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D7.4 Current standards gap analysis and input to SDOs

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PIONEERS
INNOVATION FOR RIDER SAFETY

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Publishable Executive Summary

This deliverable summarize the results of the studies and tests proposed during PIONEERS project to serve as inputs for corresponding SDOs to maximise the impact of the Project.

It has been considered that the interactions between the project and the SDOs are all those regulatory aspects and current standards that could be revised or improved thanks to the developments of the Project.

Therefore, to summarize these interactions the main work in this deliverable has been to carry out a gap analysis to identify which are the project recommendations to improve the SDOs so that the PPEs and motorcycles tests consider all the learnings of the project.

The improved test methods should be developed from formulated concept technology (TRL 2) to actual operational environment proven system (TRL 9), meaning that full standards should be produced towards actual implementation.

For each PPE identified within the different body regions, their respective achievements during the project have been detailed, which will also serve to present them, if required, to their different identified SDOs.

For the neck and pelvis section, it has been identified that currently there are no existing normative groups, which greatly limits the development of the protective equipment since they are not covered by any standard. Therefore, it should be considered to create a working group that allows the creation of a specific regulation for these devices because, despite not having an assigned work group, they are important for the rider's protection.

This document is strictly linked to Task 7.3 objectives. This document, as mentioned above, will be the base for proposing through meetings to the different SDOs the improvements found in the project in relation to the different PPEs identified. This activity will be included in the D7.3 *Dissemination and international cooperation strategy plan: Beyond PIONEERS* that will be submitted at the end of the project.

Legal Disclaimer

Abbreviations and Acronyms

Acronym	Definition
H2020	Horizon 2020
TRL 2	Technology readiness level 2
TRL 9	Technology readiness level 9
PPE	Personal Protective Equipment
PTW	Powered Two-Wheeler
SDO	Standards Development Organizations
ROM	Range of motion
HIC	Head injury criterion
BriC	Brain injury criterion
ATD	Anthropological Theory of the Didactic
WG9	Working Group 9
MATD	Motorcyclist Anthropometric Test Device
IWG-HP	Informal Working Group on Head Protection
GRSP	Global Road Safety Partnership

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1 Purpose of the document

The purpose of this deliverable is to maximise the impact of the project to the stakeholders and end users in terms of increase of use-rate and awareness raising. Moreover, to provide input generated in the project to relevant standardisation groups for Personal Protective Equipment (PPE) and motorcycle. In order to do it, the necessary relevant current standards will be reviewed and updated and if necessary, recommendations to create new ones will be provided.

As procedures for the development and full approval of new standards, or new versions of current standards, are rather not flexible, a coordinated strategy will be set up so that the expected outcomes from the project will be available in accordance with relevant international forums, particularly with SDO for PPE and motorcycle. This will be done by ensuring an extensive cooperation with these organisations.

Setting up a coordinated strategy to make the expected project outcomes available for the most important international forums, particularly the Standards Development Organizations (SDO) for PPE and motorcycle, is, in addition to the abovementioned, one of the main purposes of this project deliverable.

PIONEERS project plan is to use the content of this document in the meetings to be held with the SDOs. The objective of these meetings is to introduce PIONEERS findings to these key stakeholders to improve the current standards.

2 Introduction

Throughout this document it has been identified the different partners and regulatory groups linked to PPE. The different body regions have been identified and with them the normative groups to which they belong.

The most relevant results have been presented in order to serve as input for the different SDOs as tools to update the current standards.

With this deliverable, one of the aim of PIONEERS project has been met by designing field-effectiveness driven test methods (virtual and physical), with a high degree of reliability and repeatability to assess current and future safety systems under realistic impact conditions and also by providing input to the standardisation groups (e.g. CEN), in order to develop the new generation of PPEs prototypes and on-board safety systems.

3 SDOs gap analysis

The main partners involved in this deliverable have used the findings made during the project to develop a gap analysis with the current SDOs. This information is relevant as it can be used to improve Test methods.

