (M16.1)

New Jersey barriers are present only on the road reserved only for the traffic of motor vehicles M16 Banja Luka - Klašnice. Their function is to physically separate the driveways. In the majority of cases, one line of these barriers is enough but there are two lines on the M16 path for reasons that are not defined. Roadside disturbances on this section are largely adequately protected, but the beginning of the new jersey barriers are a problem if a moving vehicle hits one of them. Any beginning is not protected in any measure, and it also represents a sort of a catapult for a vehicle in case of a collision.

Figure 7. Unprotected new jersey barrier (M16.1)

An additional indispensable item on this section of the road are the paytoll booths that are not in operation and currently present, in such a state, only an obstacle and endanger the safety of traffic due to their inadequate protection against possible vehicle collisions.

Figure 8. Paytoll booths (M16)

Unprotected petrol stations are a subcategory because there is only one unprotected station in the speed limit zone of 80km/h. Other gas stations on the whole observed section of the road are located in zones where the speed limit is 50km/h. Therefore even if they have similar characteristics to the gas station in question, no further changes are needed. The curbs set up at the access road do not represent any kind of protection against collision and can not prevent the vehicle from passing. An advertisement with fuel prices is placed very close to the edge of the driveway, with its foundation of concrete structure, which in most cases expands so it poses additional danger. Also, the iron poles of lighting are in the immediate vicinity of the structures.

Security risks analysis

The observed section of the road M16.1 contain a mixed function of local and remote traffic, which indicates different speeds of allowed movement. Pedestrians and bikers also use this route, but are present mostly in liner settlements and villages than in rural areas. Tractors and other transport vehicles used by farmers are most often present in rural areas. The presence of connecting roads, without traffic signalization and without asphalt cover, from various private estates is quite large. Mixed road users with varying speed and safety requirements make these a high-risk road sections. On the other hand, if we look at the road reserved only for the traffic of motor vehicles M16 these listed characteristics are not present. Driveway directions are physically separated, working machines and tractors are not present in the traffic flow, no connecting roads and the speed of movement is quite constant without sudden changes. But there are other issues that need to be addressed, such as: inadequately protected beginnings and endings of New Jersey barriers and toll booths that are not in function. [6]

Identified safety risks for the observed road sections
Function and road environment:

- Along the observed sections there are connecting roads without traffic signalization and without built-in asphalt cover;
- In some segments there are "wild" bus stops that are not illuminated and properly marked;
- Speed limit signs on certain parts of the road are not placed in appropriate ways, causing drivers to not respect them.

Cross-sectional profile:

- The driveway is divided by a central line, the edge lines that are in poor conditions (damaged and with poor retro-reflection);
- The edges of the driveway are damaged, the soft shoulders are not in the same level with the driveway (especially on section M16.1) and do not have enough width;
- The ruts made of car tires are visible, which prevents drainage from the driveway. This factor will cause aquaplanning when it rains;
- The driveway surface, especially on the road section M16.1, is smooth and slippery with a low adhesion coefficient, especially in rainy conditions;
- There are no transverse inclinations on the carriageway in some segments and where they are present they're not properly directed.

Passive safety features:

- Raised sidewalks are present along the road section M16.1. Raised both by the driveway and by the soft shoulders;
- Unprotected drains, electricity and public lighting poles;
- Lack of rebound fences in most of the curves;
- Existing rebound fences are not long enough and do not have safe endings and beginnings;
- Unprotected beginnings of the New Jersey barriers on the road M16.

Proposal of safety solutions

After the identification of roadside disturbances and security risk analysis on the observed sections of the road, this chapter will show the possible solutions for the improvement of roadside disturbances protection. Short,medium and long term solutions will be displayed.

Short term solutions are a type of solution that can be implemented in a short period of time. It is especially important to have stable goals and ideas regarding short-term measures for further implementation of medium and long-term measures. Therefore, through the short-term measures within this report, the following items are recommended:

- Replacement of concrete and iron poles with passive safety poles where possible;
- Where the replacement of existing poles is not possible, it is necessary to protect the poles with appropriate crash cushions especially for zones 50km/h and zones over 70km/h;
- Fixing the rebound fences in general with a special emphasis on the correct ways of their beginnings and endings;
- Protecting the beginnings of "New Jersey" barriers with End-Terminals on the road section M16 Banja Luka - Klašnice;
- Installation of rebound fences before and after the bridges and removal of the existing voids between the end of the rebound fence and the beginning of the protective fences on the bridge.

Medium term solutions

- Removal of a large number of unshielded connecting roads on section M16.1 and creation of a pair of collecting paths by segments.

Long term solution

- Permanent removal of all roadside disturbances where possible.

Passive safety poles and crash cushions

Poles must comply with the requirements of EN-40 and/or EN 12899 for traffic signs in terms of carrying capacity for certain types of road equipment (portal and semi-portable constructions, traffic signaling constructions as well as public lighting poles). In order for such pillars to be passive and safe, they must comply with EN 12767. [8]

EN 12767 differs three categories of poles in terms of energy absorption during a vehicle impact:

- HE - high energy absorption;
- LE - low absorption;
- NE - without energy absorption.

Areas of use of these poles are very wide and can easily be applied to solve the observed problems in this case study. Poles must be passively secure on [8]:

- All roads outside the inhabbitated areas, where the speed limit is higher than 50 km/h and where the poles are not protected by a rebound fence;
- All roads, where the speed limit is less than 50 km/h and the poles are less than 4m from the driveway surface and are not protected by a rebound fence;
- Always when the pole is behind the rebound fence but is in the area of its working width.

