CHALLENGES TO REDUCE SPEED OF MOTORCYCLES IN STARI LOG CURVES

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ABSTRACT

Based on EU statistics in 2017, powered two wheelers account for 1,8 % of the total traffic flow. Alarming fact is that 17 % of total road victims are powered two wheelers.
In comprehensive study made in Slovenia regarding Traffic Safety and contributing factors to Road Accidents, the results showed that the most risky group are motorcyclists (with similar percentage of victims as in EU), followed by cyclists and pedestrians. The study also showed that major contributing factor to fatal road accidents, approximately 40 %, is due to unadjusted speed.
The present research is about improving Traffic Safety, for motorcyclists from infrastructure point of view, on one of road section for motorcyclists in Slovenia (Stari Log curves).
The research was conducted in 4 phases: (1) Overview of accident data, inspection of signage and markings and hidden speed measurements. (2) Improving road signage according to national regulations (usage of signage which road uses are already familiar with) and to measure the effect with Eye-Tracking system. (3) Additional hidden speed measurements with before / after study. Implementation of new “special” markings, and again evaluation with Eye-Tracking system. (4) Final analysis with matrix of how road (re)design influences drivers (motorcyclists) behaviour regarding speed reduction and their perception of the road (signage and curves).

1. INTRODUCTION

Single-vehicle drivers tend to underestimate the speed in roadways [5]. Underestimation of speed in curved roadways occur particularly during curve approach and curve entry, mainly because drivers’ fail to perceive curve layout (roadway geometry) due to obstructed sight distance or optical illusion.
Sight distance is one of the most important factors of roads safety because it allows drivers receiving in advanced information needed to accommodate their driving to the road conditions and to the changing margin of safety [4]. Considering the fact that drivers’ perceives over 90 % of driving related information visually (with their eyes), visual perception is one of the key components in safe driving and therefore in road safety.

This research focuses on drivers' perception in different phases of road layout re-design and consequently the speed adaptation in the curves. The research examines various preventive measures regarding speed-cognition control, and how proper road design can influence drivers' perception and decision-making.

1.1. Existing situation

Due to roads' geometry (hilly and curvy) and the fact it runs mainly outside settlements, it is very popular with single-vehicle users (motorcyclists), which usually drive faster than generally recommended by the law or limited with a traffic sign. In addition, other drivers tend to evolve higher speeds, as well.

Road section is also recognised as a motorcycle road, that is why information signs "Dangerous road section" are put in place at several locations (see Figure 1), and local speed limits are posted at more dangerous curves, where curve radius changes more than usual (sharper and/or longer curves).

"Figure 1 – Information sign »Dangerous Road Section«"

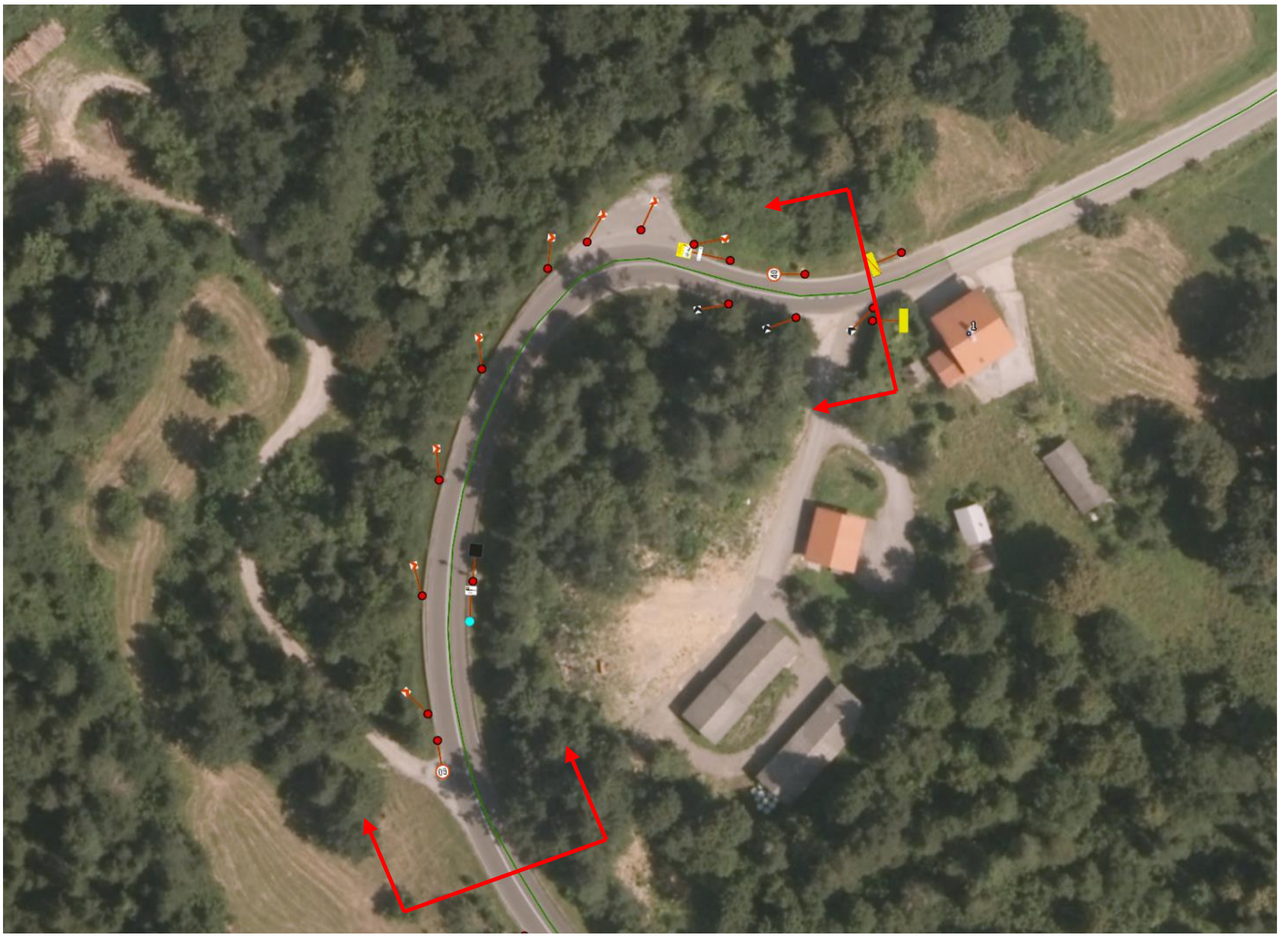
One of these curves are also Stari Log curves between km 10.950 and km 11.130, where speed limit is reduced to 40 km/h, and where additionally LED traffic sign is set up to warn drivers driving with higher speeds that limited to (40 km/h).

