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STRATEGIC DIRECTION SESSION ST3

SAFETY AND SUSTAINABILITY

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1. INTRODUCTION

We all know that Vision Zero, Sustainable Safety, the Safe System Approach, or whatever we call or name our Road Safety programmes or resolutions, are based on a multi-stakeholder systematic approach and commitment to jointly work towards zero fatalities and zero severe injuries.

Unfortunately, in past years we partly forgot that Road Safety is a Shared Responsibility and sometimes we mainly focus only on road infrastructure in terms of its deficiencies, especially when investigating traffic accidents. In addition, human factors, in connection with road safety, are often wrongly or inadequately interpreted. We too often choose not to understand the psychological needs of humans (road users) in connection with road design (such as Self-explanatory Roads), as well as from a physical point of view (such as Forgiving Roadsides). If we would really like to improve the infrastructure for road users, especially for vulnerable road users (VRUs), we must understand the cause, or set of related causes, that led to a driver's mistake resulting in an accident. We must understand the driver's needs regarding how our perception and our mind works and that "what you see is not always what you get" (perceive and understand), as our mind sometimes plays tricks on us (optical illusions, etc.). In addition to all those mental limitations, we must as well understand and be familiar with our physical (biomechanical) limitations. This is very important especially regarding motorcyclists, as motorcyclists, except for helmet and clothing, do not have any other proper protection. Furthermore, standards in this field, seen from an infrastructure point of view, are almost non-existent (except for the European standard CEN/TS 17342:2019 Road restraint systems – Motorcycle road restraint systems which reduce the impact severity of motorcyclist collisions with safety barriers).

So, EU Directives, the public, road users, experts, politicians, road safety auditors, etc., expect the road operator to provide safe road infrastructure that will do all the magic considering Vision Zero, even though we (road operators) do not have at our disposal proper proactive solutions in the form of standards, technical specifications, products, etc. Mostly what we have are some solutions to mitigate the consequences of accidents (such as continuous and discontinuous motorcyclist protection systems). Meaning that a mistake has already been made and an accident can be expected to happen.

That is why the Slovenian Infrastructure Agency decided to start pilot projects and the evaluation thereof, i.e. to find proactive solutions to improve motorcyclists' safety on roads. Our focus was to find Human Factors solutions, how to communicate with motorcyclists to provide them with self-explanatory or, better said, intuitive road designs. In order to address them in such a way that they will intuitively reduce their speed and change their mode or riding. In addition, if something does happen, as all the factors are hard to control, the consequences of a fall must, to the greatest degree possible, be within the tolerance of the human body.

2. BACKGROUND

Motorcyclists or "powered two-wheelers (PTW)" belong to the group of vulnerable road users for several reasons:

- they are not surrounded by a "shield";
- the driving dynamics of a single-track vehicle differs from the driving dynamics of two-track vehicles (single-track: handlebar and leaning; two-track: steering wheel);
- the small mass compared to other motorised vehicles coming from the opposite direction;
- the small transverse profile compared to other types of motorised vehicles (harder to identify);
- measures to ensure passive safety are generally suited to two-track vehicles and can pose a danger to single-track vehicles; and
- motorcycles have a higher kW/kg ratio compared to two-track vehicles.

The European Commission has also recognised this, which is why in the amendment to Directive 2008/96 (Directive 2019/1936) it explicitly classifies motorcyclists as a group of vulnerable road users:

- special attention must be paid to the safety of pedestrians, cyclists and motorcyclists ("...in all phases... projects should be checked for all groups of vulnerable road users...") – the new article 6b;
- vulnerable road users are precisely defined in the new Article 2 (10);
- Annex II: new requirements (n and h) are included, especially for powered two-wheelers.

The popularity of motorcycles in Slovenia is continuously increasing. In Slovenia, according to the latest data from the Ministry of Infrastructure, the number of issued driving licenses for both category A and category B is approximately 195,000. The number of registered motorcycles is increasing, and along with the growth in the number of motorcyclists on the roads, there is an increasing probability of their involvement in traffic accidents.

