Project nº 218741
Co-financed by European Commission

D2.4 – 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.**

Grant Agreement No.: **218741**

Responsible*:* **IDIADA**

Internal Quality Reviewer: **UNIFI**

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 WP2 “Review of Standards - Current Science & Technology”, the Task 2.1, “Evaluation of actual roadside motorist protection systems regulations” and task 2.2, “State of the Art Systems” aim to review the current regulations and most up to date technology respectively.

Task 2.3, “Definition of necessities and requirements for future roadside motorist protection systems” defines the new criteria required to evaluate future systems. From this any new designs will be compared and a judgement will be passed on whether it meets the specified requirements.

This deliverable D2.4 represents a summary report of the main findings of WP2.

INDEX

WORKPACKAGE 2 SUMMARY REPORT

1. INTRODUCTION

Deliverable 2.4 is a compilation and summary of the most important aspects from Deliverables 2.1a, 2.1b, 2.1c, 2.2 and 2.3. The main purpose of this assemblage deliverable is to provide the reader with a very direct and explicit idea of the work progress that can be found in the precedent deliverables. This is helpful in the location of specific topics of interest and aids in the dissemination of the work package information.

2. TASK 2.1 EVALUATION OF ACTUAL ROADSIDE MOTORIST PROTECTION SYSTEMS REGULATIONS

2.1 D2.1A REPORT ON REVISION OF REGULATION UNE135900

2.1.1 ACCIDENTOLOGY/DEFINING THE PROBLEM

From 1995 to 2003 motorcycle accidents in Spain decreased from about 12000 to approximately 10000. However, in the following 2 years accidents increased by over 20% to around 12700. In the same 2 year time period accidents for all type of vehicles decreased by approximately 12.5%. It is important to point out that the number of motorcycles in Spain increased from 1,330,000 in 1997 to 1,806,000 in 2005. In 2003 a motorcyclist was 19 times more likely to be in an accident than other vehicles but by 2005 this had raised to 26.9 times.

The death toll concerning motorcycle accidents remains quite constant (comprised between 3.00 and 3.50) whereas the death index for other vehicles is shown to be constantly decreasing since 1995. Accidents involving motorcycles have been annually increasing for the past years, and severity remains constant. Other vehicles show a considerable decrease in number of accidents and their severity, the death index falling from more than 4.5% in 1995 to less than 3.5% in 2005.

There are three different areas that are used to classify motorcycle accidents and each poses their own risks: urban, rural and other. 67% of the victims are involved in accidents occurring in urban areas and represent 18% of the motorcyclist fatalities whereas the accidents occurring in rural areas (only 31% of the victims) are responsible for 78% of the motorcyclist fatalities.

In urban areas in terms of number of victims, the most common accidents are the collision with vehicle (79% of the victims). Considering the fatalities only, the more aggressive accidents for the motorcyclists are the impact against a tree or a post (1 death in 5.6 victims). Considering the severe injury risk criterion, the crash into a wall or a building shows a significant aggressiveness (7 out of 10 collisions with severe injuries).

In rural areas, the impact into a tree or a post is the most aggressive type of accident (1 out of 5 being killed). The second and third accident types according to this classification are the "other impact" and the "impact into a safety barrier", with respectively 1 of every 7.2 and 1 of every 8.7 motorcyclists killed. The average Fatal Risk of accident occurring in rural area was about 7.2 (10 times more than the urban area's FR).

Considering Severe Injury Risk criteria, the safety barrier has the highest ratio of 69.2% (7 out of 10 severely injured). In other terms, if both deceased and severely injured people are considered, the road side barrier is more aggressive to the motorcyclist than the object it is meant to be protecting them from. The rural area has been shown to be the main area of interest when considering the safety barrier impact configuration.

Guardrails are 4 times more aggressive for motorcyclists than for car occupants, considering only the death numbers (11.5% compared to 2.9%), and 5.7 times more considering both deceased and severely injured (69.2% compared to 12.2%). Therefore guardrails should be the systems receiving more attention in terms of motorcyclist protection.

