POWERED TWO WHEELERS INTEGRATED SAFETY – FIRST RESULTS OF THE SIM PROJECT

Mario Donato, Santucci
Marco, Pieve
Piaggio & C. SpA
Italy
Jens, König
DEKRA Automobil GmbH
Germany
Elena, Bianco
Centro Ricerche Fiat
Italy
Jesús, Vázquez de Prada Martinez
CIDAUT
Spain
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ABSTRACT

First outcomes of activities carried out in Safety In Motion EU project are hereafter described. SIM Project is aimed at identifying a suitable and comprehensive safety strategy for powered-two-wheel (PTW) vehicles, in order to avoid road accidents and/or mitigate their consequences.

Starting from the outcomes of previous accidentology activities an in-depth analysis was conducted focusing on the scenarios identified as the most frequent and dangerous for PTWs accidents. Significant accident parameters were identified and related values were analyzed. Also a technology evaluation based on state-of-the-art analysis as well as partners expertise was conducted and the effectiveness of potential benefits of safety systems was evaluated in reconstructed accident scenarios.

On such a basis a PTW safety strategy has been identified in all safety areas.

The active safety improvement is reached by actively controlling PTW stability and improving riding comfort (advanced braking and suspension systems).

In preventive safety area an HMI Information Management concept for motorbike was identified as the most effective solution for enhancing the PTW rider's awareness. Focusing on passive safety aspects, a frontal airbag fitted on motorcycle (aiming at protecting rider against the primary impact) and an inflatable wearable device (mainly for secondary impact) have been chosen to be tested either separately and jointly.

The following safety devices have been finally selected in order to be implemented and tested on vehicle prototypes:

- Active Brake System
- Stability management by traction control
- Semi-Active Suspension System
- Frontal airbag
- Inflatable wearable device
- HMI Information management concept for motorBikes (IMB)
- Enhanced HMI (ergonomic handlebar controls, wireless communication, Head-Up Display)

An integral approach to PTW safety enhancement was adopted, since all the safety devices will be implemented and tested on the same vehicle platform, the innovative PTW tilting three-wheelers Piaggio MP3.

INTRODUCTION

The background of SIM project are the findings of the MAIDS project [1] which main objectives are:

- the identification of the main factors that contribute to PTW accidents causation;
- the definition and proposal of suitable countermeasures in order to reduce the number of accidents and mitigate the consequences for the rider.

MAIDS causative factors have been categorized in three items or pillars of safety:
-Powered-two wheelers
-Human
-Infrastructure.

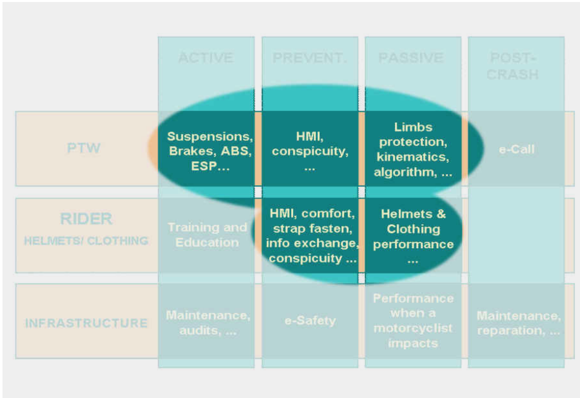

Figure 1. The Safety Matrix

The approach of SIM project is described by the Safety matrix (**Figure 1**) where the pillars of safety are crossed with the typical safety areas.

SIM project is mainly focused on **integrated safety** for **PTW**.

Even if the human factor belongs to PTW rider and vehicle driver (i.e. car, bus and truck), nevertheless SIM activities deal with this topic from PTW rider perspective in terms of protective devices (helmet and clothing) and HMI improvement.

The activities' flow within the project started with the analysis phase, based on accidentology and effectiveness evaluation of the most promising safety devices. After the safety devices have been selected, their development has been carried out for more than one year. In the last phase of the project the adopted solution will be integrated and tested into the final prototypes.