Although the total number of traffic accidents in Slovenia has been decreasing in recent years, the number of accidents involving motorcycle riders has been increasing. The share of severely injured and killed motorcyclists is significantly higher than their share in the traffic structure compared to the total number of injured and killed on Slovenian roads.

In the past, the Slovenian Infrastructure Agency, alone or in cooperation with other competent Slovenian institutions, carried out a series of activities in the field of improving the traffic safety of motorcyclists: preventive actions and education, additional traffic signals, and the improvement of traffic safety conditions on/along roads. However, most of these activities were curative.

With this new proactive approach, Slovenia has taken a step closer to Vision Zero (especially for motorcyclists) in the field of designing, equipping and maintaining roads.

3. PILOT PROJECTS BEFORE A WIDER SYSTEMATIC APPROACH

Pilot projects were implemented on road sections where specific issues, problems or, better-said, challenges were identified. In this paper we will present five (5) pilot projects, and some additional solutions, as well as an evaluation and the background thereof, so that readers may better understand why and how we systematically approached improvements in motorcyclist safety interventions.

3.1. 1st Pilot Project – Special Road Marking on the Road to "Rakitna"

Our first challenge brought us an opportunity for cross-border collaboration with our Austrian colleagues from the Office of the Corinthian Provincial Government, Ing. Gerald Höher.

We, similar as our Austrian colleagues, had issues regarding the state road "Rakitna-Podpeč", where a well-organised group of motorcycle racers would gather and race around the curves. That was a big safety problem, as well a noise pollution issue. As this group was well organised (there were lookouts with radio connections), police could not intervene or when they did come, the racing would have already stopped. As police could not be present 24/7, people living there would turn to the road operator and ask for infrastructure measures.

We knew that the majority of drivers (of both cars and motorcycles) were driving within the safety regulation requirements (perhaps motorcyclists a bit faster – as their driving dynamics allow it), but they did not pose a real safety or environmental issues, so they should not be "punished" by severe infrastructure measures. We needed to calm down and channel those racers so that they would stop racing, riding and leaning over into the opposite traffic lane.

That is why we contacted, with the help of and connection with the Conference of European Directors of Roads (CEDR), Road Safety Working Group, our Austrian colleagues, who already had experience with similar challenges.

Together we identified 15 left side curves that had a limited sight distance and motorcyclists did in a way blindly lean over the middle line, extending into the other driving lane with their body or motorcycle.

Figure 1 – Special motorcycle marking and a vertical information sign.

After implementation, there was a large positive reaction (from people living there, from other drivers, as well from car and motorcycle drivers, the police and the relevant

municipalities), but there was also a significant bad reaction and pressure from the racing community to remove the special markings.

We stood our ground and proved by an independent evaluation (monitoring) that the solution works. The measures had a positive impact on the traffic safety of motorcyclists. The number of accidents in exposed (marked) curves decreased by as much as 71% in the comparable period after the measures were implemented (comparing 3 years before and 3 years after implementation). The number of all accidents in exposed (marked) curves decreased by more than 56%.

In the entire area (from km 4,281 to km 8,737), meaning not only in exposed / marked curves, the number of all accidents decreased by 29%, and the number of motorcycle accidents by just under 21%.

After that (first) pilot project, the Ministry of Infrastructure made changes to the legislation, thereby allowing road operators to carry out future pilot projects, whose evaluation and results must then be reported back to the Ministry. This also entails that our first pilot project was also the first pilot project in general on state roads, and triggered a change in the legislation (the Roads Act).

3.2. 2nd Pilot Project – Reducing Speed and Raising Drivers' Perception of "Stari Log" curves

Due to frequent traffic accidents in one of the curves before entering the town Stari Log, we decided to calm traffic with improved guidance through the curve and enhanced warning of the curve itself. The project was carried out in two steps.

