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PIONEERS
INNOVATION FOR RIDER SAFETY

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Publishable Executive Summary

This deliverable includes a business & exploitation plan of the developments carried out in the PIONEERS project. The work has been structured in three parts:

The first part of the work has been to identify which PIONEEERS developments have the greatest potential for a commercial launch. The identified products have been the following seven: Helmets, garment research, airbag jackets, pelvic protector, boots, motorcycle lateral impact mitigation system and motorcycle lateral airbag.

The second part of the document has been to decide which factors could better represent the expected benefits or technical obstacles for a successful launch of these seven material solutions on the market. The factors that have been selected to assess the expected benefits have been safety and market interest and the factors to ensure that there are no major barriers have been technical viability, environmental aspects and regulatory aspects. Therefore, these five factors have been those that have been used to evaluate the seven products in terms of commercial and exploitation potential.

The third part has been to evaluate these five factors for each of the seven solutions to determine the commercial & exploitation readiness level of these solutions for their commercial launch:

In terms of PPEs: **Helmets** have improved safety performance and thermal aspects, very important and decisive issues for the user. In terms of **airbag jackets and garment research,** the implementation of new test methods should help to have jackets with improved safety. PIONEERS has developed **pelvic protector** prototypes that have been demonstrated to reduce crash effects in moderate severity simulated frontal impacts. Improvements in **boots** made by PIONEERS are aimed to protect ankle with a specific internal bio-mechanical structure. In terms of on board systems for lateral protection: **Lateral impact mitigation system** (Safety Leg Cover) has an advantage, they are a reinforced solution currently on the market. Finally, **lateral airbags** are potentially applicable, but there are some difficulties.

This deliverable is part of Task 7.3 Standardisation and exploitation whose main objective is to provide insights in the optimal exploitation of PIONEER solutions. Deliverable 7.5 will be the base to prepare meetings with market stakeholders to help the motorcycle sector in Europe. 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
PPE	Personal Protective Equipment
PTW	Powered Two Wheelers
EPS	Expanded polystyrene foam
AART	Advanced Abrasion Resistance Tester
AIS	Abbreviated Injury Scale
SLC	Safety Leg Cover
IPA / IPS	Impact protection to the ankle and/or shin

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1 Purpose of the document

The purpose of this deliverable is to make a business and product exploitation plan for PIONEERS Solutions considering the benefits and the difficulties that need to be overcome to move forward commercially. To achieve this purpose, the document includes analysis of different aspects related to its commercial launching.

Throughout the document, safety performance of the solutions developed by PRIONEERS have been evaluated. A broad vision has been considered, from the case of the accident to the description of the specifications reached and their improvements

This deliverable also includes aspects related to technological feasibility by explaining if the prototype is viable in terms of business level and if the manufacturing process can be carried out. Besides, the document involves environmental and regulatory aspects. Finally, the market interests related to the project solutions have also been considered.

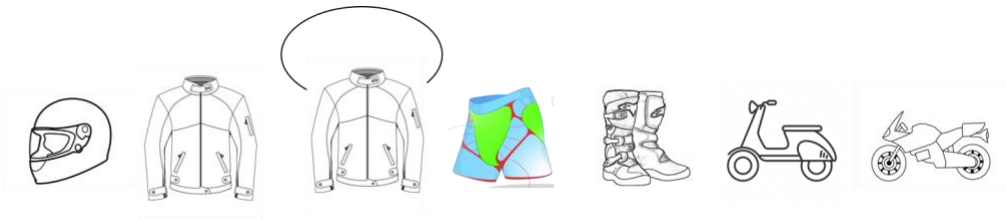
The ultimate goal of this deliverable is to identify the readiness level of these solutions for their commercial launch. This information is important for the next steps in the project, not only for being a technological project but also to be a useful project to support the motorcycle sector in Europe.

2 Introduction and methodology

This document aims to show protection equipment solutions developed during PIONEERS project from new perspectives.

It is intended to identify the viability of its business models in the market making an analysis of different solutions such as helmets, garment, airbag jacket, pelvic protector, boots, on board systems for lateral protection.

To ensure that these solutions are ready to an optimal exploitation in market, the new PIONEERS solutions are going to be analysed from five perspectives.



Safety	✓	✓	✓	✓	✓	✓	✓
Technical viability	✓	✓	✓	✓	✓	✓	✓
Environmental aspects	✓	✓	✓	✓	✓	✓	✓
Regulatory aspects	✓	✓	✓	✓	✓	✓	✓
Market interest	✓	✓	✓	✓	✓	✓	✓

Figure 1. Methodology summary

Safety: To measure the performance of these solutions in terms of user safety. To which extent the proposed solutions are better than the current ones? Which new benefits include Pioneers products?

Technical viability: To ensure that PIONEERS Solutions are items that can be manufactured industrially, and for example, that they can achieve time-feasible mass manufacturing process.