Aware of this problem and of the fact that these guardrails work well for other vehicles, the governments and barrier manufacturers are now developing adaptive systems that are usually mounted onto the original barriers, to improve the protection for motorcyclists but also other vulnerable road users. However, it is quite clear through this study that the efforts given to this field are not enough. Before studying the systems themselves and proposing potential improvements, it is absolutely necessary to carry out an in depth study of the guardrail accident cases and determine the important parameters to consider when designing such devices.

2.1.2 MOTORCYCLIST VS. GUARDRAIL IMPACTS: IN DEPTH STUDY CHARACTERISING PARAMETERS

The major aspect concerns the state of the motorcyclist at the impact time; the restraint system might obviously be different if designed to restrain a driven motorcycle or to restrain a motorcyclist sliding on the road.

An evidently important parameter is the impact speed of the driver into the guardrail. The dynamic of impacts shows the importance of this criterion for the design of the protective device. Also, the trajectory of the driver impacting the barrier will be important in the accident. The trajectory can be represented by the angle with which the driver will impact the guardrail.

According to the data, the most common accidents occur with an impact angle of less than 25º (50% of the accidents), then the ranges of 25º to 35º and 35º to 45º both represent 1 case for every 5 crashes into guardrail.

2.1.3 REVIEW OF REGULATIONS

The assessment of the systems is based on several tests consisting in impacting a dummy (Hybrid III with some modifications) leaning on its back against the system to be assessed at a speed of 60 or 70 kph and with an impact angle of 30º. There are 3 types of test that are carried out: post centred impact, post off centred impact and mid span centred impact.

The assessment of the system is based on the bio mechanic measurements of the HIC 36 and of the neck forces and moments. Limit values are defined and measured signals have to be contained into template curves defined by the norm. The legislation finally assesses the system as being of level I (very good protection of the motorcyclist) or level II (homologated but protection could be better).

2.1.4 CONSIDERATIONS OF THE UNE 135900

Strengths:

- Full scale test- The procedure defines a full scale test with an entire dummy (instead of body part impacts) which allows a complete analysis of the dummy's behaviour at the impact time but also its trajectory after the impact.
- Impact velocity- By considering the cases involving severely injured victims, a velocity of 60 or 70 kph would probably be higher than the average of real cases, tending to give empiric situations, consequently leading to development of good protecting systems.
- Trajectories- Testing the systems under several trajectories allows assessing the system under different impact locations, which is good for the structure analysis of the whole system.

Weaknesses:

- Impact angle- Systems homologated through a 30º impact angle are probably not as efficient when being impacted with another angle, especially higher angles. The procedure as such is consequently only covering a fraction of the real accident situations.
- Propelling system- The dummy is released two meters from the barrier. This is a considerable distance and might lead to considerable variations (position, angle, velocity) from one test to another, compromising the repeatability of the legislation.
- Ambient conditions- Conditions are not defined by this regulation. Depending on the conditions under which the tests are carried out, the results might change and therefore the assessment of the system also.
- Bio fidelity of the dummy- The measuring points in the dummy concern the accelerations experienced by the head and the forces and moments in the upper neck. It has been shown in the in-depth study that injuries in the abdomen and in the rest of the body are as frequent as head and neck. Potential improvements or adaptations of the dummy could investigate this area as well.

2.1.5 TEST VALIDATION

Impact Angle- It has been shown that the system fulfils the requirements for the norm but it is not necessarily protecting a motorcyclist impacting with an angle of 45º, at the same speed. In addition to that, it has been pointed out that the testing procedure defined by the UNE 135900 is representing the specific case in which the motorcyclist impacts both its head and shoulder at the same time.

Ambient Conditions- According to this test, it is actually difficult to explain accurately the exact cause of that temperature influence but the two major issues are the following:

- Head structure and materials properties changes with temperature
- Sensor stability

More testing needs to be carried out to verify the results.

2.1.6 CONCLUSIONS

- Motorcyclists do not receive the same level of protection from road side barriers as other vehicle users
- Areas of the protocol to be improved: Impact angle, propelling system, ambient conditions and bio fidelity of the dummy.
- An outside test track was developed for use with the regulation
- A simulation model was developed but needs to be verified with real tests
- The improvement of this regulation will benefit industrial design
- There needs to be a larger variety of data collected on motorcycle accidents.