The road surface is in general in good condition and slipperiness does not pose a threat (more than normal) in dry or wet conditions.

"Figure 2 – LED traffic sign (40 km/h)"

2. RESEARCH APPROACH

The main objective of this research was to evaluate different approaches regarding the different types of markings (setting up traffic different equipment and road markings) to reduce speed (mainly of motorcycles) in Stari Log curves.



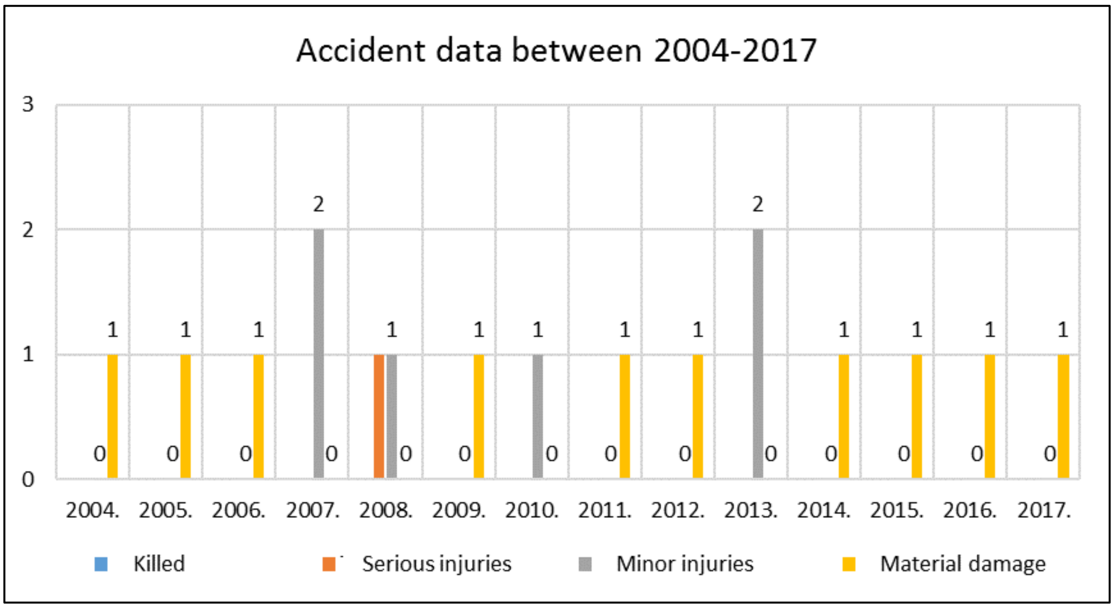
"Figure 3 – Stari Log curves between km 10.950 and km 11.130"

2.1. Phase 1

In phase 1, we did an overview of accident data, inspection of signage and markings and hidden speed measurements. Upon information gathered, we than decided about the approach to reduce speeds and enhance driver perception regarding road geometry (sharp curve).

2.1.1 *Accident data*

Looking at the official accident data, based on police reports, from 2004 until 2017, the curves do not stand out regarding accidents statistics, in the meaning of "black spot".