Environmental aspects: An important point is to confirm that PIONEERS solutions are safe and respectful with the world, like in current solutions. For example, in terms of materials used or fabrication process. In order to explain these aspects, manufacturers have been asked.

Regulatory aspects: It is needed to ensure that PIONEERS solutions are complying with all current regulations/homologations in Europe. The next step would be to validate the solutions with American and/or Asian rules which are out of the project's scope.

Market interest: To know if PIONEERS solutions fit with user's needs. To understand better the consumer Deliverable D1.2 *Rider needs* has been taken to account. It includes qualitative and quantitative information from users from three of the main important markets in Europe: France, Italy and Spain. Information from Australia is also available.

3 Content

Within this section the fields of safety, technical viability, environmental aspects and market interest are explained for each protection equipment developed during the project.

3.1 Helmet

This section aims to present the benefits of the introduction of improved motorcycle helmets. Based on advanced test methods and assessment criteria, the potential of optimized helmets can be made visible to promote the commercial launch.

3.1.1 Safety

Although the use of motorcycle helmets is mandatory in the EU, head and brain injuries are still a predominant risk in PTW accidents. Available helmets are tested and assessed in linear impacts without the consideration of rotational kinematics. It is well known that rotational kinematics is the dominant factor for brain injury risk and common in real world accident situations. A fundamental contribution of the scientific partners of PIONEERS has been given for the latest series of amendment of UN Regulation No.22, which sets safety standards for motorcycling helmets. The current version of the (UN Regulation No.22-06) came into force on January 4th, 2021 and includes new oblique tests for assessing helmets rotational impact management. The increased level of protection that helmets validated with these regulations will have a considerable impact on European road safety. This is the first regulation adopted at international level with “oblique tests”. The reason why it is important to test helmets obliquely and require the mitigation of sudden head rotations is explained in detail by the work of WP2 on head biomechanics and WP3 on helmet test methods and will not be further expanded here.

The helmet prototypes developed by DAINESE were designed targeting the mitigation of head rotation and contrarily to the helmets currently available, they have been optimized to have the best performance on this regard. Due to the new regulation and the new targets for helmet optimizations, once it is accepted, all motorcycle helmets sold in the future will be improved and will lead to a lower head injury risk in motorcycling in accidents.

3.1.2 Technical viability

Two types of new manufacturing process have been used for producing the energy absorbing liner of the helmet prototypes, but all other components have been produced with standard manufacturing processes.

The first technique is 3D printing. As of today, this is still not ready for mass production for the medium and low segments of the market. However, the increase in liner production costs, will be offset by the additional features that the technology will bring about for the premium segment of the market. First, the helmets will be made to match the head of the wearer (custom made), drastically increasing comfort. Secondly, they will be fully breathable avoiding most of thermal stress to the wearer. Finally, and most importantly, the prototypes are designed with a novel technology to manage energy in a way which minimizes the rotational components of impact. This feature will stick out from other technologies currently available for its effectiveness and will be a unique selling point for the helmets produced with it.

The other manufacturing process is more viable for all the segments of the market and entails the pre-assembling of modular structures into a full liner. Each module is produced with conventional injection moulding. Though the pre-assembling slightly slows down helmet production time, even in this case the advantages offset the additional costs, which are the same as per the 3D printed structure. The only difference being that for this second technology the helmets will be of standard shape and not custom made.

3.1.3 Environmental aspects

Notably motorcycling helmets are not recyclable due to the use of glues and EPS foams. However, the new manufacturing process for the energy absorbing liner will be friendlier to the environment as it makes use of plastic materials which are recyclable. All the components of the helmet prototypes comply with EU rules about dangerous substances and the environment. All parts are produced with approved materials and components that are commercially available and comply with EU regulation.

3.1.4 Regulatory aspects

The helmet prototypes have been designed to meet the previously mentioned new regulation UN Regulation No.22-06. Once industrialized, the helmets will therefore be able to be sold across Europe and many other countries adopting this regulation for the foreseeable future. The technology is also compatible with all known helmet standards in force across the world and thus suitable for worldwide adoption.

3.1.5 Market Interest

According to PIONEERS work in WP1, Helmet is the most important protective equipment. This fact was observed in all the Focus Groups held in three European countries (France, Italy and Spain) and was observed in the three types of users (Leisure riders, Commuter rides and Pillion riders).

The novel features introduced in the helmet prototypes have been carefully selected by analysing the work of WP1 on customer needs. Thermal stress is a major problem for motorcyclists and the technologies developed will address it in an unprecedented way. This is expected to expand helmet use in places where adoption is not universal due to heat and to penetrate drastically in all other areas. A considerable portion of motorcyclists are leisure riders who favour good and warm weather and thus thermal comfort is paramount. In addition, the unique safety features of the developed helmets are expected to appeal to most riders thanks to the awareness campaigns which will be launched at the end of the PIONEERS project.