2.2 D2.1B REPORT ON REVISION OF REGULATION EQUS9910208C

2.2.1 PROTOCOL

The protocol (EQUS9910208C) has many similarities with the Spanish regulation UNE 135900 but there are some variations. There is a slight difference in the positioning of the dummy. In addition this protocol only tests the safety of the motorcyclist in the middle of the barrier.

There are 2 test configurations. The first compares to an impact with a trajectory of an angle at 30º where the head and shoulders also impact at this angle. The second also has a trajectory of 30º but this time the body is placed parallel to the barrier. In both cases the impact velocity is 60km/h with a tolerance of 5%. The dummy used is a special dummy comprised of different parts of various other dummies.

2.2.2 CONSIDERATIONS OF EQUS9910208C

Strengths:

- Full Scale Test- The procedure defined by LIER defines a full scale test with an entire dummy (instead of body part impacts) which allows a complete analysis of the dummy's behaviour at the impact time but also its trajectory after the impact.
- Impact Velocity- By considering the cases involving severely injured victims, a velocity of 60 kph would probably be higher than the average of real cases,

tending to give empiric situations, consequently leading to development of good protecting systems.
- Dummy Positions- Testing the systems with several dummy positions allows for an assessment of two possible injurious situations.

Weaknesses:
- Impact Angle- These systems are probably not as efficient when being impacted with another angle, especially higher angles which may lead to higher stress on head and neck. The procedure as such is consequently only covering a fraction of the real accident situations.
- Bio-fidelity of the dummy- The dummy used is designed for frontal crashes and hence some of the parts are not adapted for these kinds of tests. More work needs to be done in obtaining a dummy with higher bio-fidelity for these tests.

2.2.3 CONCLUSIONS

UNE 135900 differs from the LIER test in the amount of tests and the impact configuration for the dummy.

In both cases, the dummy launching and approaching speed is 60 km/h, as this velocity is found to be a little above average on this type of accidents, providing a worst case scenario result. Validation for the systems comes from the HIC values obtained from the dummy measurements. Also, the dummies have to be launched on their back from a launching device and must slide for at least 2 m before contacting the barrier.

2.3 D2.1C REPORT ON REVISION OF ADDITIONAL STUDIES

2.3.1 OTHER STUDIES

a) Polytechnic University of Milan

The Polytechnic University of Milan carried out a study which consisted of a test performed by computer simulation. In this test, the motorcyclist is leaning on its side and turned to the barrier. The impact angle is 15º.

b) University Putra Malaysia/Qatar University

In a collaboration project between the University Putra Malaysia and Qatar University, a simulation for a motorcycle and rider crash against a barrier was performed by using MADYMO software. It was found that W-beam guardrails are dangerous to motorcyclists as it causes them to slide on top of the barrier and then land on their heads.

c) Monash University, Accident Research Centre

This is a feasibility study performed by the Monash University for the Australian Transport Safety Bureau. Analysis was made as to where would be the optimal area for the rider to be redirected in a collision. Recommendations were made regarding development, cost and time scales.

d) Centre for Rapid and Sustainable Product Development INDEA (Portugal)

The report analysed in this section is a project carried out by a group of researchers in which they design a new protective device for metallic barriers for motorcyclists. In this occasion, they follow the ruling on EN 1317 for barrier homologation purposes and performed crash tests. From the results a new product was designed and optimized using LS-Dyna Software.

e) Organisme impartial de Contrôle de Produits pour la Construction (COPRO)

This document is a technical data sheet from the COPRO organization, where the requirements for the design, production and installation of safety barriers are listed.

f) Government of Portugal

This document is a translation from a Portuguese Regulamentar Decree that makes it mandatory to install motorcyclist protection systems in known “black spots” and other dangerous areas along the national road system.

g) FEMA (Federation of European Motorcyclists Associations)

The Federation of European Motorcyclists Associations created in the year 2000 a research document focusing on the safety measures employed on road and highways regarding motorcycle riders. The report is an extensive document covering very important areas of investigation for this topic. There is analysis of the current state of affairs followed by some recommendations.

h) APROSYS Report, Ludwig Maximilians Universität München (LMU)