"Figure 4 – Traffic accidents between km 10.950 and km 11.130"

In the period of 14 years, there were seventeen (17) accidents on this road section. Ten (10) accidents were only with material damage, six (6) accidents with minor injuries and one (1) accident with serious injuries. The main reasons for the accidents (according to police data) are:

- unadjusted speed (in 14 cases), and
- wrong direction of the travel / wrong side of the road (in 3 cases).

Beside official accident data, there were several reports from maintenance crew regarding damage (hit and run) of traffic signs, especially the information sign "Dangerous road section" as showed in Figure 5. In addition, scratch marks on road safety barriers prove that more things occur in these curves than official accidents data shows.

“Figure 5 – Frequented damage of traffic sign”

2.1.2. *Inspection of signage and markings*

The inspection of visibility and retro reflectivity of signage and markings has been made. From 43 inspected traffic signs, 8 (19 %) did not meet the requirements regarding night visibility ($cd.lx^{-1}m^{2}$), as other 35 (81 %) met the requirements according to the Rules on traffic signs and road equipment (Official Gazette of RS, No. 99/15, 46/17 and 59/18).

“Table 1 – Minimum coefficient retro reflectivity R_A; Class RA3 (unit $cd.lx^{-1}m^{2}$)”

Geometry measurement		Color					
α [°]	B_1 [°]	white	yellow	Red	blue	green	fluorescent yellow-green
0.2	5	430	350	110	25	45	375
0.33	5	300	250	75	17	35	270
1.0	5	80	65	20	5	10	70
0.2	15	350	270	90	20	35	-
0.33	15	250	200	65	15	25	-
1.0	15	60	45	16	3.5	7	-
0.2	30	235	190	60	11	24	200
0.33	30	150	130	35	7	18	140
1.0	30	50	40	13	2.5	5	43
0.2	40	55	40	12	3	7	36
0.33	40	30	25	7	2	4	24
1.0	40	15	13	5	1	2	9

As road marking are concerned, they were inspected at interval of 50 m. According to rules, a minimum retro reflectivity of 100 $mcd/luxm^2$ must be ensured, but the markings in average achieved153 $mcd/luxm^2$, which is more than is required by the Rules on traffic signs and road equipment (Official Gazette of RS, No. 99/15, 46/17 and 59/18).

“Table 2 – Minimum values of the characteristics of existing markings on the road surface”

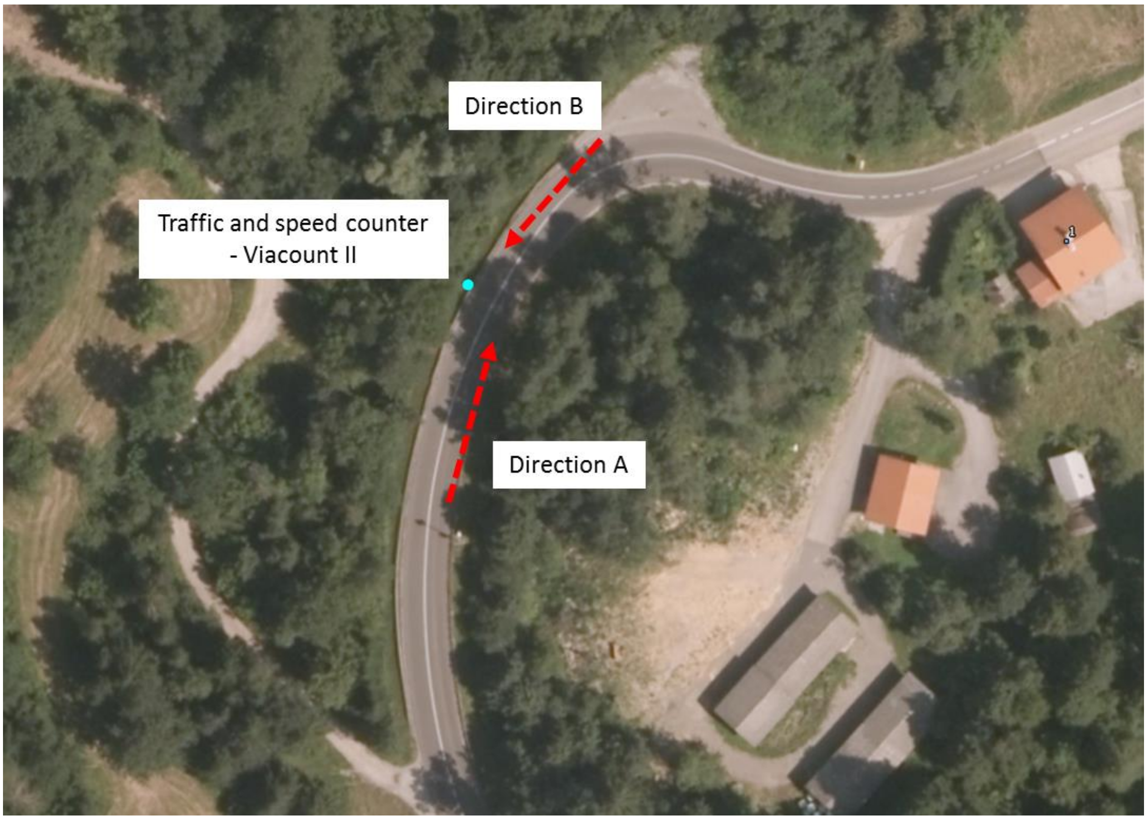
Traffic volume		Motorways and expressways		Other roads	
Features indications on the road	Color	minimum value		minimum value	
		(mcd/luxm^2)	class	(mcd/luxm^2)	class
Coefficient reflective brightness (R_L) - Night visibility in dry conditions	WHITE	≥ 100	R2	≥ 100	R2
	YELLOW	≥ 100	R1	≥ 100	R1
Coefficient reflective brightness (R_w) - Night visibility in wet conditions *	WHITE	≥ 35	RW2	≥ 25	RW1
	YELLOW	≥ 25	RW1	≥ 25	RW1
Coefficient reflective brightness (Q_d) - Day visibility in dry conditions	WHITE	≥ 130	Q3	≥ 130	Q3
	YELLOW	≥ 100	Q2	≥ 100	Q2
Slipperiness (SRT)	WHITE	≥ 45	S1	≥ 45	S1
	YELLOW	≥ 45	S1	≥ 45	S1
Brightness factor (β)	WHITE	≥ 0.40	B3	≥ 0.40	B3