The first step was to optimise the traffic signs before and in the curve itself with improved guidance through the curve (Table 1). In the second step, we added some additional elements to enhance guidance through the curve (Table 2).

In this project, we used hidden speed measurements and eye-tracking analysis to identify if the interventions performed had a positive (or negative) effect on the visual detection and perception of the course of the road, and speed. The evaluation was carried out by the Faculty of Transport and Traffic Sciences, University of Zagreb.

Table 1 – 1st phase: before/after the intervention and the impact on drivers' perception.

	Before	After	Intervention	Impact on perception
1st phase			Relocation of information sign "Dangerous Road Section"	Important positive impact
			Replacement of existing chevron signs with passive safe chevrons and bollards for guidance true the curve	Significant positive impact
			Replacement of existing chevron signs with passive safe bollards for guidance true the curve	Important positive impact

Table 2 – 2nd phase: before/after the intervention and the impact on drivers' perception.

	Before	After	Intervention	Impact on perception
2nd phase			*Adding red/white elements in the groove of road safety barrier*	Important positive impact
			*Adding red/white markings on the edge of the road*	Little positive impact
			Adding chevron signs on the bollards	No impact

From this research, we can conclude the following:

- the participants examined (drivers of cars and single-track vehicles) were most focused on the middle line in the daytime and at night, then on the inner part of the curve, and least on the outer part of the curve;
- after the installation of additional traffic signalisation and equipment, a large number of fixations and fast eye movements between fixations are recorded. It can be concluded that the drivers' view was more focused on the added elements, as they wanted to get as much visual information as possible, to clearly detect the course of the road;
- the red/white elements mounted on road safety barriers (the outer part of the curve) attracted more views from drivers compared to the red/white markings on the edge of the road (the inner part of the curve);
- the installation of additional red/white elements on road safety barriers had an impact on speed in the curve, for both cars and single-track vehicles (motorcyclists). Speed was reduced on average by 11%;
- signs for guidance through the curve (chevrons) and the red/white elements placed on road safety barriers have proven to be the best solution to (pre)warn and guide drivers through the curve.

The most important aspect is that since the pilot project we have not had any accidents on this curve.

3.3. 3rd Pilot Project – Implementing Passive Safe Elements for Guidance through 5 Curves Near the Town "Lašče pri Dvoru"

We identified an increased number of accidents involving motorcyclists in five (5) curves near the town Lašče pri Dvoru, which is why this road section was marked as a dangerous section for motorcyclists. As we already had experience that speed limit traffic signs do not actually improve driving speed, except in combination with speed cameras, we have decided to try to lower speeds (without placing speed limit signs) and improve guidance through curves with passive safe elements, using a human factors approach.

Previously, we have already made, in cooperation with the Faculty of Mechanical Engineering, University of Ljubljana, numerical simulations of passive safe bollards. These bollards were designed and tested (both by numerical simulations and experimental tests) to withstand winter conditions (i.e. they are resistant to snow pressure when ploughing) and are also motorcyclist-friendly in the event of a collision therewith.

