IMPLEMENTATION OF INFRASTRUCTURE MEASURES FOR IMPROVING POWERED TWO-WHEELERS SAFETY ON SLOVENIAN NATIONAL ROAD NETWORK

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ABSTRACT

Riders of powered two-wheelers (PTWs) are one of the most vulnerable groups of road users. Risk of traffic accident fatalities for PTW riders is eighteen times higher than for the car drivers. Until 1996, PTW riders accounted for 9.5 % of all road accident fatalities in 2006, 6.200 PTW riders died in traffic accidents in the European Union (EU), what already represents 16 % of all road accident fatalities. On the other hand, PTW riders travelled only 2 % of total travelled kilometers.
According to the report (ETSC, 2007) on "Road safety performance index" that ranked the safety of PTW riders in Europe, Slovenia "won" the first place: we have the largest number of PTW rider's deaths per billion travelled km in 2006 (more than 350, while the EU average was 86). Another very concerning fact is that we have the highest ratio of death rate per billion km ridden by PTW riders to corresponding rate for car drivers in 2006 (more than 50, EU average 18!).
In Slovenia, the problem of PTW riders' safety was detected and recorded very early. As a result – at the national, i.e. state level – measures were adopted relatively soon to remedy or at least improve the problematic situation as regards PTW riders' safety on Slovenian roads. For example, the National Road Traffic Safety Programme for the period 2007–2011, which was adopted in 2006, discussed, in terms of expertise and safety, the most demanding and the most pressing problems in road traffic in the Republic of Slovenia.
One of the "key actors" - in terms of implementing the infrastructure measures for improving (also) PTWs safety on Slovenian roads - were (and still is) Slovenian Roads Agency under the jurisdiction of Ministry of Infrastructure and Spatial Planning. Measures, which were implementing by Slovenian Roads Agency on national road network, include:

- installation of additional security elements for PTWs on existing guardrails;
- installation of traffic signs which warn PTW riders on a dangerous road section;

- installation of traffic signs which warn drivers on “black spot” location;
- realization of a research project "Measures to improve traffic safety of PTW riders in Slovenia". The project aimed to identify the causes and reasons for critical traffic safety of PTW riders and identify potential locations with congestion of traffic accidents involved PTW riders on the national road network. In the project there have been also proposed measures for improving traffic safety of PTW riders in Slovenia.

In the article the above listed measures implementing by Slovenian Roads Agency are described and analyzed. Additional focus was made on survey research, with which we established the efficiencies of two types of infrastructural measures for improving PTWs traffic safety on Slovenian national road network.

Keywords:
Powered two-wheelers (PTWs), road traffic safety, efficiencies of infrastructure measures, before-after analysis

INTRODUCTION

Currently, almost 40,000 persons are killed every year on EU roads. About 6,500 of them are drivers and passengers of Powered Two Wheelers (PTWs i.e. motorcycles and mopeds). Motorcycle or moped travel carries a risk of death per kilometer travelled 20 times higher than for car travel. Therefore, the safety of vulnerable road users, including motorcycle and moped riders, is one of the priorities of the EU. (PISa, 2007)

Convergent studies (MAIDS, 2012) allow us today to state that significant number of accidents result from infrastructure shortcomings. PTWs differ in their use of the road in a number of ways from other vehicles and riders have different needs. Predictable road geometry, good visibility, obstacle free zones and good quality road surface with high levels of skid resistance are some major examples. While important for all road users, they are essential for PTWs.

Some recent publications from Belgium, France, Germany, Norway, The Netherlands and The United Kingdom show that a civil engineering handbook is a practical instrument for improving road safety for PTWs, just by emphasizing the engineering items to consider during the design and maintenance of infrastructure. In this handbook (ACEM, 2006), ACEM has expanded this information on a European scale to further develop awareness.

Road safety needs an integrated approach and infrastructure is one of the leads to reach the EU target of halving the number of road accident victims by 2010. In parallel with the EU Road Safety Action Programme, the Motorcycle Industry has pursued a broad approach to cover all areas of PTW safety: the EU Road Safety Charter (vehicle technology), the Initial Rider Training project (user behavior) and, today, the European road design guidelines (infrastructure).