This report is part of the Task 4.1.3 from the APROSYS project and the objective is to obtain specific accident scenarios for motorcycle accidents taking into consideration the kinematics of the rider and vehicle and also the injuries sustained by the motorcyclists during impact.

i) DEKRA Automobil GMBH & Monash University

This paper describes relevant real-world accident scenarios, the different roadside protection systems used for the tests, the crash tests performed, the modelling of the systems and the results. It proposes improvements to barrier systems to reduce injury severity.

j) University Putra Malaysia

This paper includes the description of a three-dimensional computer simulation of the kinematics impact of motorcycle and dummy with W-beam guardrails, in 45º and 90 º configurations. This simulation is based on the test procedure recommended by ISO 13232.

k) Ludwig Maximilians University; DEKRA Automobil; CIDAUT; Universidad de Valladolid

The study hereby presented includes a broad analysis of four in-depth accident databases, in order to evaluate the nature of motorcyclist’s impacts with barriers and to gain knowledge in addition to the anecdotal cases reported in literature reviews. Approximately 1000 accidents of powered two wheelers from the four databases were considered for this paper.

I) Università Degli Studi Di Firenze

The thesis hereby presented performs a study on the injuries attained by riders when impacting a roadside barrier, a test procedure proposition, the actual state of the art of motorcycle friendly barriers found in Italy and it also gives and introduction for modelling and simulating these kind of systems.

2.3.2 CONCLUSIONS

The review provided in this document clearly shows that plenty of efforts are being made worldwide to prevent fatalities due to motorcycle accidents. Some of the most important concerns are the accidents involving motorcycle drivers and roadside barriers, which are originally designed to retain heavy vehicles.

The study hereby presented included some of the most important developments carried out in the field of simulation, crash testing, product design and protocol evaluation. We can also find the protocols established and proposed by several universities, whom consider the existing protocols and existing products to make a correlation and use the better characteristics of each system while eliminating the unnecessary or redundant characteristics.

Simulation can be considered one of the most important findings in this paper, as most of the work analyzed focuses on the development and correlation of programs that allow virtual simulation of the systems (with all material characteristics), motorcycle and dummy models (for dynamic analysis and HIC measurements), and replication of real life accidents in order to associate a certain dynamic and mechanical performance to be later evaluated in bias of developing better protective devices.

3. TASK 2.2 MAIN FINDINGS OF THE ANALYSIS OF THE STATE OF THE ART SYSTEMS

3.1 INTRODUCTION

In order to offer better protection in case of a motorcycle accident, it is necessary to install special safety systems that absorb or attenuate the rider and motorcycle energy producing the lowest damage possible.

Today, we can find a series of systems used throughout different countries to provide motorcyclist protection in case of skidding out of the road or direct collision against a guardrail. These systems have two main classifications: punctual protection systems and continuous protection systems. In this stage of the project, we have given two approaches to analyze the available designs: a type of protection or design approach, including the categorized systems and a materials approach, in order to obtain the best information available.

3.2 REVIEW OF STATE OF THE ART MOTORCYCLIST PROTECTION SYSTEMS

3.2.1 TYPE OF SYSTEMS

In the area of road restraint systems, we can observe that the actual systems in use have the principal function of absorbing energy from the vehicle, redirect it to a safe area within the road and avoid the impact with hazardous obstacles behind the restraint system (trees, poles, cliffs and rocks). The system has, then, to comply with certain standards and conform to official testing, confirming that the performance is safe enough for road users.

Nevertheless, these systems are not tested for two wheel vehicles. As for bigger and heavier vehicles, the systems tend to be sturdy and with high endurance, allowing a car or heavy truck to slow down and stay on the main road. For motorcycles, these systems are too exceeded in performance, since two wheel vehicles are smaller, lighter and respond to different dynamics.

Knowing that the injury mechanisms of the road restraint systems as for vulnerable users are the contacts with the posts, sharp edges or the under running of the beam (where a more hazardous object or ravine might be found), some solutions have been proposed. The two major selections are:

- Punctual Energy Absorbers
- Continuous Systems to Redirect the Riders

Punctual Energy Absorbers- Nowadays some models of crash barrier impact attenuators exist. In addition to absorbing rider energy when being compressed they prevent him from impacting the sharp edges of the posts. This positive effect is however reduced with the speed of the impact since the amount of energy which is absorbed is limited by the size of the device (up to speed about 50 to 60 kph). This makes those systems suitable for urban areas or tight bends.