In terms of PPEs, it has been decided to structure the document based on the body regions and identifying the corresponding SDOs in each case. Regarding Motorcycles, the work has been focused on improving on-board systems for lateral protection Test methods.

Below is shown the different inputs that the project will be able to offer to the corresponding regulatory groups.

3.1 Personal Protective Equipment (PPE)

3.1.1 Head

Head protection for Powered Two-Wheeler (PTW) riders is provided by motorcycle helmets. Helmets, in order to be sold as protective helmets for motorcyclists, have to comply the specifications defined in UN Regulation No. 22. The currently used test method for helmets only considers linear impacts as well as assessment criteria based on these linear impacts. The objective of the project was to improve regulation UN Regulation No. 22 in order to progress towards advanced head protection capability. Two key aspects were considered within PIONEERS, i.e. the impact conditions, by introducing oblique impacts in addition to the linear ones and the pass/fail criteria that should be based on new knowledge coming from biomechanics research.

The SDOs identified are World Forum for Harmonization of Vehicle Regulations (WP.29), Working Party on Passive Safety (GRSP), PH Protective Helmets (UN Regulation No. 22), and also CEN-TC158-WG11 for bike and sport helmets.

The proposal made for the improvement of UN Regulation No. 22-05, first has considered the helmeted head impact conditions. Based on the computation of the kinematic of motorcyclist's victims under real world accident as well as in virtual accidents, it has been demonstrated and accepted that the head typically impacts with an initial velocity vector that is not perpendicular to the impacting surface but presents a significant impact angle leading to head angular acceleration. As the brain is extremely vulnerable under angular acceleration, efforts were made in order to develop a set of three oblique impacts. Discussions within the IWG-HP (Informal Working Group on Head Protection) of GRSP as well as during a specific workshop organized

in February 2019 led to the definition of three oblique impacts called Xrot, Yrot and Zrot as shown in Figure 1. It was also strongly recommended to change the EN960 headform to the Hybrid III headform or to a new headform, in order to ensure realistic inertial properties.

As it was not possible to implement all these changes into UN Regulation No.22-06, it was decided to keep the EN960 headform and to introduce only two of the three proposed oblique impacts (Xrot and Yrot). It was accepted to consider advanced head forms and Zrot impact in a phase II of UN Regulation No.22-06. It was further accepted that in Phase II the advanced headform with recording of angular acceleration should also be used for linear impacts as it is well known that the so-called linear impacts conduct to angular loading of the headform.

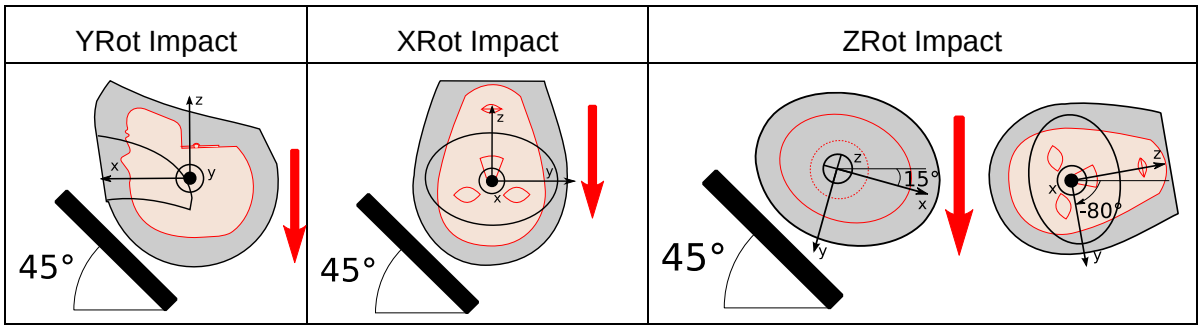

Figure 1. Illustration of the three impact conditions proposed for R22-06-Phase II