* Coefficient reflective brightness - night visibility in wet conditions is required only for Type II markings in accordance with standard SIST EN 1436

As signage and markings is concerned they are in good condition (except 8 traffic signs which were scheduled for replacement true road maintenance). Road signage and markings do not pose or represent any deficiency from infrastructure point of view.

2.1.3. *Hidden speed measurements*

Hidden speed measurements were conducted with the device Viacount II. The device enables vehicle counting and speed measurement (for both oncoming and departing traffic). The device documents vehicles according to the time (time and date) and according to speed and length of the vehicle.
Between the period of 3.7.2018 and 17.7.2018, the counter registered 12.989 vehicles (average daily traffic 922 vehicles) in direction A and 13.528 vehicles (average daily traffic 961 vehicles) in direction B.

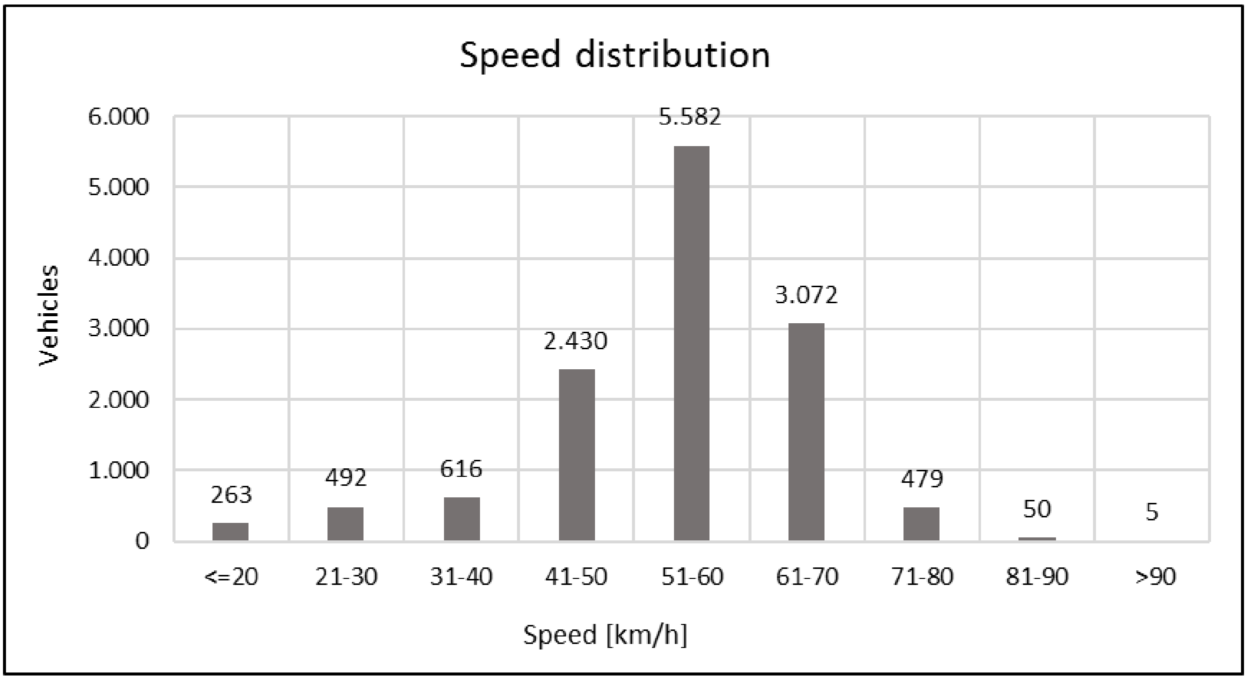


“Figure 6 – Position of hidden speed device and the direction of travels / measurements”

Cars represent the majority of vehicles (around 70 %), while second place is divided between single-vehicles and vans (around 10 %), depending on direction of travel.