The direct opinion of PTW users from UK (MAG, 2005) to government official’s press for European legislators to make changes to EN1317 CEN Standards so that: (i) all current vehicle restraint systems meet the same standard of tests for motorcyclists for central reservation protection as applied to all other vehicles. (ii) motorcycle-friendly secondary rails and all other forms of post protection devices are included in the standards of tests for other vehicles.

Also, the National Swedish Road Administration estimates that the crash barriers save 22 lives per year and 42 persons from getting seriously injured. However, the Swedish Motorcyclists Association has opposed the cable barriers since the very beginning. They are not the best solution for all road users, and definitely not for the PTWs. When an obstacle-free roadside is not achievable and crash barriers meet the requirements of European Standard EN 1317. It is therefore crucial that the European Standard is changed or expanded to include testing with PTWs.

According to the report (ETSC, 2007) on "Road safety performance index", that ranked the safety of PTW riders in Europe, where Slovenia "won" the "first place" and due to the research performed in (Šraml et al, 2012), which overview and analyzed the main causes "why we are so "bad" in PTWs safety on Slovenian roads", the Slovenian authorities among our research activities try to react and improve PTWs road safety.

Although paper (Šraml et al., 2012) already describes some statistical data, following some fact is highlighted. In the paper all statistical data regarding PTWs safety activities between 2006-2012 are carefully presented and analyzed, however, we have to emphasize some crucial data. PTWs rider safety was reduced in 2011 compared with PTWs traffic safety in year 2010, despite all activities (particularly additional lamellas and special signs). In the year 2011 it was recorded 1.269 (in 2010: 1.193) traffic accidents where PTWs rider were involved, among all 30 were killed (in 2010: 23). In year 2011, 214 were hard injured (in year 2010: 211), easier injured were 694 (in year 2010: 679) PTWs rider. In all accidents in 2011, there were also four passengers killed (in 2010: 2). Although, traffic safety of PTWs in 2011 was deteriorated, comparing year 2010, the fact is, that each year number of registered PTW vehicles are rising in we can expect that trend in future years as well. This can also be one fact of deteriorated of PTW traffic safety. However, the main reasons of PTW traffic accidents are (still): (i) ignoring priority rules, (ii) unadjusted speed, (iii) incorrect driving site and direction and (iv) incorrect overtaking. Therefore, we have set some activities and goals to improve safety situation. The main goal is to reduce number of fatalities and hard injured of PTW riders in the frame of 50% till the 2021, regarding year 2010. We make first steps, and some of measures (starting from 2006) are already analyzed in present paper.

First infrastructure measure that was analyzed in detail is roadside barriers. Several research works have been done on this topic. A detailed study of 418 PTW's accidents involving road safety barriers by (Brailly, 1998) shows that in PTW accidents involving road barriers the risk of a fatal outcome is five times greater than the national rate for all PTW accidents; they account for 8% of all PTW fatalities; for 13% of all traffic fatalities. Therefore the general principle of a PTW friendly safety barrier is to protect a fallen motorcyclist from crashing into support posts. Further on, roadside safety constructions are mainly designed using the car as design vehicle. A PTW, however, requires another approach. The Motorcycle Accident In-DepthStudy (MAIDS, 2012) showed that the fourth most likely obstacle to be struck was 'fixed obstacles' such as barriers, signs and trees. The vulnerability of the PTWs often leads to major injuries or even fatal crashes because of the presence of obstacles alongside the road (urban and rural). Obviously, facts from the literature review show, that some segments of barriers alongside the road should be adjusted for the PTW riders.

Secondly, the additional warning signs, that reminds PTWs riders on i.e. dangerous sections and black spots, where special caution and speed adjustment is needed. We analyzed also the combinations of both infrastructure measures (additional lamellas at barriers and the panels with special PTW's warning signs).

Therefore, in the following paper we try to analyses the main improvements of traffic safety regarding PTWs due to implementation of infrastructure measures, with before-after analysis.