The proposal made to improve the UN Regulation No.22-05 also considered the pass/fail criteria by introducing advanced tissue level injury criteria that take into account simultaneously the 6D linear and angular loading of the head. Figure 2 illustrates the so-called experimental vs numerical test method which permits to introduce model-based brain injury criteria into an experimental helmet evaluation. However, in UN Regulation No.22-06 this proposal was not accepted mainly because it was unsure if an existing helmet could fulfil this pass/fail criteria. Therefore very basic criteria expressed in terms of HIC and BriC were introduced. With the introduction of model-based injury criteria the risk of brain injury can be quantified related to specific brain injury risk levels. This enables the definition of a regulatory threshold in order to set the requirements in a balanced way to ensure minimum protection but also to encourage further developments and improvements in head protection.

Interestingly is obtained to add a specific Article to UN Regulation No.22-06, saying that Test Houses should make available test results for Research Organisations for further investigation of advanced pass/fail criteria to be implemented in Phase II of UN Regulation No.22-06.

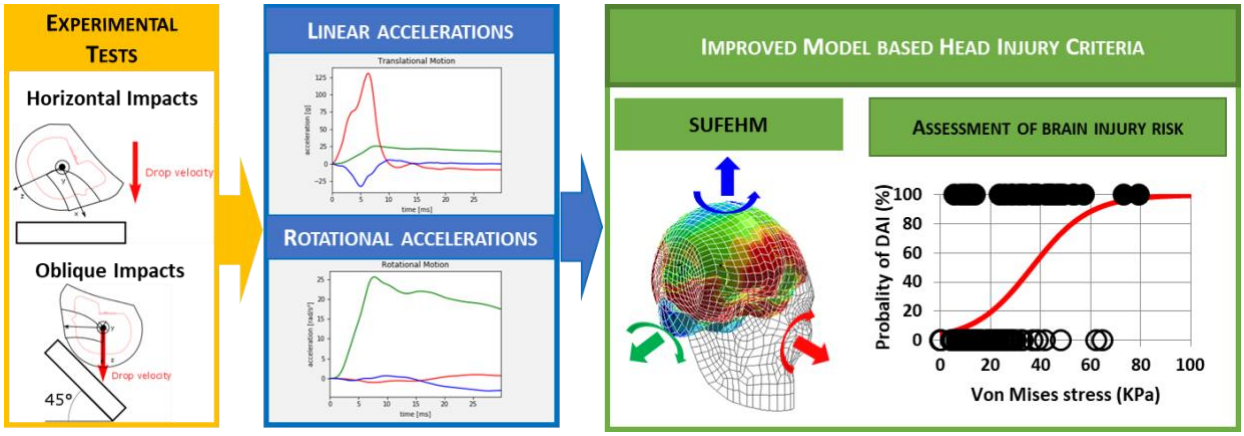

Figure 2. Illustration of the coupled experimental versus numerical helmet test method suggested for Phase II of R22-06. The experimental headform acceleration curves are considered as the initial condition of the numerical head impact simulation followed by the assessment of brain injury risk.

3.1.2 Neck

Neck protection can be provided by neck braces which prevent the head from reaching an excessive Range Of Motion (ROM). Nowadays, no test standard exists that assesses the protective effect of a neck brace. The neck or cervical spine is one of the most complex parts of the human body. Existing neck injury assessments do not consider omnidirectional loading found in PTW accidents and there is a lack of appropriated neck surrogates in Anthropological Theory of the Didactic (ATDs). Furthermore, the protective effect of a neck brace depends on the interaction between helmet and neck brace and cannot be assessed independently. PIONEERS delivers a first step towards neck brace assessments based on geometrical characteristics.