“Table 3 – Speed and vehicle classification from direction A”

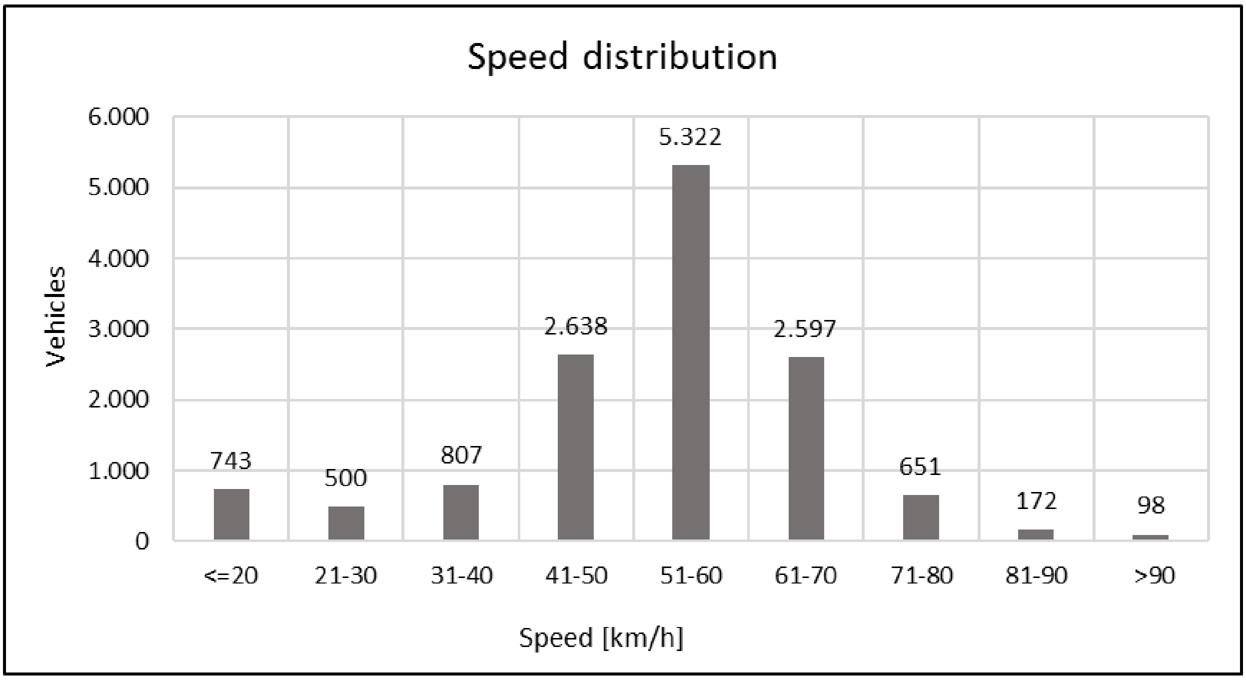
Speed [km/h]	Single-vehicles	Cars	Vans	Trucks	Trucks with trailer	Total
<=20	249	12	1	1	0	263
21-30	442	33	6	10	1	492
31-40	139	315	52	50	60	616
41-50	60	1.535	293	250	292	2.430
51-60	23	4.363	708	343	145	5.582
61-70	15	2.547	404	91	15	3.072
71-80	10	378	85	6	0	479
81-90	3	40	7	0	0	50
>90	0	3	2	0	0	5
Total	941	9.226	1.558	751	513	12.989
	7,24 %	71,03 %	11,99 %	5,78 %	3,95 %	100,00 %



“Figure 7 – Speed distribution from direction A”

“Table 4 – Speed and vehicle classification from direction B”

Speed [km/h]	Single-vehicles	Cars	Vans	Trucks	Trucks with trailer	Total
<=20	432	103	23	51	134	743
21-30	370	43	14	18	55	500
31-40	184	277	78	134	134	807
41-50	65	1.600	408	292	273	2.638
51-60	191	4.112	685	267	67	5.322
61-70	228	2.101	213	52	3	2.597
71-80	90	545	14	1	1	651
81-90	26	145	1	0	0	172
>90	12	85	1	0	0	98
Total	1.598	9.011	1.437	815	667	13.528
	11,81 %	66,61 %	10,62 %	6,02 %	4,93 %	100,00 %



“Figure 8 – Speed distribution from direction B”

From the Table 3 and Figure 7, we can see that majority of vehicles, in direction A, are driving with speeds between 51-60 km/h and 61-70 km/h, which is more than is allowed by the speed limit 40 km/h. That means that 70,74 % of drivers drive over the posted speed limit of 40 km/h.