INFRASTRUCTURE MEASURES FOR IMPROVING PTW'S TRAFFIC SAFETY

Infrastructure measures, mentioned in the introduction chapter (additional warning signs for PTW riders and additional lamellas at safety barriers in curves), look like to be of the great importance regarding improvements of PTW traffic safety, generally, as obviously on Slovenian roads. Those measures represent "immediate measures", which could be installed "quickly", without time-consuming procedures, although previous studies, where and why should be installed is, of course, needed. Another positive characteristic represent small investment costs: those measures are known as low-cost measures for improving PTW traffic safety.

The additional warning signs for PTW riders

The additional warning signs for PTW riders are known across Europe in different form. Mostly they derive from different safety campaigns for PTW riders. Alongside highly frequented motorcycle signposts, displays, roadside boards and bills remind/alert PTW riders of possible dangerous situations (sections, intersections etc.).
In EU project 2-BE-SAFE (2-BE-SAFE, 2012) performed analysis indicate that there could be the problem of signposts, displays, roadside boards and bills alongside roads - road users attention may be drawn away from tasks required for safe riding.
In Slovenia, the additional warning signs for PTW riders, in similar form as ours additional warning signs for "dangerous road sections / intersections" ("black spots"), are in used since 2006. In our case, those additional warning signs look more like traffic signs (Fig. 1). We could say that this kind of warning signs should be classified in group of informational / notifying traffic signs.
Additional warning signs for PTW riders usually contain information about length of dangerous section, for example of 3000 meters. Since those sections are relatively long (between 1500 m and 10 000 m) we could put legally question about "validity" of these signs through entire section (since the riders can easy "forget" the warning sign while riding alongside the road).
The additional warning signs for PTW riders should be installed on those road sections, where the large proportion of PTW riders in traffic flow occurred. Especially, another attention should be given to "tourists PTW routes" where during touristic season enlarged proportion of PTW riders from abroad often happened.

Figure 1: The additional warning signs

Additional lamellas at safety barriers

Guard rails (safety barriers) have been designed to prevent cars from colliding with obstacles behind the rail. They should absorb kinetic energy and control the trajectory of the vehicle in

collision with the rail. Existing rails have not been designed for collisions by PTW's and may cause severe injuries to their riders (SafetyNet, 2009).
The general principle of a PTW-friendly safety barrier is to protect the fallen PTW rider from jutting support posts. In our case, additional lamellas were placed onto some existing safety barriers (Figure 2).
Installation of additional lamellas is an immediate measure, particularly at the location of road curves, were "classic" steel barriers are already installed. The installation of additional lamellas were taken on the locations where (i) in the past more accidents with hard injured PTW riders occurred and (ii) extremely high proportion of PTW riders at traffic flow occurred. Those road sections represented curved road alignments, mostly in hilly area. Additional lamella was installed along entire length of existing safety barrier at the particular section / curve.

Figure 2: The additional lamellas at existing safety barrier

2.3 Combination of both measures

Combination of both safety measures represents additional lamellas at safety barriers on road sections with additional warning signs for PTW riders. That means road sections equipped with additional warning signs, on curves inside this section additional lamellas were installed on existing safety barriers.
Such a combination represent both, "preventive" (additional warning sign) and "curative" (additional lamellas at existing safety barriers) measure for PTW riders.

ANALYSIS OF THE EFFECTIVENESS OF IMPLEMENTED MEASURES

The PTW traffic safety - regarding our paper (Šraml et al., 2012) - was obviously "alarming" one. Therefore, in Slovenia, we stared with systematic approach to implement (among other activities to enlarge PTW rider traffic safety) infrastructural measures for improving traffic safety situation of PTW riders on our national road network. Those measures - as already described in Ch. 2 - represent (i) installation of additional warning signs for PTW riders and (ii) installation of additional lamellas on existing safety barriers in curves.

Described measures were first installed in year 2008 and their installation continues in following years. Those safety measures present low-cost solutions, therefore their effects - on improving traffic safety of PTW riders - could be significant.
Following, two main infrastructure measures, recently installed on some sections of Slovenian national road network, are presented and the methodology for their evaluation, regarding their efficiency, is described.