There is currently not an SDO known that addresses this topic. As the assessment of neck braces includes several aspects which need further research and development, the PIONEERS project proposes a geometrical assessment of helmets and neck braces in combination as the first step. By combining helmet geometry and neck brace geometry the possible range of motion can be approximated. This data can be used to identify reasonable combinations of helmets and neck braces and enables a categorization of combinations in “too restrictive”, “reasonable” and “not effective”. Furthermore, the information on helmet-brace-combinations can be used to reduce the number of possible combinations to a practicable amount for actual dynamic test developed beyond PIONEERS. The result of PIONEERS regarding neck protection is therefore seen as a base for further development in the field of neck brace assessments.

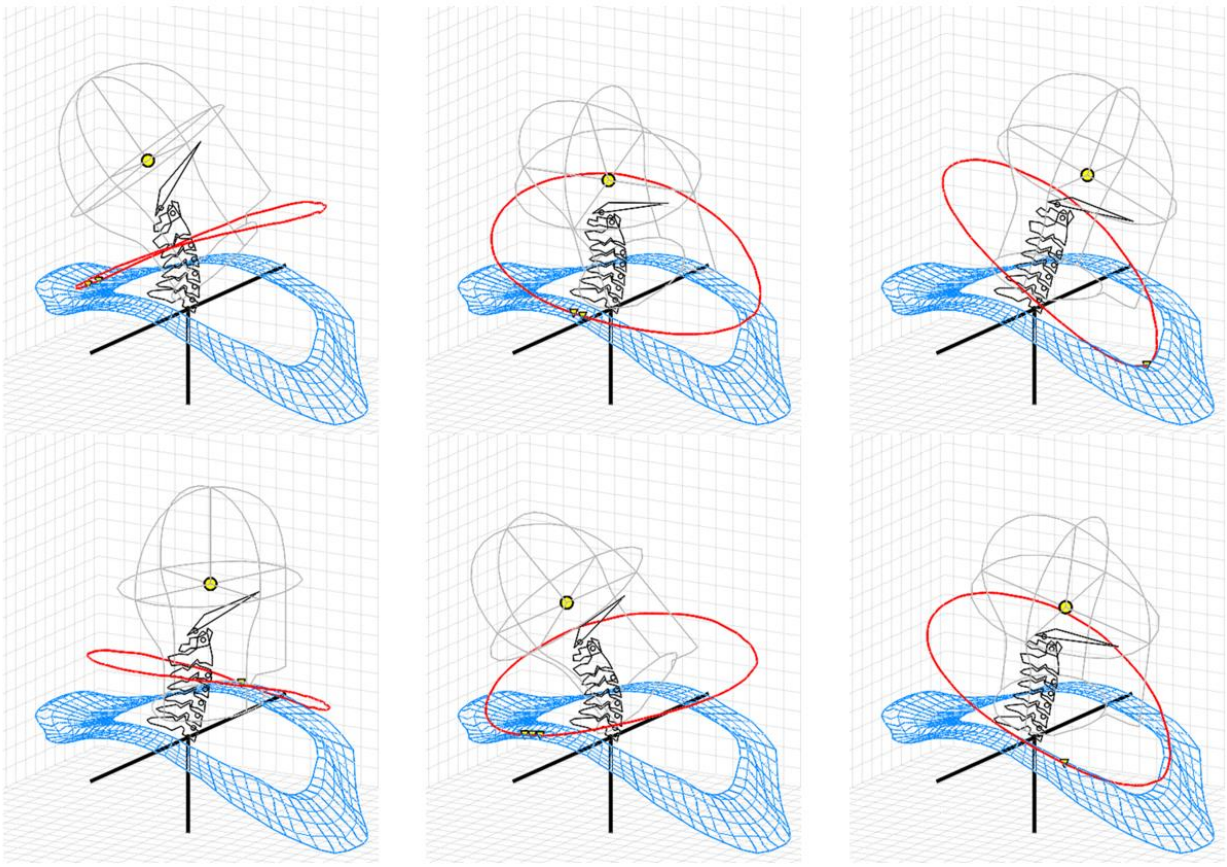

Figure 3. Geometrical assessment of ROM with one specific helmet-brace-combination

3.1.3 Thorax

Devices equipped with airbags are inside the framework of the EN 1621 standard. Within this project, in order to perform the impact on thorax for an airbag device, a new free fall test has been designed and developed for this type of PPE.

