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FP6-2005 TRANSPORT 4

SIM
SAFETY IN MOTION

Final Yearly Activity Report

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Table of Contents

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1. Project execution

Safety in Motion (SIM) Project has been co-funded by the European Commission DG RTD under 6th Framework programme and is aimed at carrying out R&D activities addressing in-depth studies of a suitable and comprehensive safety strategy for powered-two-wheel (PTW) vehicles, proven to be able to reduce road accidents and/or mitigate their consequences. Main objectives of SIM are:

- to identify a suitable integrated safety strategy for PTWs;
- to enhance preventive and active safety based on electronic vehicle sub-systems management and improving Human-Machine-Interaction (HMI);
- to focus on integral passive safety devices;

The project lasted 39 months with the involvement of 12 partners among 6 European Regions. The Consortium is well-balanced in terms of industrial partners (OEM and suppliers), universities and Research Centres with a strong expertise in vehicle safety field.

The partners involved in the SIM Project are:

- Piaggio & C. SpA
- Fundación para la Investigación y Desarrollo en Automoción (CIDAUT)
- Continental Teves AG&Co. oHG
- Centro Ricerche Fiat ScpA
- Technical University of Prague
- DALPHIMETAL ESPAÑA S.A.
- DEKRA e.V.
- NZI Technical Protection S.L.
- OHLINS RACING AB
- Savatech d.o.o., Industrial Rubber Products and Tyres
- University of Pisa

SIM is structured in six workpackages, of which one was dedicated the management of the project with the aim to ensure that the proposed objectives were achieved within the proposed resources (time, cost, human effort) and the technical outcomes were delivered with high quality.

According to the AnnexI, 45 reports have been produced as well as 6 prototypes (vehicles and components).

During the 3 years of project, the Consortium participated to many dissemination activities. A public website was created (www.sim-eu.org) and periodic Newsletters were published. Additionally the project took part to international conferences (e.g. TRA conference 2006, 2008 and in the next future TRA 2010, ESV Conference 2007 and 2009, Small Engine Technology Conference 2008, ITS Motorcycle Symposium 2009). 4 papers have been presented in Scientific Conferences and the partial results have been shown in 5 public events, from Transport Research Arena in (Gothenburg, 2006) to Intelligent Transport Systems (Stockholm, 2009). Two workshops were organised: the first one in collaboration with PISa Project (29th of May 2008 in

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Bologna, Italy) and the second one, the SIM Project Final Workshop, held in Piaggio Museum (26th of November 2009, Pontedera, Italy) with presentation of the results of the project.

Powered Two Wheelers vehicles are an effective solution for mobility in urban context (less the travel time, less the payload ratio, less the fuel consumption respect to cars), since they contribute at solving two out of the three global challenges that every road users have to face daily: traffic jam and emissions. On the other side PTW riders are considered vulnerable road users (VRUs) since in case an accident occurs the consequences for the rider are often more severe compared to car occupants. The huge accidents rate of PTWs and the severity of related consequences for the rider (injuries and fatalities) represent an high costs in terms of human lives and a relevant costs for the society.

SIM project is aimed at answering to the critical issue of road safety for powered-two-wheelers riders.

The vehicle platform selected for SIM project is the tilting three wheelers Piaggio MP3 that has a dynamic and riding behaviour similar to the conventional motorcycles: MP3 suspension system with two front wheels allows a totally free tilting motion. MP3 provides an enhanced level of safety and handling compared with a conventional scooter because of the layout of the innovative front suspension that improves the stability at high speed and reduces the braking distance and then because the vehicle is not sensitive to road surface changes and obstacles (e.g. bumps and holes) and provides a great directional feeling to the rider. MP3 also fits from the passive safety point of view, thanks to the unconventional front suspension elements that acts as an effective energy absorption structure in the case of frontal impact, enhancing the benefits from passive safety devices.

The background of the project is the findings of MAIDS project, promoted by ACEM (the association of the European PTW manufacturers) and carried out by the Motorcycle Industry with basically two objectives: to identify the main factors that contribute to PTW accidents causation and to propose effective solutions in order to reduce the number of accidents and mitigate the consequences for the rider.