Additional warning signs for PTW riders

For our observation in present analysis, 20 road sections (treatment group), where additional warning signs for PTW riders were put on place in year 2008, were selected. Those sections represents Slovenian main and regional roads, where proportion of PTW riders in traffic flow is rather high - if compare it to other road sections on the same category. Moreover, on some of those sections increased PTW traffic is recorded during summer, based on PTW riders from abroad (for example, tourists etc.). On each of those warning sign additional information present the length of the "problematic" section. The length of those sections varied between 1500 m and 10000 m with mean length of 5550 m. In the Table 1 crash data for selected road sections are shown. As the additional warning signs were installed in the year 2008 we choose 3 years period for before crashes (2005-2007) and 3 years period for after crashes (2009-2011). Crash data refer to number of (all) traffic accidents with PTW riders in given period, recorded by Slovenian Police.
For comparison group - according the recommendation (Gross et al., 2010) - we select 61 road sections with similar characteristics: length of road sections between 500 m and 8000 m (mean length of 3684 m), same length of before and after period for crash data, road sections were located on roads of the same category as those on treatment group, number of PTW riders in traffic flow (or proportion of PTW riders in traffic flow) was very similar and the characteristics of road sections (road design elements, dimension of elements etc.) also. In the Table 1 crash data for selected road sections of comparison group are also shown.

Table 1: Crash data for treatment and comparison group (additional warning signs)

	Treatment group			Comparison group		
Time period	$N_{Obs.,T}$	Mean	Var	$N_{Obs.,C}$	Mean	Var
Before	77	3,85	9,18	118	1,93	4,46
After	38	1,9	2,83	82	1,34	3,33

Because of limited number of treated sites ~~we use~~ the before-after analysis with comparison group for calculation of crash modification factor (CMF) was used. According the suggested procedure (Gross et al., 2010) we first calculate the expected number of crashes for the treatment group ($N_{Exp.,T,A}$) as shown in Eq. (1) and variance of $N_{Exp.,T,A}$, Eq. (2):

$$N_{Exp.,T,A} = N_{Obs.,T,B} \cdot \frac{N_{Obs.,C,A}}{N_{Obs.,C,B}} \qquad (1)$$

where:
$N_{Exp.,T,A}$ = the expected number of crashes in the after period for the treatment group
$N_{Obs.,T,B}$ = the observed number of crashes in the before period for the treatment group
$N_{Obs.,C,A}$ = the observed number of crashes in the after period for the comparison group
$N_{Obs.,C,B}$ = the observed number of crashes in the before period for the comparison group

$$Var(N_{Exp.,T,A}) = N^2_{Exp.,T,A} \cdot \frac{1}{N_{Obs.,T,B}} + \frac{1}{N_{Obs.,C,B}} + \frac{1}{N_{Obs.,C,A}} \qquad (2)$$

Crash modification factor (CMF) and variance of CMF were calculated according to Eq. (3) and Eq. (4). As stated in guides (Gross et al., 2010) there is a presumption of ideal comparison group. Namely, the assumption of an ideal comparison group is made to simplify the computation of the variance of the CMF, recognizing that this will result in a conservative approximation.

$$CMF = \frac{\frac{N_{Obs.,T,A}}{N_{Exp.,T,A}}}{1+\frac{Var(N_{Exp.,T,A})}{N^2_{Exp.,T,A}}} \tag{3}$$

where:

$N_{Obs.,T,A}$ = the observed number of crashes in the after period for the treatment group

$$Variance(CMF) = \frac{CMF^2 \left(\frac{1}{N_{Obs.,T,A}}+\frac{Var(N_{Exp.,T,A})}{N^2_{Exp.,T,A}}\right)}{\left(1+\frac{Var(N_{Exp.,T,A})}{N^2_{Exp.,T,A}}\right)^2} \tag{4}$$

Obtained results for $N_{Exp.,T,A}$, $Var(N_{Exp.,T,A})$, CMF, Var(CMF) and CMF for 90 percent confidence level are shown in Table 2.

