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D1.3 – FINAL REPORT (WORKPACKAGE SUMMARY REPORT)

Project Acronym: **Smart RRS**

Project Full Title: **Innovative Concepts for smart road restraint systems to provide greater safety for vulnerable road users.**

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Responsible: **Università degli Studi di Firenze**

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SUMMARY:
The objective of the "*Innovative concepts for smart road restraint systems to provide greater safety for vulnerable road users*" (Smart RRS) project is to reduce the number of injuries and deaths caused by road traffic accidents to vulnerable road users such as motorcyclists, cyclists and passengers through the development of a smart road restraint system.

Within the WP1 "Characteristics of severe road traffic accidents concerning vulnerable road users such as motorcyclists" the task 1.1, "Literature Review on Motorcycle Accidents", and the task 1.2, "In depth Motorcycle Accident Investigation" aim at identifying the characteristics of motorcycle and other vulnerable road user accidents, in general, and in particular to search for the main characteristics of those accidents where motorcyclists get injured because of contact with fixed objects, on the side of the road, or with the road restraint systems.

This deliverable, D1.3 represent a summary of the main findings of WP1.

The analysis of the literature and the successive in-depth accident study show that there is a lack of data and there is a need for more in-depth PTW's accident studies.

Another important aspect is that in about 50% of the PTW accidents against a road restrain system, the rider is still in an upright riding position when the impact occurs, with the associated risks of being thrown on or over the barrier. Currently, this scenario is not considered in existing standard and is not included in the draft standard for protective road restraint systems approved by Technical Group 1 of CEN (European Committee for Normalisation). Moreover, very few studies have been performed to assess this scenario up to now. This configuration represents a scenario to be considered in future work.

The available studies show that the impact of motorcyclists against a fixed object occurred in 4% of the cases in urban areas while it varies between 10% and 20% in rural areas which can seems a small figure. However, a fatal outcome is 2 to 5 times more likely for an impact with a crash barrier than for motorcycle accidents in general.

According to the literature review, most motorcycle collisions with crash barriers occurred at shallow angles (typically between 10° and 45°) with the rider typically sliding into the barrier at a bend. However, the in-depth study has demonstrated that larger impact angle are also possible and must be taken into account

For sliding motorcyclist, it appears clear that discontinuous systems are worse than continuous. In this scenario, post modifications together with post envelopes shows a positive approach in decreasing risks for motorcyclists. The best solution seems to be the addition of a lower rail. As this provides better energy absorption than concrete solutions or wire rope safety barriers.

Wire Rope Safety Barriers are viewed by motorcyclists as the most aggressive form of RRS. This view is supported by computer simulations and tests, which indicate that injuries will be severe if a rider hits the cables or the support.

In the majority of accidents the PTW's speed tend to be very high, especially in the case of the fatal ones.

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1. Key Words

Road safety, Vulnerable road users, Motorcyclists, Road Infrastructure, Innovative road restrain systems.

2. Introduction

The design and maintenance of road infrastructure is of particular importance for the safety of powered two-wheeler (PTWs) riders. This is due on one side, to the potential involvement in accident causation and on the other, to the possible impact of the rider with the road infrastructure in the course of an accident.

Trees, poles and sharp objects in general, represent a potential danger for PTW riders. Road Restrain Systems also called Road Safety Barriers, are supposed to avoid any direct contact of the road vehicle (and user) against these objects.

Road Engineers design road safety barriers to prevent vehicles from leaving the roadway. The design of road safety barriers is generally such that a vehicle hitting the barrier is steered back onto the road. This is generally positive for cars and heavy vehicles, but very often it can increase the risk for PTW riders, as the road safety barrier can prove to be very rigid and not able to dissipate the energy of the impact, thus causing severe injuries to the rider even at low speed.

The WP1: *Characteristics of severe road traffic accidents concerning vulnerable road users such as motorcyclists*, has been divided in two parts: On one side, an extensive review of the state of the art has been conducted with the aim of assessing the different studies and findings around the world. On the other side, an in-depth accident investigation provided a snapshot of the moment of the accident, in which either only one vehicle, the PTW (motorcycle or moped) is involved, or more vehicles are involved (one of them should be a PTW), without impact between the moving vehicles. In the following two paragraphs, the main findings of the two studies are reported.

3. Main findings of the analysis of the state of the art

Despite several studies about the impact of motorcyclist against fixed objects are available in the literature, it is important to highlight that the majority of them are based on small data sets.