3.2 Fundamental garment research

The PIONEERS project has developed a new method and an accompanied test setup to test different parameters that could lead to garment failure during an abrasive slide. These parameters were the result of a crashed garment analysis that was performed at the beginning of this project. Crashed garments were investigated macro- and microscopically to research the visual damage and to propose a cause for each type of garment failure and damage. In this way a better understanding of the fundamental causes of garment failures was achieved.

In the next stage the project focused on two phenomena that could lead to garment failure during a crash: the sudden impact of a garment on the road surface followed by an abrasive slide and the material's temperature rise that occurs during such slide. New test setups that incorporate sensors were engineered to gather data about these phenomena on the AART machine that is

used in the standardised procedure for testing protective clothing material according to EN17092-1:2020.

In the last stage of the project (Task 3.5) fundamental research focuses on the relationship between temperature rise in relation to the strength of a fabric and further exploration of the impact factor on a fabric during a real-life crash.

3.2.1 Safety

Soft tissue injuries (abrasions, cuts, lacerations and bruises) are not life-threatening in most cases, but can lead to infections, scarring and (temporary) immobility of the rider after a crash. According to a study by Rome et al., «Motorcycle protective clothing: Protection from injury or just the weather? Accident Analysis & Prevention, p.1893-1900,» 2011, looking only at open wounds (abrasions, cuts and lacerations), a 58% reduction in open wounds on the upper body can be seen when riders were wearing a motorcycle jacket. The risk of injury from an open wound is significantly lower when motorcycle garments are worn. Most soft tissue injuries occur on the legs (76%), followed by the arms (51%) and head (40%).

The above-mentioned study has also looked at protective clothing that may be damaged during an accident. Tissue damage can lead to open wound injuries. More than 25 % of the jackets and trousers worn show damage in the form of hole formation as a result of a crash. Seams fail less frequently according to literature. One possible explanation: seams have a small area in relation to the entire garment and are therefore less likely to be damaged in a crash.

Motorcyclists should be protected against skin injuries by their worn PPE (personal protective equipment). Accordingly, motorcyclist's PPE should offer resistance to impact and abrasion and comply to the PPE Regulation (EU) 2016/425. Therefore, garments are subjected to the test procedures described in EN17092-1:2002. The EN17092-series of standards includes, amongst others, several tests and demands to determine the performance of a fabric used in Motorcyclist's PPE.

A study by Meredith et al. (2014, Journal of Safety Research Volume 50) listed the frequency of different types of damage in crashed garments. 633 garment failures were analysed and classified into 5 categories: Abrasion, Tear, Burst, Cut and Unknown. Failure due to abrasion has been recorded as the most common failure (77.3%), followed by tear (11.4%) and burst (3.6%). A cut was found in only 1.3% of the failures and 6.5% were of unknown type.

The current test methods, described in EN17092-1 focus mostly on the ability of materials to resist abrasion, their tear strength and the strength of seams. Within PIONEERS the 'temperature rise' as well as the factor 'impact' during impact abrasion testing were analysed, whereas both factors were expected to influence garment failure resulting in severe injury. High temperatures can lead to heat transfer to the body as well as melting of a fabric resulting in a decrease in structural integrity and eventually failure. Sudden high impact forces can lead to sudden burst of a fabric.

In particular, measuring the temperature rise of a material and the related friction coefficient during a slide will allow for a deeper understanding and in-depth analyses of material behaviour and PPE performance. For these reasons, during the PIONEERS project additions to the EN17092-1 AART impact abrasion test machine were developed to monitor and analyse a fabric's temperature rise in 2 possible configurations and to intensify the impact force acting on the material during the first initial moment of contact of AART impact abrasion testing.

The additional impact system has been developed to simulate an intensified impact force to the standardised EN17092-1 Impact Abrasion test methodology. Allowing for in-depth research on material failure caused by burst, whilst at the same time, due to the integration into the existing methodology, maintaining the simulation of a realistic abrasion slide. The temperature measuring devices have been developed in such a way that they can be an added to the current AART Impact Abrasion test apparatus, keeping the calibration of the test setup unaffected.