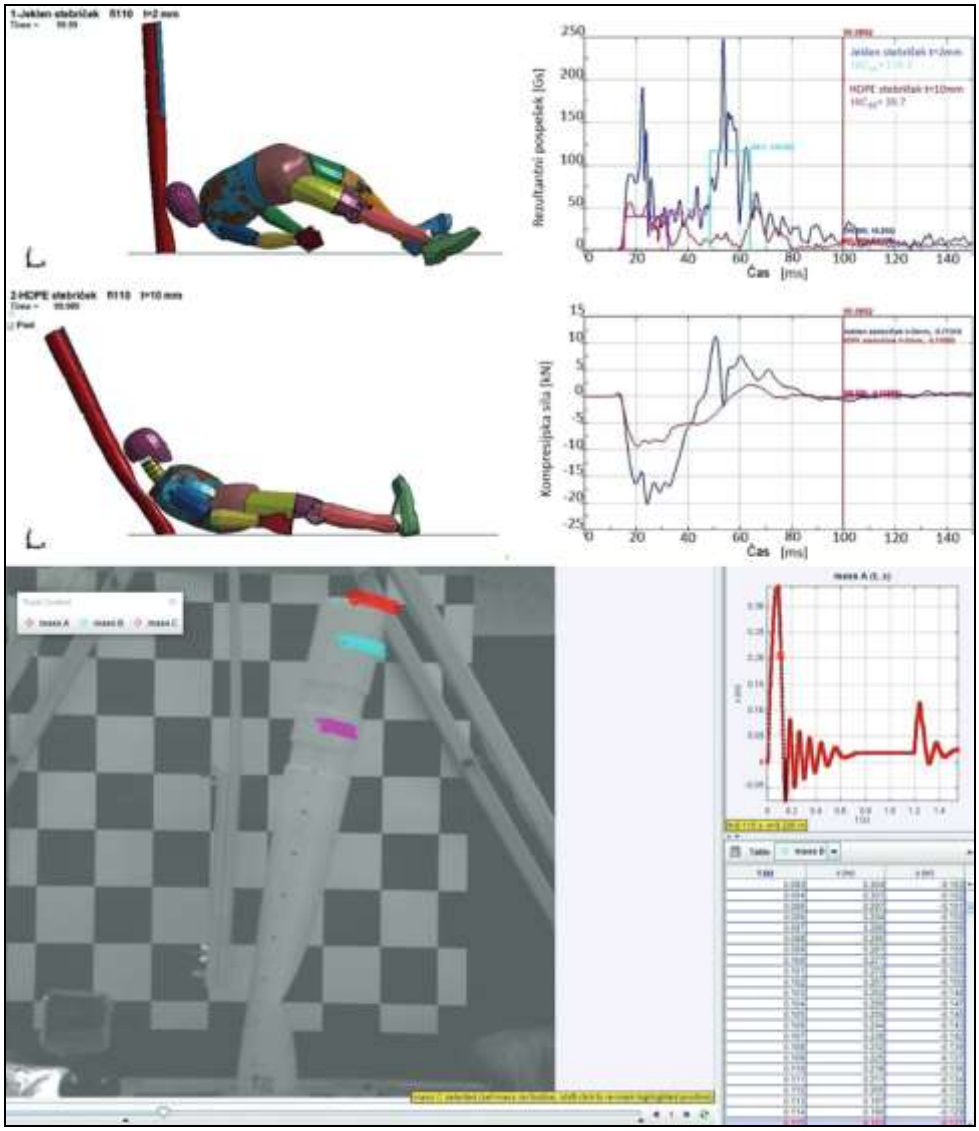

Figure 2 – Numerical simulations and experimental tests of passive safe bollards.

Alongside this pilot project, we also carried out, with the cooperation of the Faculty of Civil Engineering, Transportation Engineering and Architecture, University of Maribor, speed monitoring with hidden speed measurements, lane control (the position on the road) with hidden video cameras and expert psychological evaluation by internationally recognised human factors specialist Dr Sibylle Birth, from Germany. Here again, it is very important to recognise the importance of international cooperation and a multidisciplinary approach, as the World Road Association (WRA – PIARC) made several crucial manuals in the field of human factors and road design (the interface between human and infrastructure), (co-)authored by Dr Birth.

The results of monitoring showed us that motorcyclists tend to slow down and position themselves away from the middle lane, and more towards the middle of the traffic lane, so that they lean into the opposite traffic lane less.

The results of the human factors evaluation show that the innovative use of passive safe bollards can reduce the likelihood of accidents on a road section, as bollards give proper information regarding road alignment so that motorcyclists can adjust their speed and driving behaviour according to the geometrical elements of the given road.