SELECTION OF PTW SAFETY STRATEGY

The SIM project has established a strong collaboration link with APROSYS (Advanced PROtection SYStems) SP4 – an Integrated Project (IP) under 6th Framework Programme of the European Commission - in order to share the knowledge gained during the first phase of SP4 concerning motorcycles passive safety [2]. As a result of this collaboration, the outcomes contained in deliverables from SP4 subproject are briefly described.

During the first phase of SP4, activities were carried out to achieve the goal of extracting information about motorcyclists' road accidents. In particular, aspects such as the following were identified:

- the most relevant accident scenarios,
- the causes of the accidents,
- the interactions between PTWs / riders and vehicles,
- the interactions between PTWs / riders and infrastructure,
- the performance of motorcyclists protective devices,
- the kinematics of the collisions,
- the most frequent riders' injuries patterns.

On the basis of the mentioned features, a number of scenarios capable to represent a wide number of casualties were identified. In a first step the National Statistics of four countries (Spain, Italy, The Netherlands and Germany) have been deeply analysed. The findings were seven main accident scenarios, describing the PTW accident occurrence as a whole, **Table 1**:

Table 1 PTW main accident scenarios

Urban Area	Non Urban Area
Moped against car in intersections.	Motorcycles against car in Intersections.
Moped against car in straight roads.	Motorcycle against car in straight roads.
Motorcycle against car in intersections.	Motorcycle. Single vehicle accidents.
Motorcycle against car in straight roads.	

In a second step the identified accident scenarios were further investigated by means of in-depths databases available within the consortium (GIDAS 2002, COST 327, NL-MAIDS, DEKRA PTW), focussing mainly on passive safety aspects.

Accident In-depth Analysis

As afore mentioned the results of APROSYS SP4 have been integrated in the SIM database analyses. The identified main accident scenarios have therefore been chosen as a starting point. Within the SIM consortium the MAIDS database, the DEKRA PTW database and the GIDAS 2002 and 2003 datasets were available for examination and, as far as the databases are of very different character and the coding regulations are oftentimes not common, several shared parameters have been identified and analysed (**Table 2**)

Table 2. Common parameter list

PTW design	Visibility conditions
PTW colour	Weather conditions
PTW user injury patterns	Lighting conditions
Accident location	Technical defects
Rider behaviour before impact	Evasive manoeuvres
Kind of collision	Kind of PTW driver reaction
Tyre conditions	Accident avoidance
Influence of tyre fault	Accident causation
Classification of skidmarks	Question of guilt
Road characteristics	PTW initial driving speed
Road condition	PTW speed of first collision
Involved parties	PTW brake system
Right-of-way regulations	

By analysing the most relevant parameters it is possible to notice that in the DEKRA database, with mostly elevated speeds outside urban areas, severe and fatal injuries play a major role. In the MAIDS database 22 riders only received first aid treatment at the scene of the accident. A total of 785 riders were treated in hospital and then released. 100 PTW riders and 5 passengers died as a result of injuries sustained in the accident. The GIDAS database shows a large number of AIS 1 and AIS 2 injuries, **Figure 2.**

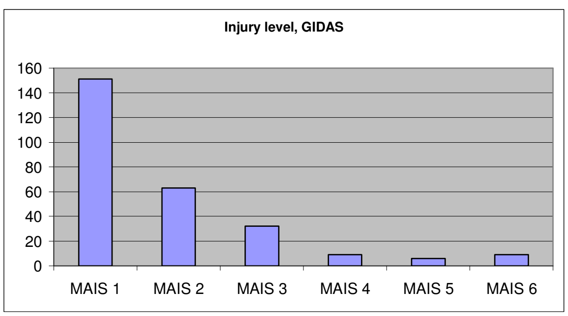

Figure 2. Injury level, GIDAS

As being representative in respect of the National Statistics in Germany, the accident site in the GIDAS database is in most cases within urban areas. The DEKRA database with its focus on severe and fatal PTW accidents shows a converse site distribution. Within MAIDS approximately two-thirds of the accidents took place in urban areas. In order to develop passive safety devices installed on the vehicle it is important to have a clear understanding of the impact kinematics. In the case of an impact against an opposing vehicle it is essential to differentiate between upright impacts and sliding impacts. In the DEKRA database most of the PTW impacts occurred in an upright driving position, **Figure 3.**