As Table 4 and Figure 8 shows, that majority of vehicles, in direction B, are driving with speeds between 51-60 km/h and speeds from 41-50 and 61-70 km/h. The last two are almost equally represented. In this direction, there are also higher speeds, as some are driving with speeds higher than 70 km/h. Consequently that means that 84,85 % of drivers are driving over the posted speed limit of 40 km/h.

2.2. Phase 2

We took into consideration, accident data, damaged signage and traffic equipment from vehicles impact, speed measurements and visibility of signage and markings, and upon that we can fairly conclude that we have a problem with speed control, because current signage and markings do not provide proper information to the drivers regarding the curve geometry and posted speed limit is not credible. Therefore, we decided to improve road signage (for guidance in curves) according to national regulations (usage of signage which road uses are already familiar with), and to measure the effect with Eye-Tracking system. The system records drivers' eye movements and what is perceived in given situation and on what driver focus on. With analysing the Eye-Tracking results, we can than better understand the driver's needs and consequently improve traffic safety situation for the drivers, to enhance perception of traffic situations and orientation in given situation.

Monitoring with Eye-Tracking system was done in three steps (before the intervention and after each step).

2.2.1 *Relocation of information sign and setting up additional signage*

First, the information sign "Dangerous Road Section" was relocated, due to many damages in the past on previous location, which was practically in the curve, and because it was partly obstructed by the traffic sign for town Stari Log, and later on with traffic sign for speed limit (40 km/h).

"Figure 9 – Relocation of information sign »Dangerous Road Section«"

Secondly, existing traffic signs for guidance true the curves (Chevrons) has been replaced with passive safe and more user-friendly signs (Chevrons) and bollards for guidance true the curves.

“Figure 10 – Traffic signs (Chevrons and bollards) – before/after”

2.3. Phase 3

We set up additional signs (Chevrons) and “special” red/white markings, and made another evaluation with the Eye-Tracking system, to see if additional progress could be made. Also another hidden speed measurements were made, for before/after study regarding the speed.

2.3.1 *Additional signage*

Red/white stripes were placed in the groove of road safety barrier at longer curve, as on smaller inner curve red/white markings were set up on the edge of the road. In addition, signs for guidance thru curve (Chevrons) were placed on the bollards on smaller curve.

“Figure 11 – Red/white markings on Road Safety Barrier”

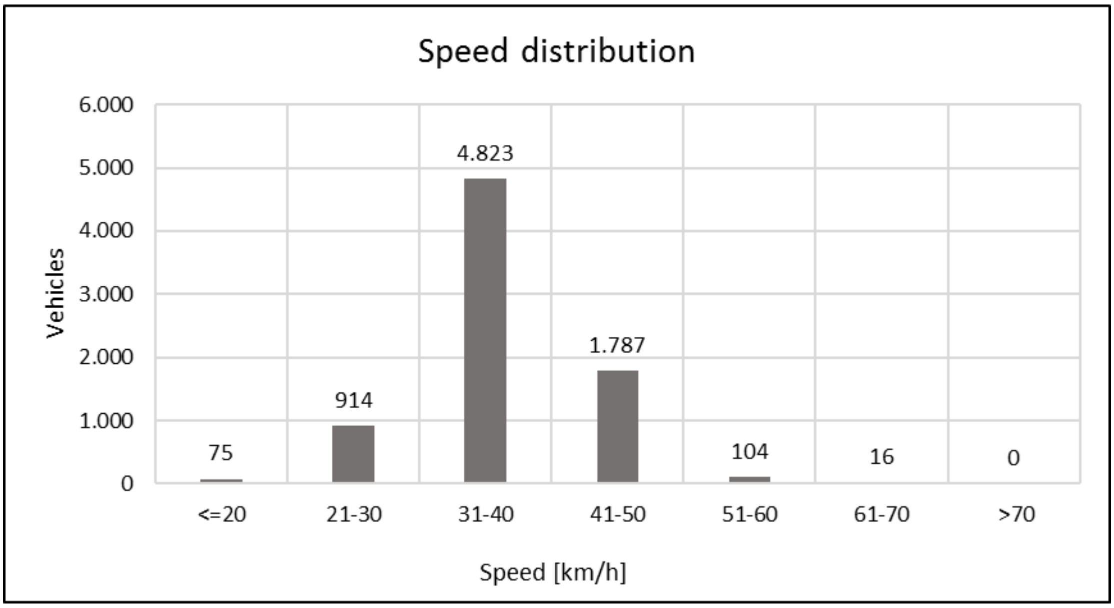
“Figure 12 – Red/white road markings and chevrons”

2.3.2 *Second hidden speed measurements*

Second hidden speed measurements were conducted in the period between 19.10.2018 and 29.10.2018, the counter registered 7.719 vehicles (average daily traffic 772 vehicles) in direction A and 7.947 vehicles (average daily traffic 795 vehicles) in direction B.