On the basis of MAIDS results and the R&D guidelines, a matrix approach to PTW safety was adopted according to the Safety Matrix (Figure 1). An integrated approach to the complex concept of motorcycle safety shall establish in fact a matrix relationship between the three main factors or pillars for safety (PTW, rider and infrastructure) and the different aspects related to accident dynamics, from before-precipitating event to crash event (dealing with preventive, active and passive safety) and post-crash motions.

SIM	ACTIVE	PREVENT.	PASSIVE	POST-CRASH
MOTORBIKE	Suspensions, Brakes, ABS, ESP…	HMI, conspicuity, ...	Limbs protection, kinematics, algorithm, ...	e-Call
MOTORCYCLIST HELMETS/ CLOTHING	Training and Education	HMI, comfort, strap fasten, info exchange, conspicuity ...	Helmets & Clothing performance ...	
INFRASTRUCTURE	Maintenance, audits, ...	e-Safety	Performance when a motorcyclist impacts	Maintenance, reparation, ...

Figure 1 – PTW Safety Matrix

SIM project activities covered some items of the matrix, focusing on vehicle aspects in all safety areas and on HMI improvement and on protective devices for the rider.

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The project objectives are the identification of a safety strategy and the development of the most relevant technologies in active, passive and preventive safety areas to be implemented in a vehicle prototype.

The project started with an analysis phase, based on accidentology and effectiveness evaluation, followed by the system development in Active, Preventive and Passive Safety areas, then the application phase and the testing.

As a first step a Safety Strategy was defined starting from an accident analysis and on the other hand pre-selecting the technology that was fundamental to get to innovative but very concrete solutions.

In the previous APROSYS project, 7 main accident scenarios have been selected for further investigation. These 7 scenarios have been identified as being the most common and severe and were the basic input for the accident analyses in SIM project.

In-depth accident databases such as MAIDS, GIDAS 2002 and 2003 and the DEKRA PTW database have been explored.

Additionally a detailed analysis of different accident scenarios with PTWs (Powered Two Wheelers) has been performed, using the DEKRA PTW-database. From this database containing 350 real-world accidents, 51 cases have been selected by imposing a reaction demand and a following braking of the motorcycle rider in order to evaluate the benefit of an advanced braking system. It was demonstrated that the majority of the accidents could have been avoided or highly mitigated with the help of the brake system.

A preliminary selection of the most promising technical solutions has been done through literature review and the state-of-the-art, and based on the partners' expertise. Pre-selection criteria were: technical feasibility, market availability (looking also at the automotive sector), potential transfer in PTW domain.

The effectiveness evaluation identified the potential benefits of the candidate technologies.

The outcome was a proposal of safety systems requirements and their technical specifications.

At the end of the analysis phase, the following safety systems requirements were selected to be developed, implemented and tested:

- Active brake system and stability management by traction control and a semi-active suspension system
- Airbag and inflatable wearable device.
- The overall requirements of an HMI management concept for PTW and an enhanced HMI by means of HUD, wireless communication and ergonomic handlebar controls.

Virtual simulation tools for designing and analysing the performances of the safety systems have been widely used and different models were developed for different applications.

Concerning active safety, the models required proper characterization of the main vehicle subsystems, such as tyres and suspensions; a detailed aerodynamic analysis was also carried out in order to obtain the aerodynamic loads in different driving conditions. A virtual driver, able to perform some typical manoeuvre has been developed. The models were validated by comparison with experimental data and used to analyse the effect of the integration of active safety systems.

Crashworthiness of the vehicle has been developed for the study of structural crashworthiness in order to find the layout of the crash sensors and ECU, to have an estimation of acceleration to define firing strategy by performing several tests at different speeds and configurations. Some of them have been tested in real crashes. Also a study of the rider protection and a virtual analysis of safety functions was accomplished.

The Safety Strategy was then implemented in terms of the following achieved technical results.

Active Safety Systems

Two active systems (advanced brake system and electronic suspension system) have been developed and integrated in the final prototype.

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The two systems are not standalone but they continuously exchange data through a dedicated CAN bus architecture so the suspension system cooperates with the brake system adapting its behaviour according to specific target functions.