Continuous System to Redirect the Riders- These systems are technically very advanced, as they are projected to adapt the shapes and the materials' properties to absorb as much energy as possible reducing the severity of impacts for motorcyclists. The most used solution consists of a lower flat rail which is added to the conventional W beam barrier. While the main function is, as mentioned above, to redirect the riders on the road, these systems are designed to absorb energy during the impact by flexion of the steel holding the plates. Nowadays, the studies and researches carried out on this field are working on systems that combine the absorption during the impact and the redirection of the riders on the road.

Combination- Some companies have started developing systems that provide the best characteristics of both systems into one single product. One of the systems uses plastic tubes underneath the guardrail while the other is a punctual beam attached to a post with a special damping system.

3.2.2 MATERIALS USED

- Steel roadside barriers.
- Plastic motorcyclist protections.
- Concrete barriers
- Wire rope safety barriers

3.3 COMMENTS AND DISCUSSION

The major brake to a massive installation of safety barriers along the roads remains the same with many systems: the cost effectiveness of the device and its installation on the roads.

Although this economic viability contradicts the VicRoads concept of creating a "safe system" (Victorian Motorcycle Road Safety Strategy), it enforces the authorities to define the "black spot zones" regarding motorcyclist crashes into barriers in order to prioritize the installation of safety devices in these areas. However it turns out that while some black spots can be clearly identified, the major part of motorcyclists-barriers impacts are randomly distributed along the roads.

In response to that economical brake, industries should aim at improving the cost efficiency of these products. Different actions could be led along the life cycle of the devices:

Design: the devices should be easily adaptable to existing barriers in order to reduce the installation time and difficulty. The materials that are used also have to be considered for questions of production rate, manufacturing duration, eventual recycling and reusing.

Manufacturing: optimization of the manufacturing process

Life: Research about materials and maintenance of the systems is required to improve the durability of the systems.

Although the lack of scientific knowledge of the motorcyclist-guardrail's impacts is partly responsible for the difficulties to improve the devices, it has been noted that a lot of studies and research has been focusing on developing MFDs, which lead to good motorcyclist protection.

An in-depth analysis on the performance and the establishment of a more strict protocol are needed. Nowadays, the performance criteria is established by the HIC 36 and pretty much all the systems mentioned have complied, having amongst them some important variations, even for the same system in two configurations. From the obtained data, we can note that punctual systems have higher HIC than continuous systems, and higher angles induce higher HIC results.

A comparison of the performance provided by each system could be a helpful tool to find the strengths and weaknesses of the different proposals, aiding in the cataloguing and establishment of a unified criteria to assess the motorcyclist friendly systems. This comparison will then become a reference for the interested parties in selecting the most adequate system according to the specific needs of the road (closed or ample curves, black spots).

3.4 STATE OF THE ART OF THE PRIMARY AND TERTIARY SAFETY SYSTEMS FOR THE SMART RRS PROJECT

3.4.1 REQUIREMENTS

- Provide timely and useful information to road users to assist in preventing accidents (primary system).
- Provide timely and useful information to the emergency service, road authorities and other road users in the event of an accident (tertiary system).
- Be integrated with the road restraint system
- Cost effective
- Minimize additional demands on the infrastructure
- To not provide additional safety risks to those colliding with the restraint systems
- Robust against the environment
- Robust against system degradation
- Robust against false triggering
- Each sensing node should know it's own location
- Should be modular
- Capable of being integrated with other roadside infrastructure and traffic management systems

Primary Sensed Parameters:

- Traffic related parameters: including volume estimates, vehicle speed and acceleration/deceleration estimates, vehicle separation and position or proximity to crash barrier. Heavy braking might also act as an indicator of potential risk for upstream traffic.
- Road conditions – perhaps of greatest concern under this category would be issues of road surface state and visibility.
- Obstacle related parameters – static obstacles in the carriageway (or indeed hard-shoulder) perhaps representing the most difficult parameters to sense.

Tertiary Sensed Parameters

- Essentially this will be to identify, locate and begin to classify barrier crash events. The sensing suite may be able to identify other features of the crash event such as fire or fuel vapour spillage.