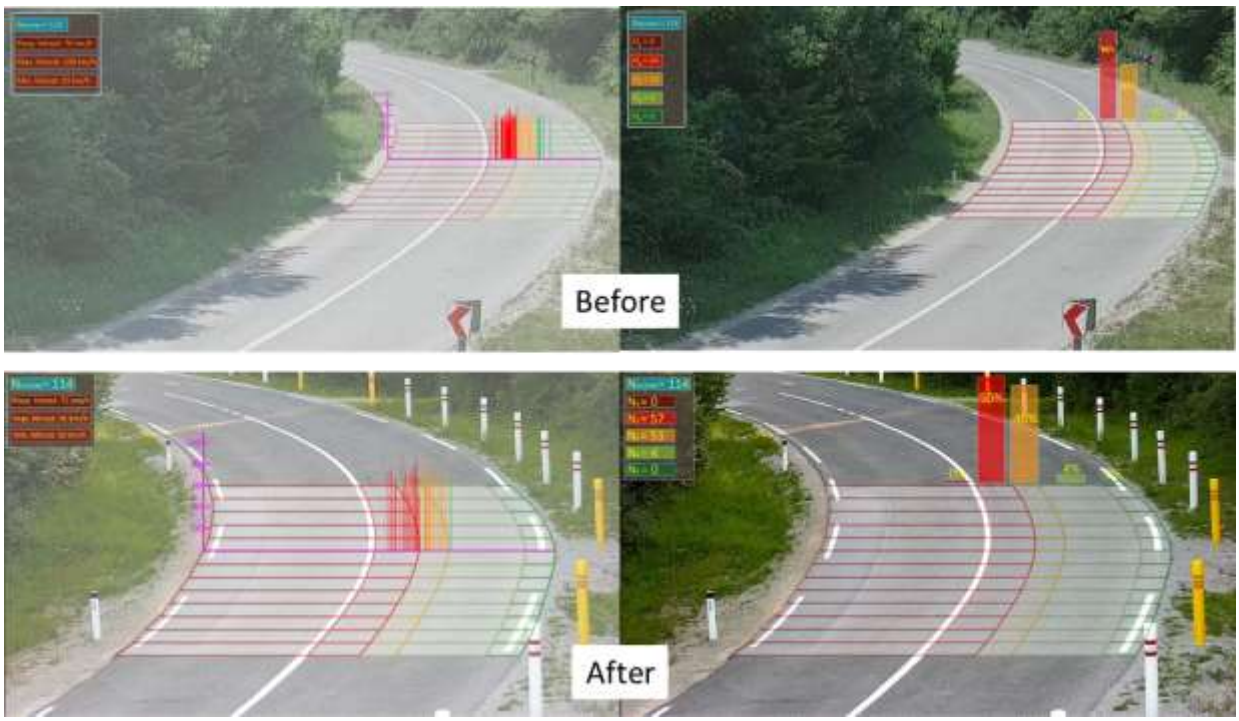

Figure 3 - Results before/after hidden speed measurements and video monitoring.

The Human Factors (H.F.) evaluation showed us a deficiency in one curve (also hidden speed measurements showed no change in speed), so we upgraded (enhanced) the perception of the curve with additional traffic equipment and took additional hidden speed measurements (Figure 4).

Znižanje hitrosti (km/h)		Motor	Osebno vozilo	Dostavno vozilo	Osebno vozilo s prikolico	Togo tovorno vozilo	Tovorno vozilo s prikolico	Priklopnik	Avtobus	**Vsa vozila**
Smer Dvor	v85 (km/h)	-9	-5	-8	-7	-5	-1	-7	-9	-7
	v95 (km/h)	-9	-6	-12	-7	-6	-2	-6	-10	-9
Smer Stari Log	v85 (km/h)	-6	-2	-2	-2	-6	-3	-2	-26	-4
	v95 (km/h)	-10	-3	-4	-3	-19	-6	-4	-24	-8

Figure 4 – Results before/after hidden speed measurements on one curve that needed to be upgraded after H.F. evaluation.

By comparing the results of hidden speed measurements after upgrading, we found that the speed percentiles V85 and V95 decreased after the installation of the traffic equipment (passive safe bollards and chevrons).