The enhanced Antilock Brake System developed consist of ABS (Antilock Brake System), FIB (Full Integral Brake), ABD (Active Brakeforce Distribution), RLP (Rear wheel Lift-off Protection) and BTCS (Brake Traction Control System) functionalities.

The main focus of the ABS development was to study the advantage of two front wheels and to find a strategy for improving the driving stability during full braking. The FIB functionality enables the driver to perform full braking with all wheels by applying just one brake lever. The TCS function is activated when the driven wheel tends to spinning due to a surplus in driving torque especially on low-friction road surfaces.

Within the purposes of the project the conventional mechanical suspension of the Piaggio MP3 motorcycle has been replaced with a state of the art electronically controlled suspension system mainly resulting in improved motorcycle handling. The system has three Setting (comfort, dynamic, automatic). Comfort and dynamic mode can be selected by the PTW rider. In Automatic mode the suspension is real-time adapted switching from Comfort to Dynamic mode and back, depending from rider demand (i.e. brake action, acceleration, cornering manoeuvre…)

Preventive Safety System

The preventive safety system implemented in the SIM prototype consist of the information management concept (IMB) for motorbikes and the enhanced HMI devices with the aim of inform the rider about the status of the vehicle and alert him in case of critical conditions.

A good management flow was guaranteed with the integration of active and preventive safety devices: at the same time, the rider can be supported by the enhanced brake and suspension devices, and by the IMB and HMI system helping him/her to be more concentrated on the riding task.

All this information generally displayed only in the central dashboard is redistributed through an enhanced HMI set-up by:

- an additional IMB display
- dedicated HMI handlebar controls
- an head-up display (HUD) mounted in the helmet
- a microphone and headsets mounted in the helmet

The SIM MP3 prototype HW architecture has been modified in order to realize an open, flexible and faster connection among the on-board electronic control units (ECUs).In particular, two CAN bus networks have been developed.

Passive Safety Systems

A cooperative architecture made of frontal airbag and an inflatable wearable device has been implemented as well as an airbag control unit with a specific algorithm for firing the devices.

The main objective of an airbag is to absorb the kinetic energy of the rider during the accident. It should avoid the injuries produced by the impact between the motorbike and the obstacle (the car, in this case)

The development of this device has been carried out in two steps:

- Design and test the components of the module
- Adapt this device to the environment

In the final prototype the airbag was located in place of the standard vehicle dashboard in order to avoid any interference during its deployment.

The purpose of the inflatable device worn by the rider is to cooperate with the airbag in reducing injuries in primary impact and to provide protection in secondary impact (i.e. when the rider is separated by the vehicle).

The airbag control system used in the SIM project is based on an airbag control system developed for a car with a specific adaptation in terms of definition of safety strategy, triggering algorithm, Time to Fire and

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sensor arrangement. This new architecture has proven to fulfil the requirements in crash lab tests and it has a great potential to fulfil all crash scenarios in the field.

The development process followed a new methodological approach that started from crashworthiness studies to get to the test of the whole chain in full crashes.

All the safety features have been implemented in the SIM vehicle platform, based on the tilting three wheelers Piaggio MP3 that has been selected because it is one of the most promising PTW concepts in terms of safety.

Final tests conducted on the integrated active safety system demonstrated a strong enhancement of the active safety level by means of:

Increase of vehicle manoeuvrability without drawbacks on rough surfaces with automatic damping adjustment

- Reduction of stopping distances by recognizing 'bad road' conditions.
- Wheel spin avoidance while accelerating or braking in curve thanks to the dynamic adaptation of ABS and TCS systems.
- Low sensitivity of performances respect to rider experience (automatic brake distribution with ABS control).
- Comfort improvement

In the last phase of SIM project airbag jacket and frontal airbag have been jointly tested in full scale crash tests in 413 and 114 configuration with PTW impacting at 48 km/h and a passenger car in static position (moving-stationary) or moving at 24 km/h.

From these tests results, the effectiveness of the passive safety systems has been evaluated by measuring biomechanical values obtained on the instrumented dummy, comparing them with data from reference crashes, (i.e. without any passive safety device) performed within APROSYS Project. The effectiveness of the integrated safety systems is demonstrated by the significant reduction obtained for the most relevant injury criteria such as the head acceleration resultant.