3.4.2 INFRASTRUCTURE BASED SENSING SYSTEMS

- Inductive Loops
- Infrastructure Based Imaging Systems
- Infrastructure Based Radar
- Other Systems

- Energy Absorption Systems
- Road Ice Detection Systems
- Weather Systems
- Acoustic Sensing Systems
- Laser Scanners
- Air Quality Monitoring Systems

3.4.3 VEHICLE BASED SENSING SYSTEMS

- Vehicle Based Imaging Systems
- Vehicle Based Radar
- Cabin Air Quality and Other Vehicle Comfort Sensing Systems
- Vehicle Crash Sensors
- Tyre Pressure Monitoring Systems

3.4.4 COMMUNICATIONS SYSTEMS

- Wireless Personal Area Networks
- Wireless LAN
- Mobile Telephone Networks
- Vehicle to Infrastructure (V2I) Communications Standards
- Connection to Existing ITS Infrastructure

3.5 CONCLUSION

The review on the state of the art of motorcyclist protection systems shows some clear evidence that the governments and private companies are starting to look for a solution to the serious injury problem. The conflict relies on the selection and adaptation of motorcycle friendly security systems, which are not harmonized on a European level and are manufactured by indistinct companies with different performances.

Some countries have already established their own regulations for testing motorcyclist protection systems (France, Spain, Portugal) while others are relying on these criteria to adopt the system. As of now, we can clearly select two basic protection systems that need to be improved and designed according to unified regulations. These types of systems are the punctual and the continuous protection devices.

As for punctual systems, the norms establish a maximum allowed volume and geometry, limiting their effectiveness to a lower range of speeds (max. 60 km/h) which in turn converts into very selective installation points. An added problem is that the black spots for motorcycle accidents are unclear, as they are wide spread through the road network.

In the case of continuous protection systems, their main focus relies on avoiding the rider to go underneath the guardrail and impact the posts or other hazardous obstacles that produce severe injuries. These systems can also include some energy absorbing characteristics, yet, the materials are different. Also, the mechanics of the protection device are different, as in a punctual system the impact tends to be more direct (higher angle) while the continuous system mitigates shallower impact angles.

The trend to follow is to design a polyvalent system that can provide protection in all senses to the rider, by attenuating the impact energy and redirecting him to a safe area.

Many of the actual technologies are applicable to the road restraint systems, but some issues need to be solved. The inclusion or preparation of in-vehicle systems are an option, yet the power requirements and weather resistant features need to be addressed. Actual road analysis systems can be an ideal pre set platform if used correctly and the benefits are exploited correctly. In fact, the use of pre existing road systems could save in installation and operating costs, whilst providing new safety conditions for general road users.

Having the ability to inform the drivers of all kind of vehicles about hazards on the road, accidents that have occurred, weather changes, traffic conditions and new proposed routes are the tasks for the primary safety roadside systems. Informing emergency services, incoming traffic, and providing valuable information on where the accident happened, what kind of accident, number of vehicles involved, etc… will be the task for the tertiary safety systems. Embedding both systems into one is the challenge, and the actual technology provides the elements necessary to develop such system.

4. TASK 2.3 MAIN FINDINGS OF THE DEFINITION OF NECESSITIES AND REQUIREMENTS FOR FUTURE ROADSIDE MOTORIST PROTECTION SYSTEMS

4.1 STUDY ON THE AVAILABLE TESTING PROCEDURES

4.1.1 EVALUATION OF THE NORM UNE135900

Strengths:
- Visually realistic
- The dummy is redirected so that it does not go through or underneath the system
- 2 velocities (60kmh & 70kmh)

Weaknesses:
- Environmental conditions not specified
- Unable to control the dummy in the final stages of the collision
- Only one impact angle (30º)
- Contact of the back of the dummy with the protection system may influence readings
- Difficult to control repetitiveness

4.1.2 EVALUATION OF A FULL SCALE DUMMY TEST SIMULATION UNDER THE NORM UNE 135900

Strengths:

- Gives a qualitative idea for the system's response to impact
- Flexibility in the test configuration
- Quick Configuration changes
- Contour conditions are controllable and variable
- Economical

Weaknesses:

- It does not provide quantitative values, so, it does not show a clear idea of the correspondence between theoretical and real data.
- Connections between elements as welding lines or other supports represent an uncertainty over the quality of the model according to real cases.