The speed percentile V85 in the direction of Dvor decreased from 81 km/h to 74 km/h, and the speed percentile V95 from 90 km/h to 81 km/h.

In the direction of Stari Log, the V85 speed percentile decreased from 81 km/h to 77 km/h and the V95 speed percentile from 92 km/h to 84 km/h.

In this project we also installed yellow passive safe bollards for alerting motorcyclists to less noticeable side roads connecting to the main road and an iron grid that prevents motorcyclists from hitting the road ditch culvert in the event of an accident.

Figure 5 – Iron grid covering the road ditch culvert.

3.4. 4th Pilot Project – Traffic Calming Measures in “Črni Kal” curves

In Črni Kal, we had challenges (similar to Rakitna) as regards how to slow down racers, as many accidents occur on a relatively short section of curvy road (approx. 2 km). We had few solutions in mind and decided to draw a central double continuous line with a contrasting green background (RAL 6024) between the lines. The contrasting green background between the lines is 50 cm wide, so with the lines we have together a field 80 cm wide separating the traffic lanes. In addition to the above, the traffic signals and traffic equipment (chevrons, passive safe bollards, motorcyclist protection systems) were also upgraded on the road section.

We did not wish to implement more drastic solutions (like rumble strips), as we were only targeting racers (who are involved in the majority of traffic accidents, endanger others and cause excessive noise pollution), as other motorcyclists drive in accordance with the traffic rules, and do not need to be uncomfortable (“punished”) while riding.

During the project we also introduced new solutions:

- an ITS information sign for motorcyclists before a dangerous curve (only activated by single-track vehicles when the speed limit is exceeded), showing a bilingual text: “PREHITRO / SLOW DOWN” and a silhouette of a motorcyclist driving;
- a motorcycle-friendly curb (in the event a motorcyclist falls, he or she will not be injured by it).

Figure 6 – New road design with an ITS solution.

Figure 7 – A motorcycle-friendly curb.

By the implemented measures (speed limits remained the same) we managed to reduce the speeds of motorcyclists on the road section, just by an intuitive road design (proper visual communication with the driver).

In the left curve (where a motorcycle-friendly curb was implemented), and where traffic accidents often occurred, we succeeded in slowing down motorcyclists, and positioning them away from the centre line, and more towards the middle of the traffic lane. Thereby, they lean less toward or into the opposite traffic lane, and consequently we managed to reduce possible frontal or side collisions of motorcyclists with opposing traffic.