Using information and data extracted from the project, it is intended to develop a biofidelic and realistic test method to examine the performance of these devices and ensure that the manufacturer's designs are made of good quality and will protect the torso of the riders.

The machine has been designed so it can be very severe if a high free fall distance and a high mass is used, otherwise, it can give many impact options that can be used to study different conditions taking into account the weight, height and the position in which the impact can be made.

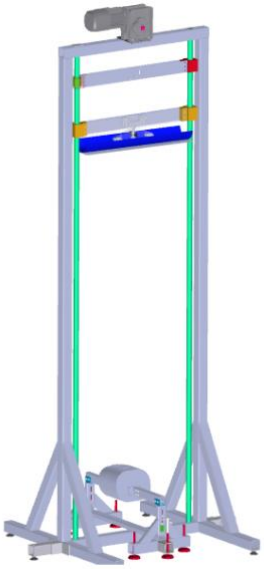

Figure 4. Impact on thorax, IDIADA's machine

The applying standard for this kind of PPE is the EN 1621. This standard is divided into two different ones: the one that finishes with a -4 (EN 1621-4) is for devices with mechanical triggering and the one with -5 (EN 1621-5) is for those devices that are characterized by not having wiring.

The work done in this section will serve as input to CEN/TC162/WG9 within Ad-Hoc group (1621-4 or 1621-5) in order to present the new testing methods. In this way, it is intended to redefine the test methods and their conditions in order to get closer to real scenarios.

The machine's design that has been developed offers a lot of combinations that can perform different impact conditions. This new test method is allowed to verify the performance of the PPE and certify a level of safety during use.

3.1.4 Pelvis

There is currently not known PPE or relevant standard for impact protection for the pelvis region of PTW riders despite a long history of evidence of pelvic injury risk through direct impact with the rider's own motorcycle fuel tank in a crash. A novel physical test method capable of comparing and evaluating pelvis PPE designs for minimising the pelvis response during fuel tank impacts has been developed in the PIONEERS project.

PIONEERS also provides the first feasibility assessment of pelvis PPE prototypes for mitigating soft tissue injuries in low speed impacts. This represents the first step towards the development of a standard, generic test method for assessing quality and performance of impact protection for the pelvis region of PTW riders.

Regarding inputs for the standardization groups, a test apparatus was designed to simulate PTW rider pelvis-fuel tank impacts. The apparatus is pictured in Figure 5 and described in more detail in PIONEERS Deliverable D3.1. The physical impact test produces pelvis kinematics consistent with that described for full scale motorcycle crash tests, and the pelvis surrogate impact response is sensitive to changes in rider posture and fuel tank angle which are characteristics linked to pelvis injury in crash investigation and computational studies.