The analysis shows that the impact of motorcyclists against a fixed object occurred in 4% of the cases in urban areas while it varies between 10% and 20% in rural areas.

The most important obstacles with a particularly severe outcome involving accidents, are trees/poles, roadside barriers and road infrastructure in general.

In approximately 50% of impacts with trees/poles and barriers the rider is upright on his motorcycle.

Impact speeds in accidents involving roadside barriers as an obstacle tend to be very high.

According to different studies, a fatal outcome is 2 to 5 times more likely for an impact with a crash barrier than for motorcycle accidents in general.

The most dangerous aspect of guardrails with respect to motorcyclists is the exposed guardrail posts.

Most motorcycle collisions with crash barriers occurred at shallow angles (typically between 45 and 10°) with the rider typically sliding into the barrier at a bend.

There is a high risk for a rider to directly hit one of the barrier posts while approaching a guardrail in a sliding position. For a distance of 2.5m between the posts, the probability is more than 35% for an angle of impact of 30 degrees, increasing to more than 70% for a 15-degree angle.

Several testing procedures have been developed in order to evaluate the injury risk of a PTW rider sliding on his own into a roadside barrier. They all have an impact angle of 30 degrees and two different orientations of the rider's longitudinal axis in common. Impact speed is between 55 and 60km/h.

Another procedure includes the motorcycle. In this case the impact angles are between 12 and 25 degrees, and the speed is 60km/h.

All these procedures require a Hybrid II/III dummy, in some case with replacement parts. The biomechanical limits applied in the tests are mostly a HIC value of 1000 and a neck extension moment of 57Nm.

The risk of injury due to hitting a fixed object appears to be related to the impact area and the rigidity of the object. Hence small rigid objects such as posts are most likely to cause injury as they concentrate the forces of impact on a small area of the human body.

The sigma post has considerably less sharp edges compared to the IPE-100 post.

For riders remaining upright when impacting the crash barriers, most injuries occur when after shallow impact, the rider slides and tumbles into the top of the supporting posts.

When a rider is impacting the barrier in upright position on the motorcycle, if the height of the barrier is too low, this may cause the motorcyclist to be thrown over.

An impact on a post can, depending on the part of the body involved, cause fatal injuries at an impact velocity of as low as 20km/h.

Impact attenuators have a significant protective effect for motorcyclists and they are suitable as an element of passive safety measures.

Collisions with a fixed object were associated with the risk of head and thorax injuries, which is at least 50% higher than for motorcycle accidents in general.

Roadside barriers presented a substantial danger to riders, causing serious lower extremity and spinal injuries as well as serious head injuries.

The performance of concrete barriers seems to be superior compared to that of conventional metal guardrail systems in a sliding impact scenario, at least for shallow angles, despite their higher stiffness. Some authors see the biggest risk for severe injuries in the sharp edges of guardrail posts, others in the edges of the metal rail.

According to a study the limit of the effectiveness of crash absorbers on barrier posts was seen to be around 50 to 60 km/h.

Due to the open nature of the design, the Wire Rope Safety Barrier system is viewed by motorcyclists as the most aggressive form of Vehicle Restraint Systems causing the most injuries to riders. This view is supported by computer simulations and tests which clearly indicate that injuries will be severe if a rider hits the cables or the exposed supporting posts of Vehicle Restraint Systems.

In a comparison between metal guardrails with an additional lower rail and concrete barriers, the performance of the metal guardrail was seen to be less aggressive than the concrete wall.

Some studies state that an additional lower rail on a roadside barrier could reduce the consequences of impact to the human body by a percentage varying between 30 and 60% of the cases.

Future research should focus on the risks associated with impacts with trees and poles and on the question: what type of roadside barrier can effectively protect PTW riders from impacts with such obstacles.

For sliding motorcyclist, it seems apparent that discontinuous systems are worse than continuous. In this scenario, post modifications together with post envelopes shows a positive approach in decreasing risks for motorcyclists.

A much better solution seems to be the addition of a lower rail. As this provides better energy absorption than concrete solutions or wire rope safety barriers. The solution can be observed in different materials (steel, plastic, rubber, etc).

However, it must also be considered that the impact scenario in an upright riding position seems to be equally important, with the associated risks of being thrown on or over the barrier, and this scenario has not be investigated in depth up to now.

4. Main findings of the analysis of the in-depth accident databases

The in-depth accident investigation has focused especially on the impact against Guardrail barrier / Posts fencing.