Within a comprehensive safety approach to the problem, SIM contributed to some aspects.

A number of advanced safety features has been chosen according to the identified safety strategy and based on their effectiveness evaluation in real accident scenarios, as well as taking into account their technical feasibility.

The final result is a concrete concept design (vehicle+helmet+clothing) that that integrates all the features (Figure 2).

Figure 2 – SIM Prototype

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2. Dissemination and use

SIM Project has been co-funded by the European Commission DG RTD under 6th Framework programme and is aimed at identifying a suitable and integrated safety strategy for Powered-Two-Wheelers (PTW) vehicles, in order to avoid road accidents or mitigate their consequences.

A suitable PTW safety strategy has been identified for all safety areas on the basis of the results of previous PTW accident studies and by an in-depth analysis on the most critical accident scenarios.

The final result of the project is an integrated PTW safety concept vehicle equipped with the most promising active, passive and preventive safety systems applicable to PTWs: a stability management system, an automatic variable damping suspension system, an airbag fitted on the vehicle, a wearable inflatable device and a HMI information management concept for motorbike.

Laboratory and Road tests have been conducted for evaluating the enhancement of active safety level in terms of handling and stability control, while the passive safety systems have been tested in full crashes to assess the injuries reduction.

PTW is still one of the most popular solutions to traffic problems, in terms of individual mobility, but there are two important aspects to be considered. Concerning the respect of the environment, PTW are a good way to reduce traffic emissions because of their limited fuel consumption and because of their capability in reducing the travelling time, being quite insensitive to traffic jams. However PTW world is continuously travelling towards new regulations, new engines and alternative energies, spending a lot of effort in improving technology. The third problem is obviously the rider safety. During last decades the development of automotive safety devices has been really impressive and the gap between PTWs and cars has increased. Motorcar's safety levels, mainly for the passive field, are a target to aim for PTWs manufacturers. The dynamic behaviour of PTWs and their riders during motion and even during crashes are so far different from motorcars and their passengers; hence the results of one field can hardly be used successfully for the other. PTWs need specific and challenging research to fill the gap.

The target drawn for SIM project has been an integrated concept design for active passive and preventive safety based on the revolutionary MP3 to reach new levels of PTW safety.
The following table gives an overview of the safety devices developed in SIM Project:

Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
New ABS braking system for PTW vehicles.	Motorcycles manufacturers	SOP End 2011	Not known at the moment	PIAGGIO, CONTI
Electronically controlled suspension system.	Motorcycles manufacturers	5-8 years	Previous patent on the CES valve EP0942195 US6311812 SE523534	PIAGGIO, OHLINS
Innovative Human Machine Interface (HMI)	Helmets and motorcycles manufacturers	2011	Possible patent	CRF, NZI, PIAGGIO

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Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
Integrated inflatable devices for rider protection	Motorcycles manufacturers	-	Possible patents	DALPHIMETAL, CIDAUT, PIAGGIO

Figure 3 - Overview Table of SIM Results

New ABS braking system for PTW vehicles

The exploitable result consists in:

- Full Integral Brake System for MP3 with 3 active hydraulic circuits and different functions: ABS (Antilock Brake System), ABD (Active Brakeforce Distribution), FIB and PIB (Full and Partial Integral Brake Function), RLP (Rearwheel Lift Off), TCS (Traction Control System), BTCS (Brake Traction Control System)
- 2 channel ABS for 3 wheeler with the function ABS and RLP
- Active Body Control based on active Brake and Suspension System

The partners involved in the exploitation are Continental for the development of the Active Brake System and definition of the control strategies, Öhlins for the development of the Semiactive Suspension System and support to definition of the control strategies and Piaggio for the implementation on the vehicle.