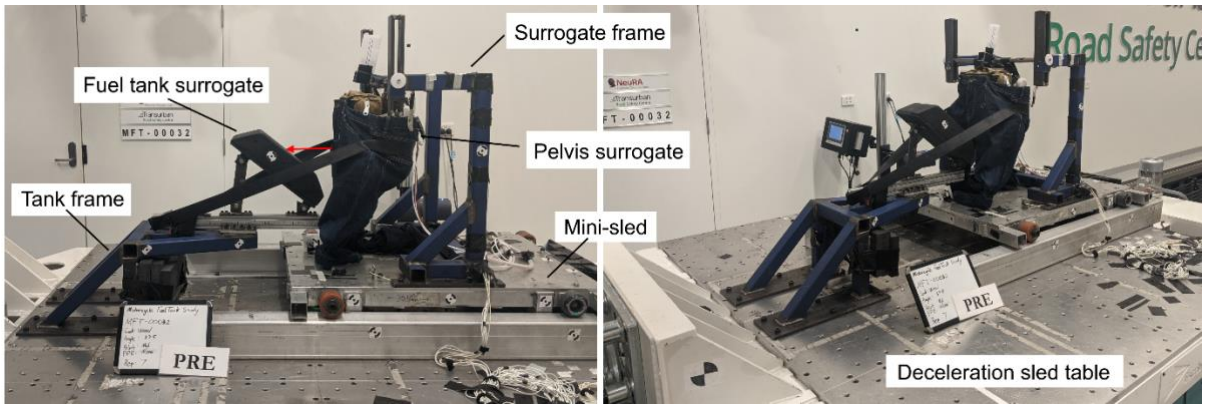

Figure 5. Sled test apparatus showing mini-sled, pelvis surrogate and surrogate frame which travels toward the fuel tank frame and tank surrogate (red arrow) mounted on the deceleration sled table.

Seven pelvis prototype impact protectors were tested with the novel test apparatus at an impact speed of 18 km/h. The pelvis response varied among the different protector materials and thicknesses, distinguishing designs that may provide better protection for riders in a crash. Test performance of potential pelvis impact protectors in the innovative PIONEERS test method and simplified impact drop testing could help to the development and implementation of impact protector requirements similar to EN 1621 standards for PTW pelvis protection.

3.1.5 Upper extremities

The proposal is to discuss the integration of further measured variables into the currently standardised procedure for testing protective clothing material according to EN 17092-1:2020. In particular, the variables of temperature and friction coefficient curve over the course of the test provide a deeper understanding of material behaviour in the event of a fall, as well as possible injury possibilities due to burns or insufficiently reduced impact speed.