The accidents were analyzed with regard to the PTW and rider kinematics, roadside infrastructure and surrounding conditions, trauma suffered by the riders and the effectiveness of the body coverage material.

The analysis has considered real accidents provided by three “In-depth accidents databases”: MAIDS (by ACEM), CENTRO ZARAGOZA, APPLUS IDIADA for a total of 239 accidents.

Fatal and serious accidents for which an impact of the PTW against ”Guardrail barrier/Post fencing” or against a “Buildings structures/embankment/tree/ditch or low lying depression” occurred has been analyzed.

In the majority of the cases, the PTW speed is higher in the fatal accident than in the serious ones. This is especially true for the accidents that include impact with a Guardrail barrier/Post fencing. In about the 70% of the fatal accidents the PTW speed is over 70km/h; it’s interesting to remark that the impact with this obstacle, even for serious accidents, is characterized (68,4%) by a PTW speed over 50km/h.

In the majority of fatal accidents in which there is an impact against a Guardrail barrier/Post fencing, the PTW roll angle, is different from zero; whereas if we consider the other obstacles, the higher percentage (53,3%) of PTW have an angle at impact equal to zero. The roll angle in the serious accidents, for which there was an impact with Guardrail barrier/Post fencing, is generally equal or lower to zero whereas for the impact with the other obstacle it assumes an opposite direction (>=0).

The fatal accidents are characterized by a wider PTW sideslip angle, respect to the serious even if the interval -30,30 degree accounts for the higher percentage. The majority of the accidents, independently from the severity, occurs in a curve. Nevertheless there are some differences between the obstacles the Guardrail barrier/Post fencing is hit essentially in a curve to the left; vice-versa the 45% of fatal accidents, characterized by the impact with Buildings structures/embankment/tree/ditch or low lying depression, occurred in a straight road.

Generally the impact with the Guardrail barrier/Post fencing occurred in a crowder (light or moderate) traffic condition than the impact with other obstacles (light or absent).

There is a higher percentage of fatal accidents occurred with a good visibility respect to the serious.

Considering the mobile view obstruction experienced by the rider at the time of precipitating event, it is present more frequently for serious accidents respect to the fatal and especially for the impact with Guardrail barrier/Post fencing.
The accidents occur, in the majority of the cases, with clear weather. However, it's interesting to remark that in the case of impact with Guardrail barrier/Post fencing, about 40% of fatal accidents, occur with not clear weather; moreover the 52,6% of serious accidents, relating to the impact with Buildings structures/embankment/tree/ditch or low lying depression, occur with not clear weather.

Some of the variables, do not show sensible difference between fatal and serious accidents. In the majority of the cases: the PTW's part involved as first in the accident is the front or the centre; the roadside do not present defects and the riders do not experiment view obstruction, at the time of the precipitating event, due to stationary obstacle.

Moving the attention towards the PTW's rider kinematics, respect to the severity of the accidents and the obstacles of impact, some interesting results can be highlighted: The PTW rider impact speed decreases passing from fatal to serious accidents and from the impact with the Guardrail barrier/Post fencing to the impact with other obstacles; all the fatal accidents due to an impact with a Guardrail barrier/Post fencing, occurred at a speed over 70km/h and even the 43% of serious injuries, were above the mentioned speed. In the impact with a Buildings structures/embankment/tree/ditch or low lying depression, the 50% of fatal accidents occur at a speed between 51 and 70km/h whereas the same percentage of serious injuries occur at a speed lower than 51km/h.

With the available information, regarding the rider's orientation respect to the road tangent, especially for the impact with Guardrail barrier/Post fencing it appears that the angle for fatal accidents is lower than for the serious ones. Among the fatal accidents there is a higher percentage of riders, respect to the serious, that impact against the elements of the Guardrail barrier: the 24,1% and 20,7% of riders, dead within 30 days, impacted respectively with the post and the rail of the barrier.

It's interesting to notice that the number of riders dead at the scene of accident is higher for the impact against a Guardrail barrier/Posts fencing than for the impact with the other obstacles.

Considering the injuries severity suffered by the rider on the different body parts when impacting with the roadside obstacles, it appears very clearly that the impact obstacle influences them. In general the injury severity of the impact against a Guardrail barrier/Posts fencing is higher (AIS 3-6) than for the impact with Buildings structures/embankment/tree/ditch or low lying depression (AIS 1-2).