Figure 9. Example of the behavior of a passive pole

In case the replacement of the existing poles with a passive safety ones is not possible, there is an another method of protection against vehicle impacts. SMA Tree crash cushion is the best solution for this. Originally designed to protect trees from possible vehicle impacts, it can be applied with the same analogy for poles as well. Figure 11 shows the technical characteristics of the SMA crash cushion. Note that this system is 80% re-usable after an impact of a vehicle. The absorbent cells can be replaced and the crash cushion can again perform its full function. [9]

Figure 10. Technical characteristics

The green zone is the area where the tree or pole is located and can be in the width of 1m to 1.5m. The kinetic energy produced during the impact is gradually absorbed from this system by preventing serious injuries on the passengers in the vehicle.

Protection of the beginnings of New Jersey barriers

On the road reserved only for the traffic of motor vehicles M16 there are several New Jersey barriers whose beginnings are not protected in any measure and some of them have already traces of vehicle imapcts. Since speeds on this road are more than 100km/h, adequate protection and prevention of catapulting vehicles in the event of a collision is a must have thing. [11]

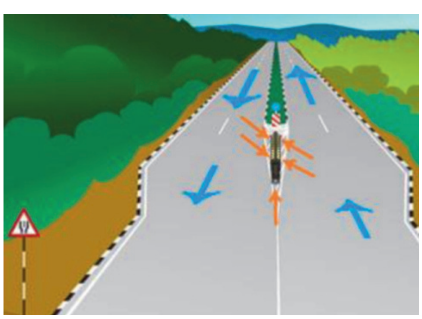

Figure 11. M16 example situation

Blue arrows indicate the direction of movement of the vehicles while the orange arrows indicate the possible directions of movement of the vehicles during an impact with the SMA end terminal.

There are two types of these structures [11]:

- SMA T2 for speeds up to 80km/h;
- SMA T4 for speeds up to 110km/h.

SMA end terminals are a really innovative product on the market because they are double sided which means that they absorb the energy of the impact from both sides and therefore can be installed both in front of the roadside barrier, and in front of the median barrier. Also bi-directional, they absorb the energy of the impacting vehicles coming from both directions of the driveway. For this reason, they can be installed both at the begin and at the end of the barriers. [11]

The behavior of SMA End Terminals during the impact is similar to the behavior of Crash Cushions because of their similar absorbing system. SMA T2 and T4 are different from the competitor's end terminals because they have an enery absorbing system made of collapsing beam with controlled deformation, patented from Industry A.M.S. srl. . They avoid any possibility to have an unpredictable behaviour – especially in case of out-of-norm impacts – in order to adequately protect the passengers from serious injuries. SMA end terminals are tested to absorb the impact of a vehicle with a mass between 900 and 1500 kg. Thanks to their structure in steel, SMA T2 and T4, after the impact do not release debris on the road because they don't break but become more compact by reducing their lenght. SMA end terminals guarantee the maximal protection for the passengers of the impacting vehicles and other road users. Like the SMA crash cushion absorber, this system can be used again after the impact, by only changing the damaged parts of the terminal, that is the modular system. [11]

Correct execution of the beginnings and endings of rebound fences and their maintence

As shown, the beginnings and endings of rebound fences are not executed in the right way and pose a serious threat in case of a vehicle impact. Many fences have not been repaired after the earlier accidents and can not perform their function in the right way. So the only possible solution to the problem in this case is:

- Fixature or replacement of the rebound fences that have been damaged during vehicle collision;
- The beginnings and endings of fences must be executed out in the right way so that they do not have a sharp beginning and end that can break through the front of the vehicle. The beginning must not be in such a form to catapult the vehicle into the air during collision.

Rebound fences before bridges and fences on the bridges

Before and after the bridge, there are no rebound fences that would prevent the possible landing of the vehicle into the slope before the passage. It is necessary to install a rebound fence of an adequate length before the passage and after the passage, so that possible exit of the vehicles in that zones are prevented. Rebound fences should be connected with the fence on the bridge, the pedestrian zone if present, should be protected from the external influence of traffic of motor vehicles. Fences on bridges are in a catastrophic state in most cases or do not exist at all, so this aspect should be solved by placing adequate certified protective fences.

CONCLUSION

One of the tasks of this case study was to determine the safety risks of the observed road sections from the aspect of passive road safety. The ultimate goal of the research basically offers a solution to modernize the road and remove and protect roadside disturbances in order to create the prerequisites for reducing traffic accident consequences. By implementing measures to eliminate potential security threats, it is possible to get a road that forgives driver errors. Therefore, it is necessary to create a roadside ambient amplitude that will not bring participants into a dangerous or fatal situation.

All this being said, investment in traffic safety should not be considered a cost, but vice versa. It is a gain in terms of more saved lives, minor serious bodily injuries and minor material damage in the aftermath of traffic accidents.

In addition to the implementation of this measuers, there is a need for them to be maintained regularly. By investing in equipment and financing future projects in the area of traffic safety it is possible to reduce the consequences of traffic accidents and increase the overall level of safety on Republic of Srpska's roads. By reducing the consequences, spending of the budget will reduce, social situation in the society will improve, which is evident from the Study of the Economic Institute in Banja Luka in 2012.

Having examined all the information presented in this paper and the possible solutions that exist and are implemented in the world, through the precise visions and goals it is possible to significantly change the condition of the roads in question and remove or adequately protect the roadside disturbances.

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