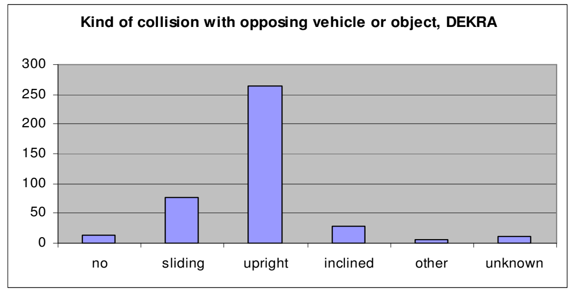

Figure 3. Kind of collision, DEKRA

In the DEKRA as well as in the GIDAS datasets the road was mainly dry. Only few cases with wet or moist road surface were recorded. In MAIDS data the roadway was found to be dry and free of contamination in 84.7% of all accidents ,wet in 7.9% of all collected cases. Ice, snow and mud were reported in 5 cases respectively and gravel or sand was reported in 2.5% of all cases. The main part of the PTW crashes occur on straight normal roads.. About half of the PTW accidents in MAIDS happen on minor arterial road or local street, according to urban area characteristics. Based on MAIDS data, roughly in 70% of the cases the PTW was travelling on a straight path. Junctions, intersections and curves – especially in rural areas – do also play an important role. As reported also in detail MAIDS data show that more than 50% of accidents happen at intersections. The different intersection types reported in MAIDS are shown in **Figure 4**.

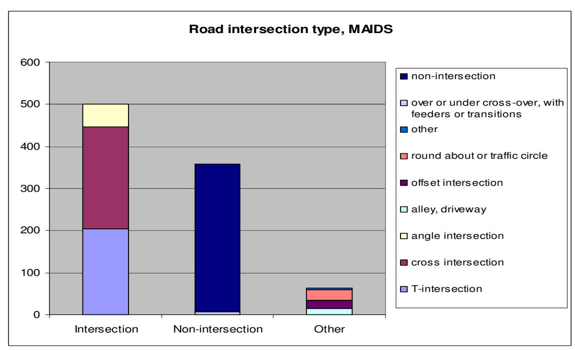

Figure 4. Intersection type, MAIDS

In the major part of the accidents the road surface is made of asphalt. MAIDS data indicates that in 56% of the cases asphalt was found in optimal condition. As expected the passenger car was in the three databases the main opposing vehicle within PTW crashes followed by PTW–PTW and PTW–pedestrian as well as PTW- truck impacts, **Figure 5**.

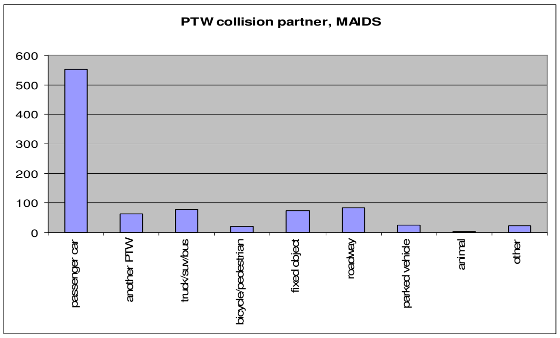

Figure 5. PTW collision partner, MAIDS

As far as the weather at the time the PTW accident happened is concerned, a distinction between clear/sunny/dry, cloudy but dry, rainless not further indicated, rain, fog/haze, hail/snow, and storm/gust of wind has been made. Most PTW accidents happened at dry weather conditions confirming the assumption that motorcycle riding is mostly a leisure activity. In the DEKRA cases were a sight obstruction at the accident scene was detectable mostly bushes or trees limited the vehicle users view. For the GIDAS database sight obstructions have been classified as being non-permanent (e.g. parked vehicles) or permanent (e.g. buildings). In 9.5% of the cases a mobile vehicle obstructed the view of the PTW rider, while in about 10% of the cases a mobile view obstruction for the OV driver was present at the time of accident. As for the light conditions most accidents happened at daytime. In Germany it is mandatory for powered two-wheelers to have the low-beam light switched on also at daylight. In most of the cases of the DEKRA and GIDAS database the PTW driver met this demand, however a not negligible amount of PTW drivers disregarded this directive, **Figure 6**.