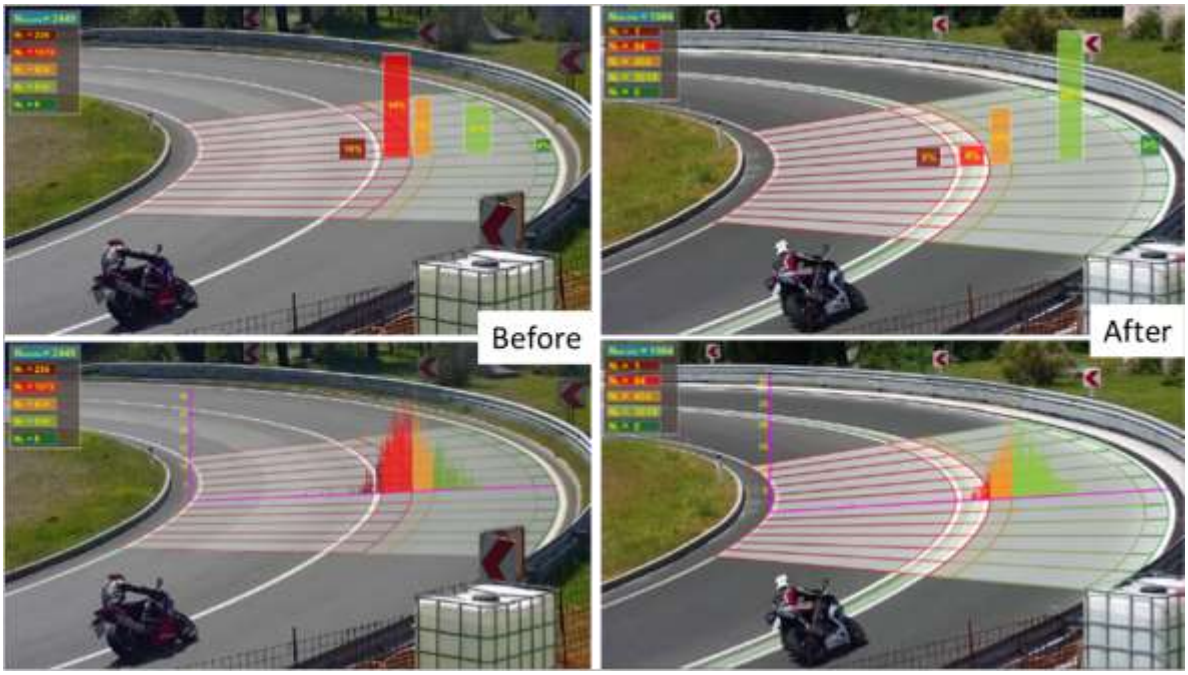

Figure 8 – Results before/after hidden video monitoring.

3.5. 5th Pilot Project – Implementation of Trapezoidal Mesh Panels on Two Road Sections

In this case, motorcyclists were not the primary challenge (no accidents, as the road is not very popular among them), but due to the narrow road, trucks often drive through and on the road bank. Due to that, gravel is almost always present on the road, and the bank needs constant repair.

We first wanted to see how trapezoidal mesh panels perform on a narrow road, where they are constantly driven on by vehicles. In addition, we needed to see their performance during the winter and with the use of snow ploughs, before we introduce them to roads with a greater presence of motorcyclists.


Figure 9 – Trapezoidal mesh panels in the road bank.

Following more than one year of observations, the conclusion was that trapezoidal mesh panels are an excellent replacement for classic roadside banks, both on less congested roads and on heavily congested roads.
By laying the panels, the presence of gravel on the road was eliminated, as well a dangerous edge – the difference between a road and a bank is no longer a threat to road

users. Statements confirm the fact that implementing trapezoidal mesh panels for stabilising the road bank improves the safety of all road users, especially motorcyclists and cyclists.

3.6. Additional measures

Additionally, we designed information signs for preventive purposes with appeals to drivers to “Stay on your side” (“*Ostani na svoji strani*”). These informative / educational / awareness-raising signs are to be set up on carefully selected places alongside roads to warn motorcyclists to take care. Those places where motorcycle accidents happen due to a frontal or side collision of a motorcyclist with opposing traffic, where the motorcyclists were leaning over the centre line, or even driving on the other side of the line, are to be identified.

Figure 10 – Design of the information sign “Stay on your side” (for roads with or without a centre line).

The Slovenian Infrastructure Agency, in collaboration with the Police, the Ambulance Station of the University Clinical Centre Ljubljana and the national automobile association – AMZS, made two short movies showing how to help motorcyclists in need (in the event of an accident).

Figure 11 – Clips from two short films.

The purpose of these short films is to teach people to not be afraid to help, as they can really make the difference between life and death, and they can get all the support needed from specially trained staff at the emergency number 112.

The Agency also tackled noise pollution, which namely comes from motorcyclists in the Triglav National Park. For this purpose, we designed special bilingual signs to address drivers if they are driving too fast or if they are being too loud.

Figure 12 – Bilingual information signs with LED panels showing excessive noise levels and speeding.

For now, we have had positive feedback from the public and Triglav National Park, so there are talks to install more of such information signs. Before/after monitoring of speed and noise levels is also planned.

Last, but not least, the Agency is supporting research on the development of a crash cushion for motorcyclists, which has had really good preliminary results. By supporting innovative products and solutions, we also gain an opportunity to learn and have state-of-the-art solutions that enhance road safety.