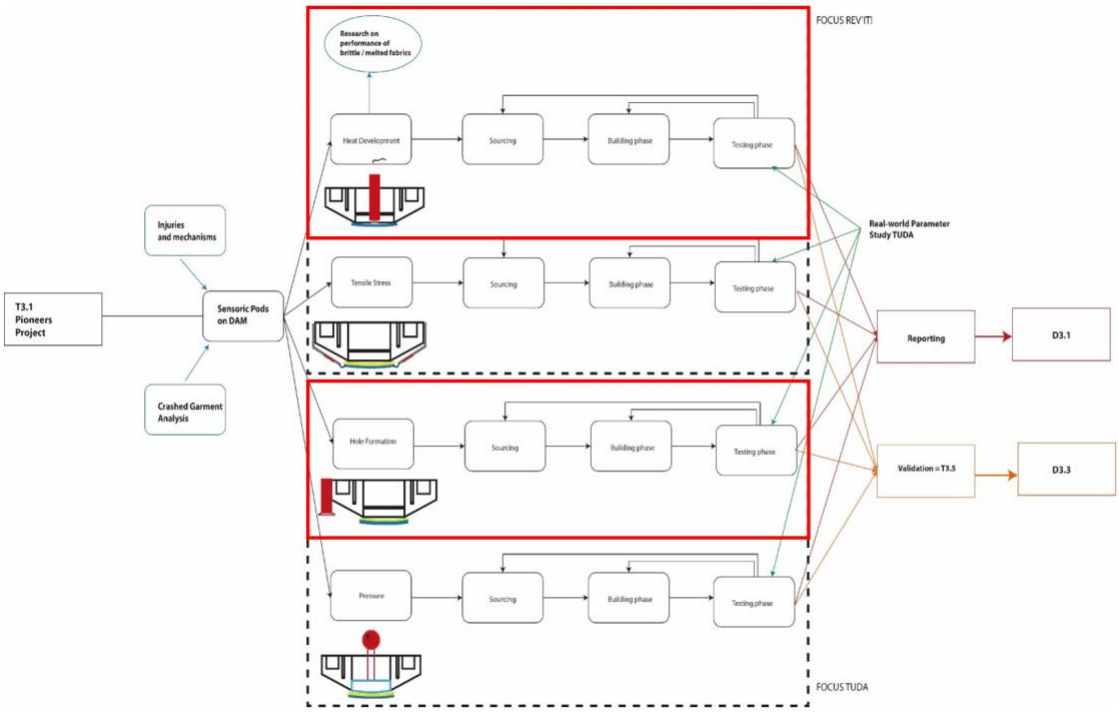

Figure 6. Different Test Setups for additional Parameters

The SDOs identified are the EN 17092-1:2020, Part 1: Test methods. and CEN/TC 162/WG 9 - Motorcycle rider protective clothing.

Different parameters for the evaluation of protective clothing material tests in WP3 within task 3.1 were investigated. In particular, the development of temperature in relation to the remaining friction parameters provides additional results to those prescribed in the current standard EN 17092-1 Test Protective Clothing Material, such as the hole formation criterion Yes/No. For this purpose, it is necessary to discuss whether it is appropriate to include further parameters in the test procedure.

3.1.6 Lower extremities

The objective of this section has been to design a new and realistic test method apart from the one described in the specific regulation for boots (EN 13634), in order to perform the ankle bending and study its reaction, all this has been done taking into account information extracted directly from real accident scenarios.

In this case, manufacturers will be able to benefit from this test to draw conclusions about their prototypes and in a future be able to update and reinforce them based on the results through innovative protections.

Seeing what is written in the current standard for this type of PPE, it has been decided to propose a series of tests focused on the behaviour of the ankle in the event of an accident. On this occasion, the inversion-eversion and extension-flexion movements have been taken into account.

Figure 7. Bending on ankle machine for boots, flexion-extension mode.

Figure 8. Bending on ankle machine for boots, eversion mode.

The only applying standard for this kind of PPE is the EN 13634. This European Standard applies to protective footwear for motorcyclists while riding motorcycles, whether on the road or off-road surfaces. It specifies the protection requirements, ergonomic characteristics, safety, mechanical properties, marking and information for the users. It also specifies the appropriate test methods.

New parameters had been proved to be checked in a boot. During this work it has been intended to expand the test methods section and thus be able to evaluate more parameters of the boot that are not being verified so far. Specifically, the inversion-eversion and the flexion-extension are the four new parameters that could be added into the applying standard (EN 13634) in order to increase the safety in boots.

3.2 Motorcycles, on board systems for lateral protection

As the development of a new standard method for on-board systems has not been envisaged within PIONEERS, the aim of this section is to provide suggestions on the test methodology for evaluating motorcycle on-board systems for side protection regardless of the adopted technical solutions (e.g. cover with protection bars), starting from the existing reference.

At the moment the only existing reference is the ISO13232:2005 standard, *'Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles'*, developed in 1996 and revised in 2005. The approach of the ISO is the comparison of results of full-scale crash tests with a number of numerical simulations of PTW-to-car impact scenarios, aimed at assessing that protective on-board devices are not more harmful compared with the base configuration (i.e. PTW not equipped with on-board protective devices).

To be consistent with ISO13232:2005 and obtain comparable results, the methodology described in this standard has been used as a reference in PIONEERS.

On top of that, the application of the ISO13232:2005 methodology in recent crash data triggered the question if the seven ISO impact configurations are still representative of the current European accident configurations. In such a view it is recommended to take into account what is reported in D*.1.3 Guidelines for the policy making: Future trends in accident scenarios and ISO 13232 review*, particularly the general suggestion of the need to enlarge and continuously update the accident database.

Without intention to question ISO 13232 from a scientific point of view, the following recommendations are intended to pave the way for the definition of a test methodology which applicability is compatible with time and costs of industrial product development.

An increased use of virtual simulations is expected for the initial development of protective devices in order to get the sensitivity on the effects of the various parameters on the effectiveness level of rider's protection. Real full crash tests are foreseen for final assessment of protective devices.

Below, some recommendations for the standards update.