The result can be exploited in the following way:

- Exploitation of an Hydraulic Control Unit with 3 active hydraulic channels:
  - technical threshold is the detailed definition of the system.
  - commercial threshold are the low production volumes of such a vehicle
  - the acceptance by the end customer is open. Especially the fact that the active system always influences the original handlever feeling needs to be discussed with the marketing of the motorcycle manufacturer and the end customers.
- Exploitation of an Hydraulic Control Unit with 2 ABS channels:
  - technical threshold is the detailed definition of the system. Especially the functionality of the overlay valve needs to be discussed with the end customer and the marketing of the motorcycle manufacturers.
  - commercial threshold are the low production volumes of such a vehicle
- Exploitation of an Hydraulic Control Unit with 3 active hydraulic channels and a semiactive suspension system:
  - technical threshold is the detailed definition of the system
  - commercial threshold are the low production volumes of such a vehicle

A very interesting result in terms of benefit evaluation for active safety system was gained within SIM project, confirming the potentiality of ABS system, which could have avoided collision in 50% of the analyzed DEKRA accident cases where a braking action was attempted.

For all the systems an additional development work between 2-3 years is necessary to bring the systems into the market, for the 2 channel ABS for 3 wheeler with the function ABS and RLP 1,5 years might be sufficient. A base development with an application development with several development steps needs to be defined to go on the market with such a system

Concerning IPR, there are no intellectual property rights known actually to avoid bringing the systems into the market.

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Concerning commercial contacts, an offer for the 2 channel ABS for 3 wheeler with the function ABS was transmitted to Piaggio. This system is still under discussion with Piaggio.

Electronically controlled suspension system

The exploitable result from Öhlins side is to develop a semi active suspension system for a PTW. The semi active suspension system shall provide the vehicle with good handling capacities and a safe behaviour on the road. This is possible by measuring the movements of the vehicle by several sensors, analyzing the result from the sensors in a central control unit and accordingly adjusting the damping characteristics. A quick response from the suspension system is necessary in order to adjust the vehicle behaviour in real time, therefore a special quick opening and closing pilot pressure and solenoid controlled valve is used.

Basic testing of the system on and off track has been performed by Öhlins in co-operation with partners. However, the exploitation of the product is allowed to take time in order to achieve the optimum performance.

A semi active suspension system for PTWs is attractive both in racing and in OEM and aftermarket sales. The system's ability of adapting the suspension damping to the road or track and/or the rider's behaviour is demanded in all types of PTWs, from scooters to racing bikes. A system with the ability of adjusting the suspension in such a manner that an accident possibly can be avoided, for example by preventing high side or a too heavy diving motion, could be attractive for the market.

However, this highly advanced system demands a development process stretching over a long time involving many subjects. Furthermore, the parts included in the system need to be small and light with tight tolerances and at the same time they need to be durable and as maintenance free as possible. Therefore, it is a great challenge to keep the cost of the system on such a level that is attractive to customers in all PTW segments. Existing patent applications on algorithms to adjust the damping may in the future also have some limiting effect on the control system development. Since a PTW is a vehicle very sensitive to failure in the suspension system, it is also a possibility that standardization laws will come into action demanding a fail safe system on the suspension. The fail safe system can take over – creating a basic level damping – in case of electronic and power failure. The Öhlins suspension is already equipped with such a system and is therefore not so sensitive to such possibility.

Further additional research work is necessary to continue the development of the control algorithm for the suspension system. Due to lack of internal resources, collaboration between Öhlins and the Swedish Royal Institute of Technology has started in order to intensify the algorithm development process.

The soft opening function in the electronically controlled valve in Öhlins semi active suspension system is protected by patent EP0942195B1 in Germany, Great Britain, Italy, France and the Netherlands and by patent US6311812 and SE523534 in the USA and Sweden. Further the algorithms controlling the function are under patent pending.

A basic version of this system has been demonstrated to Öhlins customers and the interest for the system has been high and pre-orders have been laid. The system is said to have great potential to improve handling on vehicles adapted both for racing and on rural roads. However, due to need of further development and adaptation of the system to the respective PTW, the introduction on the market of semi-active suspensions is not foreseen before 4-5 years.

Innovative Human Machine Interface

Within the SIM project activity, a dedicated human machine interface was studied and developed in order to increase the rider attention to the riding primary task. The increasing use of mobile phone and navigation systems as well as other new functions available on board could distract the rider, that could mislead dangerous situation and/or lose motorcycle control.