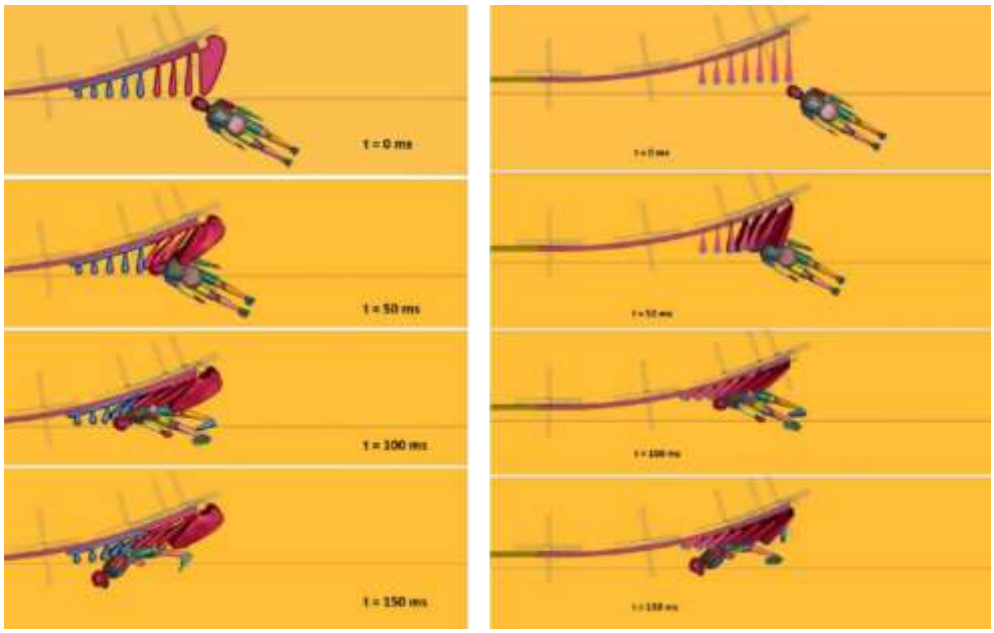

Figure 13 – Numerical simulation of a motorcycle crash cushion.

4. A SYSTEMATIC APPROACH TO IMPROVING MOTORCYCLIST SAFETY

The lessons learned and experience gained conformed that we are on the right path and thereby have the momentum to do more.

In partnership with the Faculty of Civil Engineering, Transportation Engineering and Architecture at the University of Maribor, the Faculty of Mechanical Engineering at the University of Ljubljana, and DRI Investment Management, Ltd, we made the first "Guidelines for Motorcyclist Safety" in Slovenia. These guidelines were also the basis for the Slovenian technical specification "Devices and measures to improve road safety for motorists" (currently in the conformation procedure).

Figure 14 – Slovenian Guidelines for Motorcyclist Safety

The Slovenian Roads Agency is now using the guidelines more widely and as a systematic approach to improving motorcyclist safety on state roads. We have also prepared the "Investment Project Identification Document for the Period 2023–2029", worth over EUR 22 mil., for implementing measures to improve the safety of motorcyclists on main and regional roads in the Republic of Slovenia. We identified 148 sections of so-called motorcycle roads, with a total length of 1,524 km. This length is changing (increasing) as we annually monitor motorcycle traffic and accidents related to motorcyclists. The purpose of the investment is to pursue both a preventive (proactive) and curative approach, but the basic purpose is a preventive (proactive) approach to the occurrence of traffic accidents. We are constantly learning and trying to apply pragmatic solutions that have been proven to work in practice.

We believe that through constant learning, acknowledging mistakes made, learning from them, along with a multidisciplinary approach and international collaboration, we can do much to improve the infrastructure on our roads, but definitely we must not forget about others stakeholders in the system, as only all of us can really move towards and perhaps someday Beyond Zero.

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