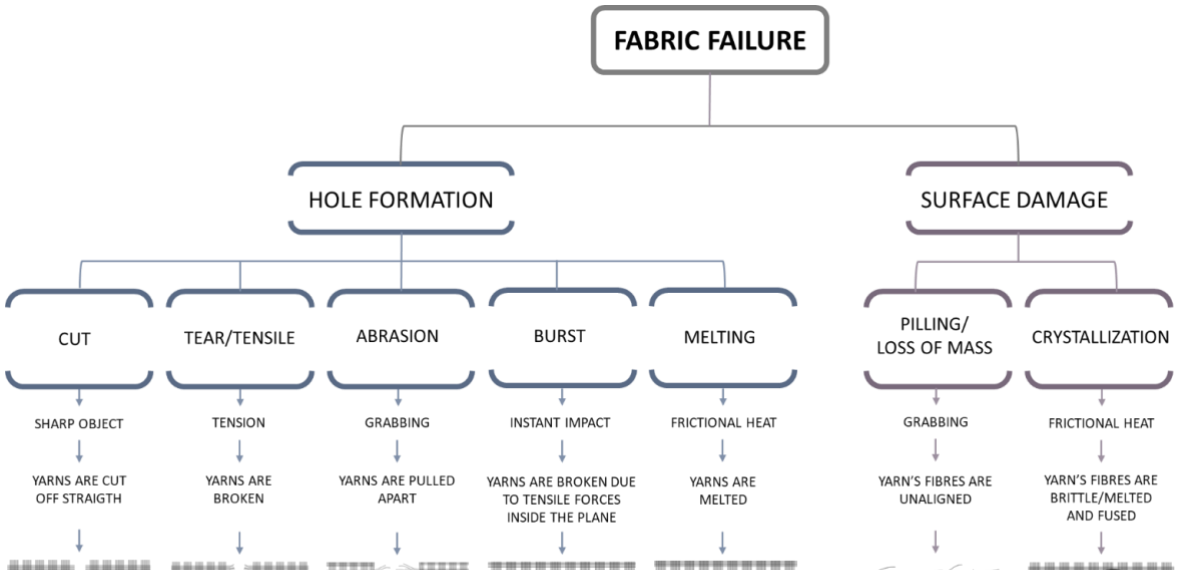


Figure 2: Crashed garment analysis categorization overview of garment failures in motorcycle crashes

3.2.2 Technical viability

The components needed to monitor and investigate the temperature rise during the process of a conditioned slide on the EN17092-1 Impact Abrasion AART setup, can be purchased in well-stocked electronics shops. The developed add-ons for temperature measurement do not interfere with the calibration of the existing AART machine, nor complicate the test setup and testing procedure. The developed Arduino and Matlab codes can be provided.

The same applies to the system used to investigate the intensification of the factor impact during Impact abrasion testing. Here, one of the most important development criteria evaluated was the ease of implementation, with simultaneous reliability of the system. For this reason, complicated additional control technology or energy supply systems were avoided. The additional system can be easily manufactured and consists only of mechanical parts. The implementation of this additional system is easy and straightforward, because it is triggered via the existing test stand.

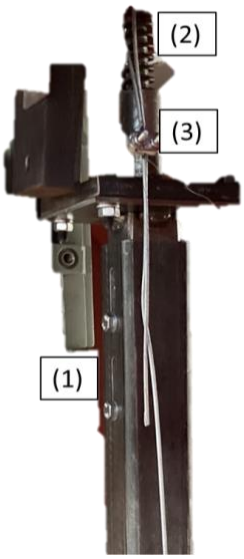


Figure 3: System developed in addition to AART Impact abrasion machine (EN17092-1) aiming to intensify the factor impact

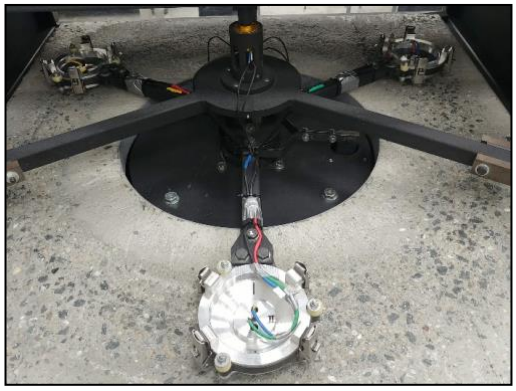


Figure 4: Temperature test setup measuring 'in-pod' (bottom of the fabric)

Figure 5: Temperature test setup measuring 'in-tile' (face side of the fabric)

3.2.3 Environmental aspects

As previously described, the additional systems and components developed within PIONEERS to monitor temperature rise and intensify impact force, consist of a few additional elements that can either be purchased or constructed with little effort. At the same time, however, the corresponding systems facilitate the acquisition of important data in relation to load and heat stress on PPE materials during a crash.

The advantage of the developed systems and components is their modularity, meaning that testing can still be carried out according to the existing standard and the existing validation, whereas the use of the additional systems is optional and does not affect calibration or validation.

The materials used to construct the monitoring systems are easy to obtain, widely available and not known to incorporate any harmful substances. Where applicable, CAD engineering has aimed for usage of 3D printed parts in order to minimize waste.

3.2.4 Regulatory aspects

Due to the focus on the integration of additional measurement systems into the existing measurement methodology according to EN 17092-1, there is initially no fear of a violation of the corresponding European regulations. The additional electronic systems are operated in the low-voltage range, so there should not be homologation problems. However, mechanical modifications to an existing test apparatus should only be carried out by qualified personnel. In addition, the durability of the corresponding components must be examined and validated based on the increased mechanical load caused by the additional impact system.

3.2.5 Market Interest

To diminish the PPE user resistance and improve the understanding in respect to safety benefits for the consumer, many applicable European standards have been developed and revised in recent years and PPE performance ratings were introduced. Motorcyclists have an interest in protecting themselves to keep them safe. With additional information about PPE materials and their crash burst protection abilities, as well as the publication of results on temperature rise during a slide, more motorcyclists could be convinced to wear protective clothing in the future and increase user acceptance. This would lead to less injuries, and therefore a reduction in medical costs and motorcycle casualties.