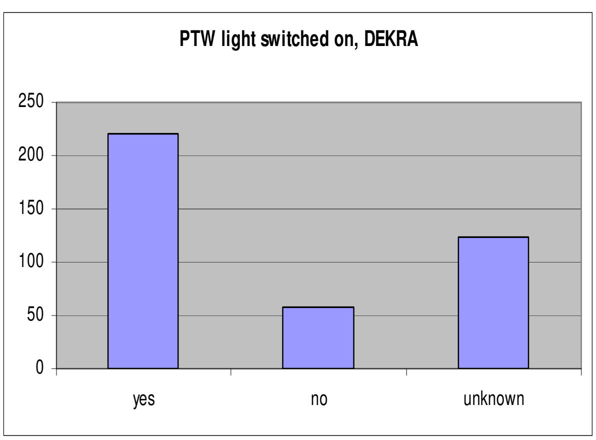

Figure 6. PTW light status

From MAIDS data, it was found that in 87.5% of the cases the main contributing factor is human related. It is divided between PTW rider (37%) and OV driver (50%). Among these a perception error of the OV driver is the most frequent event, while for the PTW rider decision and perception errors are the most relevant ones. The data in **Figure 7** indicates that a PTW rider traffic-scan error was reported in 27.7% of all cases involving an OV.

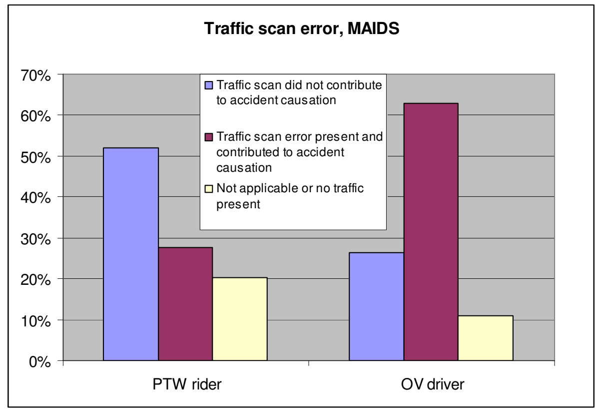

Figure 7. Traffic scan error, MAIDS

The initial driving speed bands are illustrated in **Figure 8** and **Figure 9**. In the representative GIDAS database most PTW users drove in the speed band 31–45 km/h whereas in the DEKRA database also the 61–75 km/h and the 79–90 km/h speed range is of interest. In MAIDS it was found that in roughly 45% of all cases the PTW was travelling below 45 km/h, while only in 23% of cases the travelling speed was between 46 km/h and 60 km/h. It has to be noticed that both L1 and L3 PTW legal categories are included.

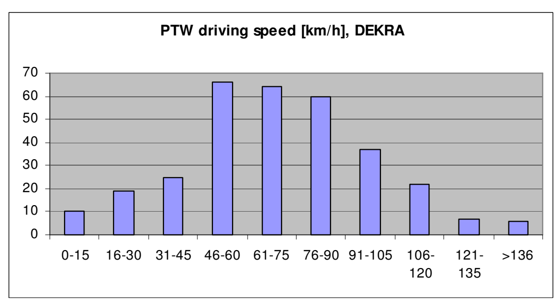

Figure 8. PTW driving speed [km/h], DEKRA

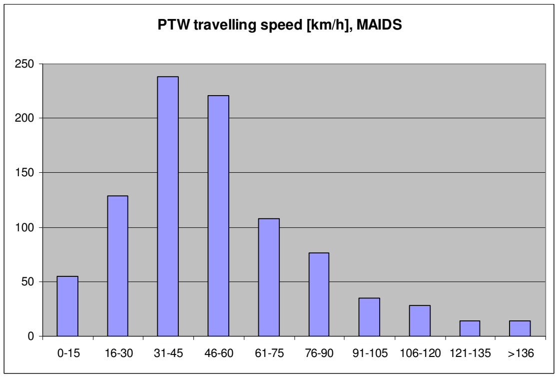

Figure 9. PTW driving speed [km/h], MAIDS

The speed of the PTW´s first collision in the DEKRA database is described in **Figure 10**. A speed reduction in respect of the initial speed is observable though not always significant.