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For this reason a good management of the flow of information provided to the rider as well as an intelligent and almost self-explaining Human Machine Interface (HMI) for the use of devices that increase the motorcycle stability while manoeuvring were studied and developed, so that the rider can be more concentrated on the riding task.

In this view was designed and developed an information management concept board (IMB) able to manage the flow of information in such a way to decrease the rider workload taking into account the need to reach rider's attention avoiding distraction and creating the proper balance of information distribution among the different HMI components.

In order to allow a safe and fast flow of information an open and flexible CAN network architecture was designed ad-hoc for the SIM MP3 prototype among the IMB and the different electronic control units (ECUs) installed on the vehicle, that became network knots.

Therefore thanks to this dedicated network in which flowed not only information about vehicle status and/or malfunction messages but also ECU settings, like suspension ones, and threshold values fixed by the rider during the riding in order for example to be alerted when the speed and/or the roll angle value go over them, the IMB is able to collect the most significant and important information from the dashboard, the mobile phone and the navigation system and redistribute them to the rider via wireless connections through different channels.

Nevertheless it is important to highlight that not only the systems output information are managed by the IMB but also the rider's input. In fact, while the output information will be distributed to the rider using the visual and the acoustic modality, the IMB can receive input commands by the rider through the vocal and the tactile modality (i.e. through the pressure of dedicated buttons). In this way the rider can set some electronic control units behaviours, like the suspension one, or select an MP3 song.

In this sense also the helmet becomes a key equipment for the transmission of information to the rider. New kind of helmets, more protective and more enveloping than in the past, represents both a safer device and a gate for signal coming from external devices (for example status of ECU on the motorcycle). For this reason, the IMB has a relevant role towards the rider, i.e. to diffuse all relevant information directly inside the helmet, avoiding the lack of attention generally due to the dashboard distraction.

The great innovation of the SIM project is due to the fact that nowadays on the motorcycle market is not present an integrated solution like the one studied and developed in this project. After-market stand-alone navigation systems or helmet that allows a Bluetooth connection with a mobile phone are examples of what can be available on the shelves as single product and it is well-known that the use of these devices separately decrease rider attention on the primary riding task. The idea of an integrated management of infotainment devices and vehicle information could then increase the rider safety while riding. Therefore the effort done within this project can be considered as a good starting point for the future trends.

CRF collaborated with PIAGGIO for the realisation of an open and flexible CAN network architecture to be installed on the MP3 vehicle, and is the responsible partner for the IMB development.

Concerning IPR, the IMB is based on the FIAT GROUP commercial product Blue&Me installed on several FIAT cars.

CRF will exploit its know-how on the IMB SW dedicated to the motorcycle designed and developed within the SIM project to the FIAT GROUP society (Magneti Marelli Electronic Systems) in charge of developing the Blue&Me platform.

With an helmet with audio link with the motorbike, instructions coming from motorbike GPS and/or mobile phone can be received by the rider. The solution can be exploited directly by selling the final helmet with the integrated device. However this device must decrease its cost to be affordable to almost everybody. The helmet cost should not be increased too much and for this, a new Bluetooth (BT) system with less

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performances (i.e. no intercom) could be considered. NZI is currently developing a new system that can match the above mentioned target.
NZI developed an helmet with integrated HUD which can be linked to the motorbike and can display key information to make the driver aware of the status of the motorbike and the actual speed. This solution can be exploited:

- by selling helmets with already integrated HUD and its MSU that will have to be connected to the motorbike by the final user. After some market research this possibility seems to be quite remote since the final cost for the user will be too high and, moreover, it will be necessary to install some electronics on the bike as aftermarket by a qualified workshop.
- by selling helmets with already integrated HUD that will be compatible with certain motorbikes that will be able to send the required info to the HUD. This possibility is still too expensive for final users mainly because of the distribution cost.
- by selling the motorbike jointly with the helmet. Also this possibility would be of course very expensive for the customer.
- by selling the HUD as external module that can be fitted into specially prepared helmets. This is the most promising way to sell the product if the helmet is sold separately and the HUD comes with the motorbike (through its distribution channel and sold with the bike and within the bike price). This solution is feasible to be submitted for a patent, however, to have the final product ready to be industrialised further development has to be done. This could be as well licensed to other helmet manufacturers if finally a patent will be applied.