3.3 Airbag Jacket

PIONEERS project has developed a machine that makes possible to evaluate devices equipped with an airbag by means of a free fall test able to vary the mass and height depending on the different impact conditions.

3.3.1 Safety

The human torso contains the majority of the organs and vital structures. An injury to the torso often results in irreversible trauma or death. According to Section 4.6 *Most common injuries* from *D1.1. Powered Two-Wheelers - Road Traffic Accident scenarios and common injuries*, motorcycle accident data demonstrate that the torso is one of the most exposed body areas to severe trauma AIS>3. Whereas direct impact to the torso represents the majority of severe trauma.

Multiple forms and techniques of impact protection for motorcyclists are known. The classic rigid protectors (merely composed of hard materials combined with foams) are often limiting the freedom of movement of the motorcyclist and therefore lacking user acceptance.

One of the most effective impact protection techniques comes in the form of AIRBAG technology, where the energy of the impact is absorbed by deforming and compressing the Airbag.

In terms of impact protection, airbags can offer until 7 times more protection than a rigid protector when assessed to the European Standard for Airbags (EN1621-4:2013).

In terms of comfort, an airbag is more beneficial compared to a rigid protector due to its flexibility and minimal volume when in deflated state. The high level of protection (inflated state) combined

with the flexibility (deflated state), allows for airbags to protect vulnerable body regions in a most effective and comfortable way.

The crash data analysed in the PIONEERS project has pointed out that the most severe injuries are correlated to crashes involving thorax impact.

3.3.2 Technical viability

MOTOAIRBAG has focused on an innovative airbag that is meant to be adopted by a large population of motorcyclists and therefore improve the user acceptance of airbag technology and PTW road safety. The airbag has been developed with special focus on 'ease of use', 'price setting' and 'wearer comfort'. The new thorax model is based on more than 20 years of experience in airbag development and human body protection; whereas special attention has been given to a very fast and reliable mechanical detection system. The prototype has been developed with a keen eye on production feasibility using existing industrial production processes (materials, assembly, etc.) and therefore is considered to be economically viable. Even though at this point in time no business model analysis is specifically made, the prototype can easily be industrialized to a cost effective product.

One of the main goals of the PIONEERS project is to enhance road safety for PTW's. In this respect the promotion and user acceptance of airbag technology forms an important pillar. Within PIONEERS, REV'IT! has challenged its own state of the art (rigid & foam protectors) by developing a thorax protector based on airbag technology that complies to EN1621-4 in respect to impact performance and inflation speed.

During the research and development trajectory a new and innovative production technique for the air bladder has been adopted, which allowed for fast and relatively cheap iterations in order to test various designs, concepts and protective areas. Although focus has not been on the triggering mechanism and technique itself, different (pyrotechnic) gas inflators have been tested in conjunction with various protective designs and bladder volumes to pass the inflation demands (according to recent developments in EN1621-4 and CEN/TC162/WG9 ad-hoc group Airbags).

Multiple vest prototypes have been developed in order to house the bladder and canister(s) and form a comfortable and lightweight airbag vest to be worn under an abrasion protective shell (EN17092-6:2020, C-U). The vest prototypes can be tested to the newly developed drop-test procedure that is based on (Hybrid III) thorax deflection and developed within the PIONEERS project.

The currently developed prototypes will be technically viable for future production; however the resources needed to invest in the triggering device and technique (e.g. algorithm based) and the need for extensive real-life and test-house validation (crash testing, on-road testing, PIONEERS drop-test based on Hybrid III thorax deflection, etc.) would have exceeded the PIONEERS project duration and budget. An EN1621-4 impact validated prototype has been developed that is in need of further research and development beyond the PIONEERS project in order to be incorporated in the collection roadmap of REV'IT!.

3.3.3 Environmental aspects

The materials used for prototyping are already designed to be recyclable in compliance with local regulation level. The assembly process totally avoids chemical substance (safe for the workers, safe for end user, safe for the environment). The product has not a specific life period: every 3/4 years it shall be sent back to the company for inspection.

The "Inspection programme" guarantees the perfect functioning of the airbag and enlarge the shelf life of the product avoiding creating additional waste and pollution.

3.3.4 Regulatory aspects

The actual European Standard for airbag is the EN 1621-4:2013; (Motorcyclists' protection against mechanical impact Part 4: Motorcyclists' mechanically activated inflatable protectors - Requirements and test methods).

The prototype totally overcomes these requirements (including the future revision requirements). It can also be electronically triggered and overcomes the preliminary requirements of the new dedicated EN 1621-5 (Motorcyclists' protection against mechanical impact Part 5: Motorcyclists' electronically activated inflatable protectors - Requirements and test methods).

During the PIONEERS project a further testing procedure was created and the prototypes will be ready to be tested and study their performance.