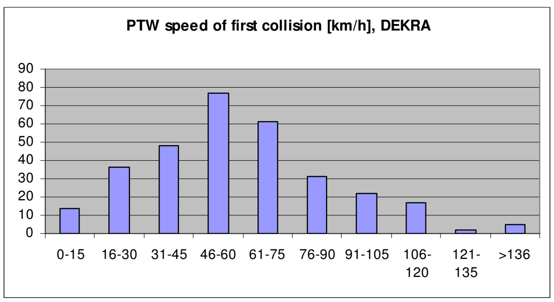

Figure 10. PTW speed of first collision [km/h], DEKRA

In the MAIDS datasets the PTW impact speed is in 63% of the cases below 45 km/h while in 17% of the cases the impact speed was found between 46 km/h and 60 km/h. In order to better understand the correlation between driving speed and first collision speed a case related speed inspection is of great help. The data was sorted in a descending order. Here, only a section in the driving speed band from 60-40 km/h is displayed, **Figure 11**. In about 50% of the displayed cases, no speed reduction prior to the first impact was detectable.

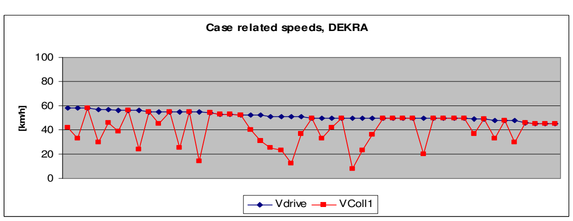

Figure 11. Case related speeds, DEKRA

For what concerning data coming from MAIDS, only cases with impact speed less than or equal to travelling speed were considered. Here, the percentage of Kinetics Energy (KE) reduction by travelling speed has been calculated. KE is defined as:

$$1 - \left(\frac{V_i}{V_t} \right)^2$$

Where Vi is the impact speed and Vt is the PTW travelling speed. In roughly 30% of these cases there was no KE reduction (with a travelling speed between 31 km/h and 45 km/h). Most of the KE reduction values (32%) is between 20% and 70% reduction in the speed range from 31-60 km/h. In most cases modern disk brakes were observed apart from a not negligible amount of drum brakes at the front wheel in the DEKRA cases. Where possible, the involved PTWs within the DEKRA and GIDAS database have been analysed in respect of anti-lock brake systems (ABS) furniture. The penetration of ABS in the motorcycle market is up to now very limited, hence only an insignificant amount of PTWs is outfitted with such systems in the investigated case collections.

Technology selection

The analysis of potential PTW and protective equipment improvement (active, passive and preventive safety devices) has been carried out starting from the literature review in PTW safety field and collecting information about state-of-the art for safety devices applied in automotive and PTW field. The state of the art of such systems is described in detail in [3].

An effectiveness evaluation has been performed on systems that can be realistically implemented on PTW based on two criteria:

- market availability and potential transfer to PTW field;
- technical feasibility (i.e. vehicle constraints).

As a result of the effectiveness evaluation a list of safety system to be installed on vehicle prototypes was defined.

Effectiveness evaluation in real accident scenarios

Starting from the previously described accident analysis and scenarios defined in **Table 1**, single cases, representative of each accident situation, have been extracted from DEKRA PTW database. The fundamental basis of the DEKRA accident database is the accumulation of written expert opinions containing the accident analyses that are drawn up by skilled forensic experts at the DEKRA branches throughout Germany. Apart from the database also the raw material (written expert opinions) is available for investigation having the advantage to extract parameters which were originally not directly implied in the database.

From the DEKRA datasets 51 cases have been selected, extracting the following parameters:

- Collision speed
- Initial speed
- Distance of falling location to collision point (if applicable)
- Braking distance (referring to the collision point)
- Mean value of braking deceleration
- Starting point of braking (referring to the collision point)
- Reaction point/reaction demand (referring to the collision point)
- Kind of reaction demand
- Road surface conditions
- Weather conditions

It is worth to be mentioned that the analysed 51 accidents have been chosen depending on reaction demand and following rider braking behaviour in order to evaluate the benefit of an advanced braking system.