“Table 5 – Speed and vehicle classification from direction A (after)”

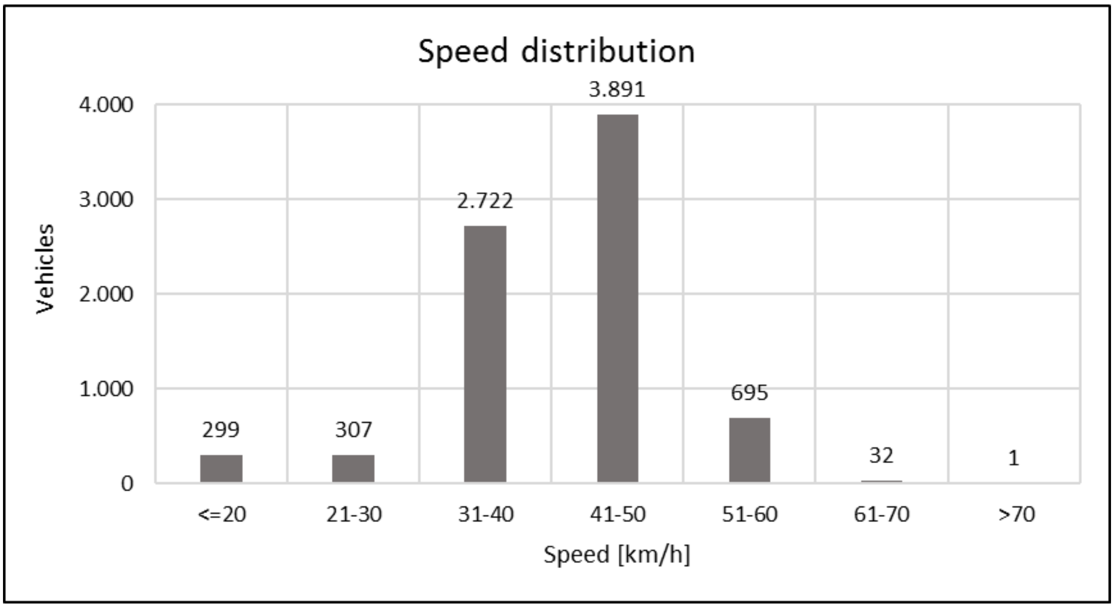
Speed [km/h]	Single-vehicles	Cars	Vans	Trucks	Trucks with trailer	Total
<=20	38	12	12	13	0	75
21-30	10	416	254	229	5	914
31-40	10	3.658	988	167	0	4.823
41-50	1	1.479	306	1	0	1.787
51-60	2	89	13	0	0	104
61-70	1	14	1	0	0	16
>70	0	0	0	0	0	0
Total	62	5.668	1.574	410	5	7.719
	0,80 %	73,43 %	20,39 %	5,31 %	0,06 %	100,00 %



“Figure 13 – Speed distribution from direction A (after)”

“Table 6 – Speed and vehicle classification from direction B (after)”

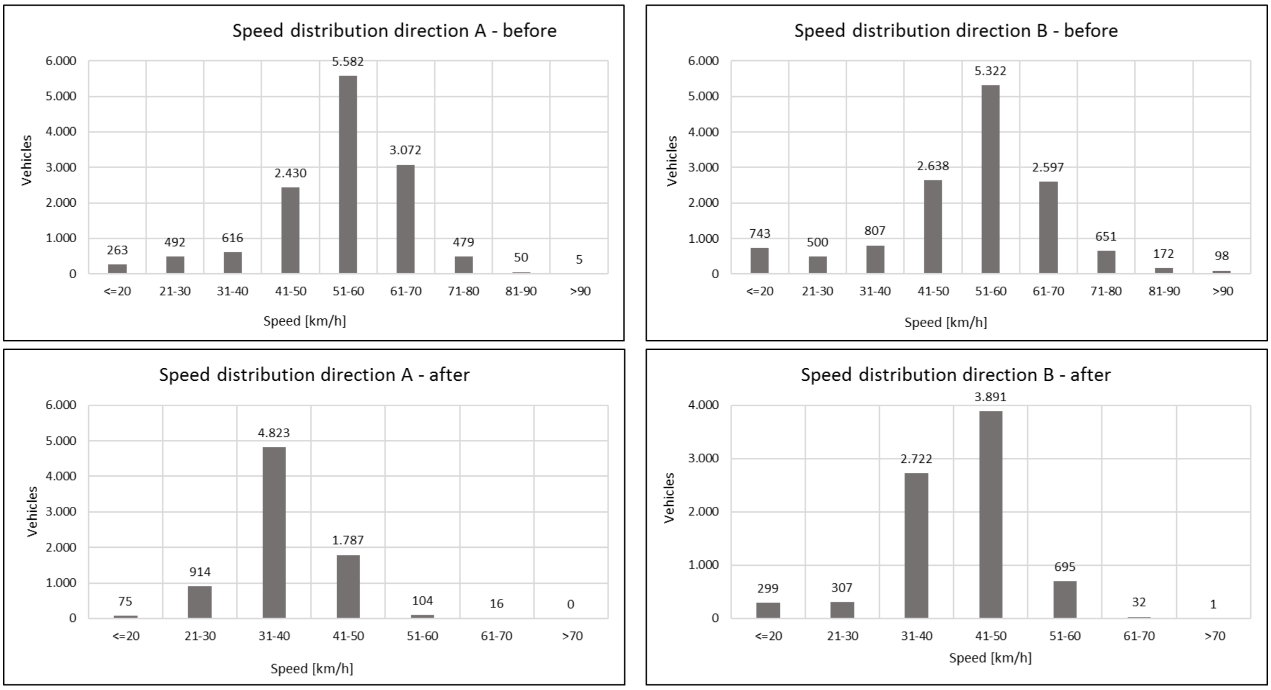
Speed [km/h]	Single-vehicles	Cars	Vans	Trucks	Trucks with trailer	Total
<=20	108	50	54	51	36	299
21-30	34	166	45	58	4	307
31-40	19	1.817	596	257	33	2.722
41-50	23	3.022	764	78	4	3.891
51-60	10	600	83	2	0	695
61-70	1	26	5	0	0	32
>70	0	1	0	0	0	1
Total	195	5.682	1.547	446	77	7.947
	2,45 %	71,50 %	19,47 %	5,61 %	0,97 %	100,00 %