In Figure 6 it is shown one of the proposals for additional testing equipment in IDIADA.

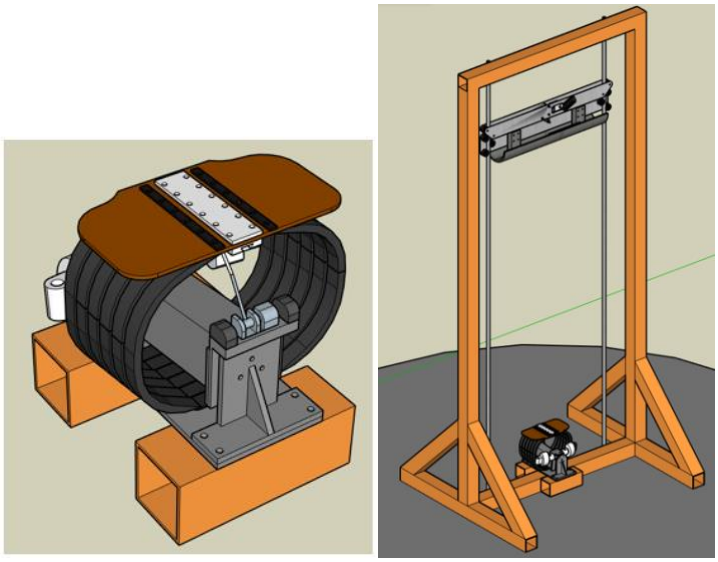


Figure 6: Sketch of the dummy base and the free fall impact machine for airbag jackets

3.3.5 Market Interest

Considering results from WP1, jackets are elements very appreciated among leisure riders, they are the second most important equipment, after helmets.

To enlarge the use of AIRBAG is one of the aims of PIONEERS Project. From Industry side, the goal is to make the AIRBAG more comfortable and more affordable for users. From PIONEERS side the goal is to reach directly the end consumer, who is the real beneficiary of this European Project.

3.4 Pelvic protector

PIONEERS Project has developed wearable pelvic protectors designed to be incorporated into motorcycle rider specific undergarments.

3.4.1 Safety

Motorcycle crashes are the most common cause of traumatic urogenital injury and fracture of the pelvis. Pelvic injuries occur to approximately one in five crashed motorcyclists who are hospitalized, and many pelvic injuries are associated with poor long-term outcomes such as chronic pain and ongoing reductions in quality of life. Further detail on this have been described by WP1 and will be not expanded in this deliverable. Despite clear evidence that motorcycle crashes are the primary cause of these injuries, there is currently no countermeasures for their prevention or for reducing the injury severity.

In the vast majority of motorcyclist pelvic injuries, the predominant contact surface associated with injury is the fuel tank of the rider's own motorcycle. Motorcycle crash testing with anthropometric test devices (ATDs) and cadavers has shown that in a frontal crash, as the motorcycle comes to a stop, the rider translates forward until the pelvis hits the fuel tank. The torso of the rider then pitches forward, and the crotch and thighs slide over the fuel tank. To date, the potential for protective clothing to play a role in mitigating these injuries has remained unexplored.

DAINESE has developed pelvic protector prototypes that have been demonstrated to reduce loads transferred to a pelvic surrogate in moderate severity simulated frontal impacts. Currently there is no data available regarding the injury tolerance of the pelvis in anteroposterior loading such that occurs in motorcycle frontal impacts. There is also currently no relevant technical standard dictating performance requirements for this type of protective equipment. Regardless of these limitations, the pelvic protectors developed in PIONEERS show excellent promise as a novel innovation to enhance motorcycle rider safety. Importantly, the design of the prototypes considered rider comfort with equal weight to safety to maximise rider acceptability of this innovation. Being the first protection of its kind with proved effectiveness, the impact of this innovation for road safety is down to promoting widespread adoption.

3.4.2 Technical viability

The main innovative content is the new protection concept itself and not the manufacturing technology. The technique used for making the prototypes are advanced but perfectly suitable for mass production at affordable prices. The innovative foam used for energy absorption is widely available as a commercial product. Technology and cost are therefore no barrier to the widespread adoption of this kind of technology.

3.4.3 Environmental aspects

All the components of the pelvis protector prototypes comply with the applying EU rules about dangerous substances and the environment. All parts are produced with approved materials and components that are commercially available. The main aspect considered while designing the prototypes was comfort as this is a very mobile part of the human body. For this reason, textiles with embedded elastomers and artificial tendons were used. These materials are notably not recyclable though they do not contain any dangerous substance for the environment when they are disposed of.

3.4.4 Regulatory aspects

This protection for the pelvis is the first of its kind to protect an area for which there are currently no requirements for mandatory safety protection. The prototypes and future industrialized products are certified with the procedure developed in PIONEERS and tested in accordance with EN1621 with the same setup used for knee or elbow protectors. Given this, there are no regulatory impediment to launch this protection worldwide.