4.1.3 EVALUATION ON THE SIMULATION OF SUBSYSTEMS (HEAD AND LEG IMPACTS AGAINST THE PROTECTION SYSTEM AT DIFFERENT ANGLES AND VELOCITIES)

Thanks to studies performed about the type of accidents and parts of the body that are more affected in motorcyclist accidents, a conclusion on which part of the body should be used in evaluating the impact absorbers was taken. The head was selected as the study element. It should be considered that the head is the most sensitive part of the body and guaranteeing that the performance of the absorbers is improved in case of head impact, any part of the body that impacts the system will be protected too.

The objective is to simulate the subsystem tests according to maximum representativity and repetitiveness criteria, and at the same time simplifying impact absorber evaluation.

Strengths:

- It gives a qualitative idea on the response of the system to impact
- Flexibility in the test configuration
- Quick configuration changes.
- Contour conditions are controllable and variable.
- Economical.
- Repetitiveness.

Weaknesses:

- It does not provide quantitative values of the results, so it does not show a clear correspondence between theoretical data and real data.
- Necessity to perform the real tests to correlate theoretical data.

4.1.4 EVALUATION OF SUBSYSTEM TESTS

To perform subsystem tests, the DITS machine must be used. The machine consists of a pneumatic actuating pump that accumulates oil until a preset pressure to obtain the desired speed. It allows testing with high accuracy, precision and repeatability.

Two possible configurations exist to evaluate the head impact with the DITS machine:

- Free flight test. This test consists of throwing the impactor used in pedestrian protection tests with the adult head form against the selected profile using free flight.
- Guided test: This test consists on taking as impactor the head of a Hybrid III dummy, the same used in norm UNE 135900, and then throw it against the metallic profile with a guided system.

Strengths:

- It gives a real quantitative idea of the energy absorbed by the protection system.
- Flexibility in the test configuration.
- Quick configuration changes.
- Contour conditions are controllable and variable.
- More economical with respect to full dummy test.
- Repeatability.
- A helmet can be put to the dummy’s head.

Weaknesses:

- Being a punctual test, only one part of the dummy is evaluated, disregarding the influence that the rest of the body may have on the head.
- The impacts after the first contact are despised, that in the case of a full dummy test, any other part of the body may impact the protection system and in which, because of the first impact, the protection system would not be efficient with the risk it supposes to the mentioned limbs.

4.1.5 PROPOSED TESTING PROTOCOL

The proposed testing protocol to evaluate motorcyclist safety barriers will be a complete program, including subsystem testing, UNE 135900 full scale testing, new protocol full scale testing, numerical calculus and simulation. Each of these tools aim at different targets that brought together will guarantee the protection of a motorcycle rider in case of accident.

4.1.6 SPECIFICATIONS TO BE COVERED BY THE PROTOCOL

- Simulations of individual subsystems and full scale dummy must be carried out
- Subsystem tests must be carried out, consisting on the impact of a dummy head into the protection system. Three different impact configurations are to be used: 30º, 45º and 60º
- The full scale dummy tests shall be made with two different configurations:

- o Norm UNE 135900 configuration: Full dummy, 60 or 70 km/h velocity, impact angle 30º (parallel to the dummy's longitudinal plane) and used for homologation.
- o New Certification configuration: Full dummy, 60 or 70 km/h velocity, impact trajectory angle 45º with a 15º deviation on the dummy's longitudinal axis, adding for total impact energy but maintaining the dummy impact configuration.

4.1.7 SUBSYSTEM TEST

a) Test Configuration

Impactor:

- Hybrid III 50th percentile dummy head with a total mass of 12.6 kg

Impactor Instrumentation:

- 3 uniaxial accelerometers or 1 triaxial accelerometer
- 1 6-axle load cell in the neck

Protection System:

- A section with a post (with or without support, according to design)
- A section with a support
- A mid-beam section

Helmet: Commercially available integral helmet, with a 1,300 kg ± 0,050 kg mass and with a polycarbonate carcass. Another helmet may be used as long as it is demonstrated that it has the equivalent mass, geometrical characteristics and materials and that it complies with ruling 22 from E/ECE/TRANS/505.

b) Biomechanical Parameters

The measured biomechanical parameter will be the HIC_{15}: head injury criteria, based on accelerations.