Table 2: Summary of calculations of effectiveness of additional warning signs

$N_{Exp.,T,A}$	$Var(N_{Exp.,T,A})$	CMF	Var(CMF)	Stand. Err.	90% confidence int. Conf. int. -	Conf. int. +
53,51	96,36	0,68	0,026	0,162	0,419	0,954

Combination: Additional lamellas at safety barriers on road sections with additional warning signs for PTW riders

For this observation we select 22 (shorter) road sections (treatment group), where additional lamellas at safety barriers on curves were installed. Those shorter sections were located inside longer road sections on which additional warning signs for PTW riders were installed. According to this description it is obviously that the "combination" of two safety measures for PTW riders was observed. Both safety measures were installed in year 2008. Similar to the treatment group in previous observation (Ch. 3.1) those sections also represent Slovenian main and regional roads, where proportion of PTW riders in traffic flow is rather high. Characteristics of selected road sections were similar to those described in Ch. 3.1.

On each of observed road section additional warning sign with information about length of the road section were installed. Moreover, on curves which have been already equipped with safety barriers additional lamellas for PTW riders were added. Those lamellas were installed on existing safety barriers on their entire length. For example, if existing safety barrier in curve was 150 m long also installed additional lamella was 150 m long. In this observation, only shorter sections (curves) were additional lamellas were installed, was analyzed. The length of observed sections varied between 100 m and 700 m with mean length of 255 m. In the Table 3 crash data for selected road sections are shown. As the safety measures were installed in year 2008 we choose 3 years period for before crashes (2005-2007) and 3 years period for after crashes (2009-2011).

For comparison group, 48 road sections with similar characteristics was selected and analyzed. In the Table 3 crash data for selected road sections of comparison group are also shown.

Table 3: Crash data for treatment and comparison group (additional lamellas at safety barriers on road sections with additional warning signs)

	Treatment group			Comparison group		
Time period	$N_{Obs.,T}$	Mean	Var	$N_{Obs.,C}$	Mean	Var
Before	33	1,5	8,07	55	1,146	1,786
After	12	0,545	1,497	34	0,708	1,189

For evaluating CMF for this group of safety measures the same methodology as described in Ch. 2 was used. Obtained results for $N_{Exp.,T,A}$, $Var(N_{Exp.,T,A})$, CMF, Var(CMF) and CMF for 90 percent confidence level are shown in Table 4.

Table 4: Summary of calculations of effectiveness of additional lamellas at safety barriers on road sections with additional warning signs

					90% confidence int.	
$N_{Exp.,T,A}$	$Var(N_{Exp.,T,A})$	CMF	Var(CMF)	Stand. Err.	Conf. int. -	Conf. int. +
20,4	32,417	0,545	0,0413	0,2033	0,211	0,88

DISCUSSION AND CONCLUSION

It is necessary to emphasis, that the present paper is the prolongation of the research work activities on the field of PTWs rider traffic safety, first published in Šraml et.al 2012.

In the present paper two infrastructure measures to enlarge PTWs road safety on Slovenian national roads are introduced: (i) the additional warning signs that warn PTW riders on dangerous road section / carful driving, (ii) combination: Additional lamellas at safety barriers on road sections with additional warning signs for PTW riders. Before and after analysis with comparison group were performed.

The main results shown, that both measures reduces number of crashes with PTW riders. Inside of 90% confidence interval we could establish CMF of 0,68 which indicates 32% reduction of traffic accidents with PTW riders on road sections where additional warning signs for PTW riders were put in place.

Similar, for shorter sections (curves) were additional safety lamellas were installed on existing safety barriers - and those shorter sections were located inside longer sections equipped with additional warning signs - we establish CMF of 0,545 (90% confidence interval: 0,211 - 0,88). In this case even larger traffic accident reduction could be expected, up to 45%.

It has to be admitted - according the obtained results, presented in Table 2 and 4 - that variance and standard error indicate greater dispersion of obtained results. Main reasons for this is small number of road sections in treatment / comparison group, small number of recorded traffic accidents with PTW riders and small length of road sections - especially when combination of additional lamellas at safety barriers on road sections with additional warning signs for PTW riders was analyzed.

To improve obtained results - or to confirm / reject established CMF larger sample of treated / comparison sites should be selected.

However, we are realized, that longer time period of observed measures and their effect should be further monitoring and some additional activities regarding infrastructure measures for improving PTW's rider safety must be obtained.
Therefore, in our further research activities, among other institutions, responsible for education, training, information etc., monitoring and observing of current infrastructure measures and additional one should be deeply analyzed and if necessary, further infrastructure implementations regarding PTW riders safety will be proposed.

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