3.4.5 Market Interest

Awareness campaigns are fundamental to promote the widespread adoption of this protection. A few riders are aware of the incidence of pelvic and particularly genital injuries which the developed prototyped protect from. The prospect of a severe injury in genital areas may be threatening for motorcyclists and knowing that there is now a solution for it is expected to appeal a considerable portion of them.

3.5 Boots

This section aims to present the benefits and technical obstacles that can be overcome in the commercial launch of the boot solution.

3.5.1 Safety

In terms of lesions, most common injuries in the lower limbs are abrasions, lacerations and fractures. According to sections *3 The voice of the customer - EICMA Survey* and 4 *Results of the EC Project RIDERSCAN* from *D1.2 Rider's needs*, motorcycle boots and shoes are the 4th protective garment most used by riders after helmets, gloves and jackets with protectors. According to a well-known research (Hurt, 1981), wearing specific boots is likely to result in 50% less foot injuries. It can be said with good approximation that with the progress of materials, research and specific standards (approvals) in recent years, this percentage has increased.

The protection of the lower leg will be improved in a new touring boot prototype, with enhanced protective performances typical sport and technical boots, normally not accessible to the large public. The choice was made according to accident scenarios review and to focus groups outcomes to provide a higher protection against impacts without affecting comfort and to meet the target of the widest range of final users.

In terms of protection, while the current standard requirements are related just to abrasion, cut resistance and transversal stiffness, the new design will enhance the protection thanks to a larger protecting area and the protection against impact on ankle (IPA) and shin (IPS), according to IPA/IPS facultative standards requirements (as in the EN 13634:2010).

To achieve this target, boots have been designed with embedded impact absorbing pads on shin and ankle area, opportunely design to grant protection and comfort. Selected materials came from Alpinestars know-how and testing of different solutions.

The protection from hyper-rotations and hyper-flexions, which are also targeted in the new design, are not currently considered in the EN 13634:2010 standard.

To achieve this target a specific internal bio-mechanical ankle structure have been designed with the function of enhance protection allowing full and free movements of the ankle.

This rigid structure has been positioned in the boot between the internal layers and the impact absorbing inserts.

3.5.2 Technical viability

Regarding the prototype done for the project, it has been designed according to state of the art of technology and manufacturing processes, so it can be industrialized.

3.5.3 Environmental aspects

In terms of environmental aspects, the new equipment is a new design, but the materials and industrial procedures used are according to state of the art of technology processes, so environmental impact is affordable.

3.5.4 Regulatory aspects

The aim of this work is to propose an update of the test methods of the standard, EN 13634, for this kind of motorcycle PPE. Important aspects have been taken into account such as bending of the ankle due to inversion and eversion movement as well as flexion and extension, which can damage the area in case of an accident.

Manufacturers would be able to use the results from the tests as an output to develop new boots prototype with innovative protection solutions for lower leg, foot and ankle and make them safer.

Below, in Figure 7, is shown one of the proposals from IDIADA in order to update the regulations of boots.

Figure 7: Photo of the flexion-extension test in laboratory

3.5.5 Market Interest

The work carried out in WP1 on the user needs did not specifically include questions about boots. However, a general conclusion in deliverable D1.2 (Rider needs) was that price and comfort were two fundamental aspects when choosing protective equipment. Therefore, if the boots offer improvements in safety, are comfortable and the prices are maintained, the acceptance of these boots in the market will be positive.

3.6 Motorcycle lateral impact mitigation system

This section aims to introduce the benefits and other perspectives that can be considered in the commercial launch of this solution.

3.6.1 Safety

The aim of the lateral impact mitigation system, which prototype was developed in Task 5.4 of the project is to mitigate the consequences (small shocks or wounds) on the rider occurred from lateral impacts of car against powered-two wheelers at low speed.

The preliminary idea of safety leg cover (SLC) started from the same concept of the genuine standard leg covers by simply adding two or three protective items fixed inside the cover, matching the legs position.

In such a way it is always provided an interface between rider lower limbs and the opponent vehicle (during the primary impact) as well as the ground (in case of fall) or any other object (secondary impact).

Virtual simulations of car impacting at 90° against scooter motorcycle equipped with SLC show a decrease of 2/3 of residual force, respect to scooter motorcycle not equipped with mitigation system. Moreover, simulations at different impact angles, performed by University of Firenze and simplified impact tests, carried out in Piaggio Mechanical Laboratories, confirmed the potential benefits of impact mitigation system.

3.6.2 Technical viability

From a technical point of view the safety leg cover is almost ready for industrialization, thanks to the close cooperation with supplier in the design and development process. Even if a detailed cost analysis has not been carried out yet, no relevant additional manufacturing costs are envisaged due to the following:

- No product modelling modifications are needed: the prototype has been developed from the design of mass production leg cover, available for a few models of Piaggio vehicles. Initial design has been modified by inserting four protective bars (two each side) place in the inner part of the cover in order not to be visible from outside
- Bars structure are made of semi-open-cell polyethylene foam, with optimal characteristics lightness, high absorbing power, low memory, quick reshape performance as well as low cost, being material easily available on the market.