- First recommendation: To start from the ISO 13232 impact configuration (car impacting the side of the PTW) but using test conditions (i.e. speed of vehicles) consistent with the expected performances of lateral protective devices in real accident scenarios.
- Second recommendation: To define a standard impact barrier to be used in full crash tests and numerical simulations, replacing the out-of-date car model of ISO 13232.

- Third recommendation: To provide full information about the MATD structure in order to enable the development of a finite element model of the dummy.
- Fourth recommendation: To integrate in the assessment of protective devices the most up to date virtual testing approaches accepted by the scientific and the industrial community.
- Fifth recommendation: Besides dummy's parameters, it would be helpful to measure accelerations also in a minimum set of points on the vehicle to be defined (i.e. wheel axle, saddle frame, steering column).

4 Conclusions

The most relevant results of this gap analysis will be the base content in order to generate inputs for the different SDOs as tools to update current standards, or as a base for those that does not have a specific standard yet.

For each PPE identified within the different body regions, their respective achievements during the project have been detailed, which will also serve to present them, if required, to their different identified SDOs.

For the neck and pelvis section, it has been identified that there are no existing normative groups, which greatly limits the development of the protective equipment since they are not covered by any standard. Therefore, it should be considered to create a working group that allows the creation of a specific regulation for these devices because, despite not having an assigned work group, they are really important for the rider's protection.

In the next table it is shown a summary of PIONEERS Project proposals:

Element	Body region / device	SDO	Proposal
PPE	Head	UN Regulation No.22 and CEN-TC158-WG11	• Angular acceleration should also be used for linear impacts • Introduction of model-based injury criteria to quantify brain injuries risk levels.
	Neck	Currently no SDO available	• First step: Geometrical assessment of helmets and neck braces in combination.
	Thorax	EN 1621	• Redefine test methods and their conditions to go closer to real scenarios. (Using new machine)
	Pelvis	Currently no SDO	• Introduce a physical test method

		available	capable of comparing and evaluating pelvis PPE designs for minimising the pelvis response during fuel tank impacts.
	Upper extremities	EN 17092-1:2020 and CEN/TC 162/WG 9	• Integrate further measured variables into the currently standardised procedure for testing protective clothing material
	Lower extremities	EN13634	• Evaluate more parameters of the boot: Inversion-eversion and flexion-extension are the four new parameters that could be added into the standard to increase the safety in boots.
Motorcycle	On board systems for lateral protection	ISO13232:2005	5 recommendations: • Use test conditions (i.e. speed of vehicles) consistent with the expected performances of lateral protective devices in real accident scenarios. • Define a standard impact barrier to be used in full crash tests and numerical simulations • Provide full information about the Crash test dummy • Integrate in the assessment of protective devices virtual testing approaches • Measure accelerations also in a minimum set of points on the vehicle

Table 1. PIONEERS Project proposals summary

5 Next steps

From the submission of this document until the end of the project, PIONEERS partners will use this deliverable as a content base to try to generate influence in the different working groups of the SDOs.

Using the information from this deliverable and the other useful from other work packages, the idea is to give as much inputs as possible to update the existing standards and try to establish new links for the other non-existing ones.

All the activity carried out from the Project to generate this influence on the SDOs from the date of submission of this deliverable until the project end date will be included in the deliverable D *7.3 Dissemination and international cooperation strategy plan: Beyond PIONEERS* that will be submitted at the end of the project.

6 Acknowledgment

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9	DUCATI	DUCATI MOTOR HOLDING SPA
10	UGE	UNIVERSITÉ GUSTAVE EIFFEL
11	LMU	LUDWIG-MAXIMILIANSUNIVERSITAET MUENCHEN
12	MOTOAIRBAG	D.P.I. SAFETY SRL DISPOSITIVI PER LA PROTEZIONE INDIVIDUALE
13	REVIT	REV'IT! SPORT INTERNATIONAL BV
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