“Figure 14 – Speed distribution from direction B (after)”

Cars represent the majority of vehicles (over 70 %), while on second place are vans (around 20 %). Single vehicles are represented in minority as in October the motorcycle session is slowly ending.

From the Table 5 and Figure 13, we can see that majority of vehicles, in direction A, are driving with speeds between 31-40 km/h and 41-50 km/h. The maximum measured speed vas from the car, 69 km/h. Only 24,72 % (before 70,74 %) of drivers drove over the posted speed limit of 40 km/h.
As Table 6 and Figure 14 shows, that majority of vehicles, in direction B, are driving with speeds between 41-50 km/h and 31-40 km/h. In this direction higher speeds remains, but extremes are much lower (for both directions). Consequently that means that 58,12 % (before 84,85 %) of drivers are driving over the posted speed limit of 40 km/h.



“Figure 15 – Speed distribution from direction A and B (before/after)”

Even though traffic volume has decreased from July to October, as the road has a seasonal meaning, we can see that speeds dropped due to enhanced (pre)warning with traffic signage and with that posted speed limit gain on its credibility.

2.4. Phase 4

In final phase an overall evaluation of Eye-Tracking monitoring has been made and results of analysis were put in to matrix, for clear illustration of how road (re)design influences drivers (motorcyclists) perception of the road (signage and curves). From the speed measurements, we can conclude that enhanced (pre)warning signalization influences on speed reduction.

From Tables: 3, 4, 5 and 6 we can see that among other vehicles also single vehicles (motorcyclists) reduced speed thru curves after addition signage has ben (re)placed.

Results of Eye-Tracking analyses are shown in matrix in Figure 16.

	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
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

“Figure 16 – Matrix of Eye-Tracking analysis”

3. CONCLUSIONS AND RECOMMENDATIONS

The aim of this research was to analyse the existing and modified traffic signalization and equipment while testing the perception and behaviour of drivers using the Eye-Trackong system to evaluate before and after interventions in the curves near town Stari Log. This part of the road was selected based on observations by the maintenance crew, which indicates that traffic accident happened more frequently than officially recorded.

From this research, we can conclude the following:

- the examinees (drivers of cars and single vehicles) were most focused on the middle line in the daytime and at night, then on the inner part of the curve, and at least on the outer part of the curve,
- after the installation of additional traffic signalization and equipment, a large number of fixations and fast eye movements between fixations are recorded. That concludes that the eyes of the examinees were more active during the second and third ride (Phase 2 and 3) and that the drivers' view was more focused on the added elements, as he/she wanted to get as much visual information as possible, to clearly detect the course of the road,
- red/white elements mounted on a road safety barrier (the outer part of the curve), attracted more views of the drivers, compared to the red/white marking on the edge of the road (the inner part of the curve),
- the installation of additional red/white elements on a road safety barrier had an impact on the speed in the curve, both for cars and single-vehicles (motorcyclists). Speed was reduced in average by 11 %,
- signs for guidance thru curve (Chevrons) and red/white elements placed on a road safety barrier have proven to be the best solution to (pre)warn and guide drivers through the curve,
- it is recommended that red/white markings, on the edge of the road, are installed in the future on similar dangerous curves, as an additional intervention for warning and guiding the drivers.

Based on the conclusion above and matrix of the Eye-Tracking analysis (Figure 16), we can conclude that the interventions performed have had a positive effect on the visual perception and detection of the course of the road.

The intervention has also contributed to reduction of vehicles speed, which should have a positive impact on the overall traffic safety situation in Stari Log curves.

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