- Additional manufacturing operations are just the insertion of the bars and the fixing system (some pieces of velcro in order to let the user adjust the position of the bars)

3.6.3 Environmental aspects

Materials used, and the fabrication process are almost the same as for mass production leg cover, therefore the environmental impact is the same. The fixing system is such to make disassembling and disposal of protective bars.

3.6.4 Regulatory aspects

Currently there is not any regulation relative to this type of safety device. So, there is no regulatory impediment to launch this protection system.

3.6.5 Market Interest

Taking as reference the not-reinforced mass production solution currently on the market, it is expected the Safety Leg Cover to have at least the same market potential, being the proposed solution slightly heavier (about 11% more) and with a market price not significantly different.

Moreover, market widespread could increase if supported by a suitable communication campaign promoting PTW safety.

3.7 Motorcycle lateral airbag

The following is the analysis of motorcycle lateral airbag considering the five perspectives to evaluate its possible market acceptance.

3.7.1 Safety

Side impacts with PTW are some of the most frequent type of accidents that involve motorcycles. The rider is directly exposed with his legs to the colliding vehicle. Lateral airbags are a passive safety device studied to reduce the effects of such impacts on rider's legs. Lateral airbags act like a cushion that absorb part of the energy of the impacting vehicle. Such type of devices are not available on any motorcycle currently on the market.

3.7.2 Technical viability

Lateral airbags are designed in order to maximize their effectiveness, having in mind the strict layout constraints of a motorcycle. They need to be placed in appropriated areas in order not to limit the capability of riding the motorcycle. Moreover, their dimensions and weight have to be controlled for the same reason. Therefore, it is not obvious to find a technical solution that allows for an effective protection within the various constraints. Not to mention the aesthetic appearance that should be also taken into account for a recreational vehicle like a motorcycle.

3.7.3 Environmental aspects

Airbags have been available for many years in the motorcycle market (in jackets) and in the automotive market. Therefore, this technology is widely implemented. The main innovation lies in placing this element on the motorcycle so that it does not influence other motorcycle functionalities (lightness, manoeuvrability, etc.). Therefore, this solution does not generate any additional environmental impact.

3.7.4 Regulatory aspects

Currently there is not any specific regulation relative to this type of safety device. So, there is no regulatory impediment to launch this protection system.

3.7.5 Market Interest

Lateral airbags are potentially applicable to all types of motorcycles. They are a passive safety device that can increase safety in urban and extra urban usage. The cost of the system should be controlled in order not to be a limit factor for the application on cheaper motorcycles. Like it

was seen in automotive industry, the impulse to apply such systems should come from regulations once it is proven that it can provide a decisive contribution to the increase of safety.

4 Conclusions

Within this document, all the protective equipment has been presented and defined according to the different perspectives introduced at the beginning of the deliverable. This work has served to identify what is the realistic viability of the proposed solutions from PIONEERS Project.

- In terms of PPE:

  Regarding **helmets**, it should be noted that safety performance and thermal aspects, very important and decisive issues for the user, have been improved. Manufacturers have developed technologies and will address them in an unprecedented way.

  In terms of **airbag jackets and garment research,** the implementation of new test methods should help to have jackets with improved safety.

  PIONEERS has developed **pelvic protector** prototypes that have been demonstrated to reduce loads transferred to a pelvic surrogate in moderate severity simulated frontal impacts. The benefits of pelvic protection should be made known because few users know this type of equipment.

  Improvements in **Boots** made by PIONEERS are aimed to protect ankle with a specific internal bio-mechanical structure This new development is according to state of the art of technology and manufacturing processes, so it should be easily placed on the market.

  In any case, an awareness campaign will be necessary to promote the widespread adoption of the whole personal protection equipment.

- In terms of on board systems for lateral protection:

  On the one hand, **lateral impact mitigation system** (Safety Leg Cover) has an advantage, they are a reinforced solution currently on the market.

  On the other hand, **lateral airbags** are potentially applicable to all types of motorcycles, but the cost should be controlled in order not to be a limit factor for the application on cheaper motorcycles.

  Regarding the lateral impact mitigation system and lateral airbags of motorcycles, market widespread could increase if supported by a suitable communication campaign promoting PTW safety.

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1	IDIADA	IDIADA AUTOMOTIVE TECHNOLOGY SA
2	UNIFI	UNIVERSITA DEGLI STUDI DI FIRENZE
3	DAINESE	DAINESE SPA
4	UNISTRA	UNIVERSITE DE STRASBOURG
5	ACASA	AUTOMOBIL CLUB ASSISTENCIA SA
6	BAST	BUNDESANSTALT FUER STRASSENWESEN
7	TUDA	TECHNISCHE UNIVERSITAT DARMSTADT
8	UNSW	UNIVERSITY OF NEW SOUTH WALES
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
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