AIS scale goes from AIS 1 to AIS 6, and as AIS number increases so does the severity of the injury. An AIS 4 is equivalent to a skull fracture with severe neurological injuries.

c) Subsystem Test Evaluation

The test will be carried out for three different angles on each of the three locations in the protection system. The evaluation will be designed during WP6, subtask 6.1 Definition of a new evaluation protocol for motorist protection systems.

The total HIC value for each of the three mentioned positions will be obtained from the subsystem simulations and the real tests, providing a coherent approach. The chart, when completed, will use a similar system to the one used in EuroNCAP, (by colour grading), and a final number will add up. If this value is over the specified approving value, then the system must be re developed. Once the tests are satisfactory and a UNE 135900 obtained, the New Certification will be extended.

It is important to mention that at this stage of the development, the evaluation system or procedure is still a proposal and could be modified, according to the necessities and to the reliability of the proposed system.

4.1.8 FULL SCALE DUMMY TEST UNDER UNE 135900 AND OUT OF NORM

a) Test configuration under norm UNE 135900 (launching position and trajectory)

- Hybrid III Dummy with modified back and pelvis (as defined in UNE 135900).
- homologated
- leather suit
- launched lying on its back

- Velocity of impact: 60 or 70 km/h
- 30º angle of trajectory.
- 30º angle of dummy axis
- Three possible impact trajectories:
  - Post centred
  - Post Off centred
  - Mid beam

If the test results show a value over the established limits in any of the categories evaluated then the test is not approved.

b) Test configuration Out of Norm (launching position and trajectory)

- Equipment as under the norm
- vertebral axis of the dummy forms a 15º angle with the launching trajectory
- approaching trajectory is aligned with the centre of gravity of the post
- more aggressive angle

c) Test Procedure

The full scale impact test consists of the launch of a dummy against a roadside barrier stretch equipped with motorist protection system at a velocity of 60 or 70 km/h, in an adequate area for this means. The dummy, at the instant of impact, will be sliding with most part of the body on the ground in a stable manner.

d) Propulsion System

The propulsion system must ensure that the dummy is free of any connection to it, at no less than 2 m from the theoretical impact point.

e) Advantages of the protocol against norm UNE135900

- guarantees an excellent repeatability because it is a guided test
- Testing different angles would dismiss this type of system and would improve the representativity of the regulation
- the development of subsystem tests has a marked inferior cost than the full dummy test

- Using a combination of full size testing, subsystem test and simulation, all aspects of the evaluation are covered, by obtaining quantitative and qualitative data that correlate directly and can be analysed altogether to obtain a general system evaluation. It guarantees a higher security and protection level for the motorcyclists when an accident occurs.

4.2 CONCLUSIONS

A proposal of a new evaluation system and a set or requirements was written.

The main point in the development of this chapter was to analyse what are the weaknesses and strengths of the actual legislative procedures and to include or propose improvements, in order to have a more accurate system validation and development.

Accidents tend to happen in several angles and several speeds. Up to date, the only difference considered in the UNE normative is the speed. We believe that this can further be improved if also a second angle of trajectory was included.

Our proposal, includes a new flowchart for activities, which in turn make a standard UNE 135900 test as a minimum requirement, and later on, begins with the development of subsystem test simulations where the amount of energy absorbed by the system will be measured. Once this simulation has been approved, then real tests will take place. If the barrier behaves as expected and approves, then the next stage is the full system simulation.

In the full system simulation, the analysed parameters are the degree of redirection provided to the rider and the biomechanical indexes obtained. Also, this simulation will include the new certification protocol that increases the angle of trajectory but maintains the same angle of impact of the dummy.

With the same procedure as in subsystems, the simulation needs to be approved prior to conducting real tests. Once all of this has been approved, a new certification can be obtained with the combined results of the UNE 135900 (considered as the minimum requirement) and the new test, increasing the degree of safety provided by the motorcyclist protection system.