MRC holds a patent on the HUD technology for helmets.

Integrated inflatable devices for rider protection

In this project a cooperative passive safety system has been developed. It is made of a frontal airbag and an airjacket, both activated by the same crash detection system.

The main objective of an Inflatable Restraint System is to absorb the kinetic energy of the rider during the accident. It should avoid the injuries produced by the impact between the motorbike and the obstacle (the car, in this case). The components of the airbag module have been designed according to the technical available volume in the Piaggio MP3.

The frontal airbag and crash detection system concept were derived by the one used in automotive applications, in terms of components (i.e. ECU, sensors, firing system and bag).

Although Time to Fire requirements and sensor ranges of the crash detection system are comparable with the car ones and the calculation methods is quite similar, the setup process and the sensitivity needed for passive safety system activations requested a relevant research work due to the specific application field in (i.e. different mass and structure, differences between vehicle's and rider's motion during post-crash phase).

A specific airbag control was developed on the basis of the automotive's one through an ad hoc algorithm and sensor arrangement.

A wearable device has been developed for a more specific motorcycle rider's protection. The airjacket solution is a concept specifically applicable in PTW domain, aimed at providing the rider with protection not only against primary impact but mainly the secondary one, when the rider is separated by the vehicle.

This research shows the significant reduction of rider injuries during an accident if the restraint system device is on the motorbike. There is an improvement on the safety of the rider due to the airbag.

Full scale crash tests have been performed within SIM to assess the behaviour of SIM passive safety system: the frontal airbag and airjacket reduced critical injuries in the upper part of the body both in standalone and in combined configuration (thus more studies are needed for leg protection).

All the devices developed for the integrated passive safety system are at the moment in a prototypal phase and need to be further improvements. For this reason market evolutions in this direction are not predictable at the moment.

On the basis of SIM project activities related to passive safety system development a patent proposal has been deposited at national level (Italy) protecting the following characteristics:

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- airbag installation in place of standard vehicle dashboard
- additional sensor on the frame frontal part
- specific crash detection algorithm.

Piaggio, Continental (Conti Temic) and Dalphimetal are the partners involved in the application entitled "Integrated system for installation, activation and support of an airbag system for motorcycle application".

Nowadays it's difficult to have a reliable forecast for the introduction of technology into the real market; customer's expectations and awareness about safety devices are quite weak and should be increased by aimed sensitization campaigns. Anyhow in the final part of SIM Project a customer survey with the aim to evaluate the market acceptance was conducted.

Among all the safety devices, the Combined Braking System with Anti Lock Brake System and the Stability Control resulted to be at this stage the most promising safety devices in terms of scooter market acceptance, as clearly resulted from the very good alignment between the market interest / expectation and the new market offer:

Concerning ABS system, this result meets with the actual commitment of ACEM on behalf of the Motorcycle Industry: since 2004 ACEM manufacturers have jointly committed to the European Road Safety Charter to progressively supply PTWs with advanced braking systems taking into account their distinctive characteristics. By 2015, 75% of type-approved street models will be available on the European market with advanced braking systems.

The preventive safety devices (Multifunction display, HUD, Bluetooth) aroused a quite tepid reaction by the respondents probably because are still considered mainly for infotainment purposes and not strictly related to safety aspects.

Concerning passive safety devices (airbag and inflatable jacket), both collected a quite good feedback in terms of interest but not in terms of real willingness to have them on the next vehicle.

SIM consortium is really confident that the request for safety on PTWs will rapidly increase and the know-how acquired in SIM activities will be precious in a short time.

Market demand for safety is still weak; it will spontaneously increase, better if will be sustained by sensitization, regulations and manufacturers inputs.

Lot of the knowledge will be soon available for the market, beginning from the active safety devices. In a few years passive safety devices will be spread on production models too, whilst preventive is every day more effective.

For the passive devices maybe it will occur a little bit more time but the path is now quite clear.

SIM Consortium is confident that SIM has been not only a successful project from a technical and managerial point of view, but also a step in the right direction for future PTW Safety, to be continued in the near future.

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