Also if database analyses can simply give general insights into the accident occurrence, for more detailed data considerations it is essential to analyse case-related accident characteristics. One opportunity to face this problem is the preparation of in-depth accident reports, containing common information about the accident and the vehicles involved, sketches, vehicle kinematics, pre-crash phase calculation tables and picture documentations (**Figure 12**). From the raw data, at DEKRA 16 in-depth accident reports have been drawn up and made available to the project consortium for further examination. analyses. The whole in-depth analyses can be found in Annex A of [3].

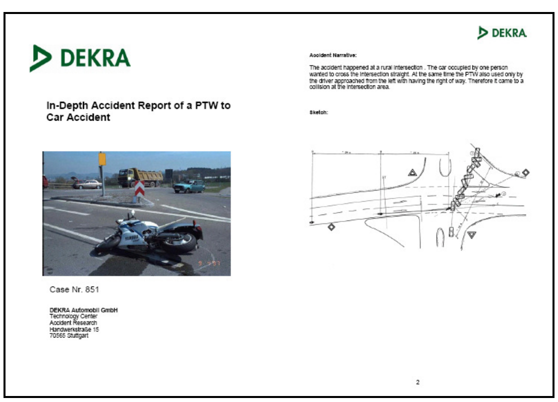

Figure 12. In-depth accident analysis example

With the data coming from the 51 cases and 16 fully reconstructed cases (DEKRA database) brake system and suspension system have been evaluated taking into account the typical "boundary" conditions of the accidents.

A different approach has been followed for the effectiveness evaluation of the passive safety devices (airbag, leg protectors, wearable devices…). that has been made starting from results of previous studies [4] and analysing 20 cases from DEKRA database in which PTW impact was against passenger car, PTW was in upright position, and the rider was severely injured or killed.

The potential benefits of HMI improvement was extrapolated mainly based on MAIDS findings that reports human factors as the main contributing accident causation factor (**Figure 13**) and according to ESoP in HMI [5].

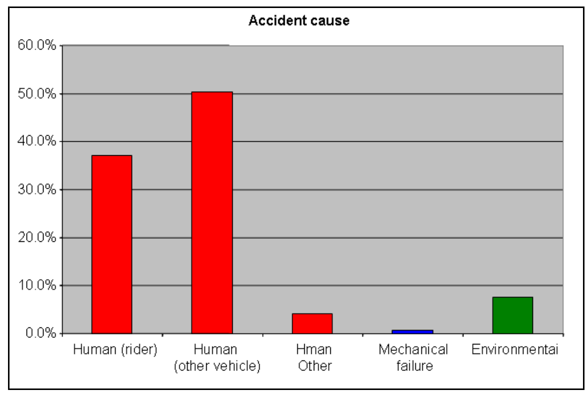

Figure 13. Accident Causes From MAIDS database.

Safety Systems Requirements

From the effectiveness evaluation, based on the partners' expertise, system requirements for most promising solutions have been set.

The brake systems analysis on real case accident scenarios pointed out that in most cases an electronic brake system with active brake distribution could lead to accident avoidance or, at least, to a massive impact energy reduction (**Figure 14**).

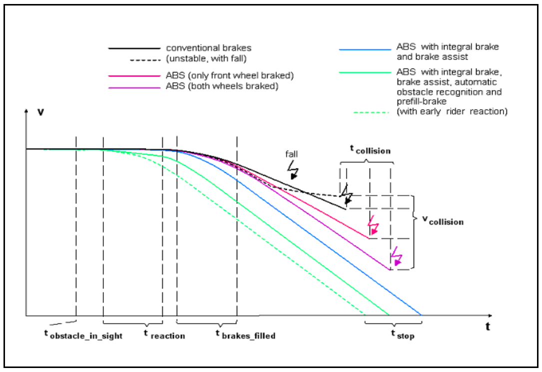

Figure 14. Performance comparison between different braking systems

To achieve that, the **advanced brake system** to be implemented in SIM prototype has to be able to independently build up pressure on each caliper, allowing active brake force distribution depending on actual grip on single wheel. By this feature it is possible to implement advanced functions for electronic brake management (e.g. rear lift off protection and brake traction control).

On the other hand the vehicle suspension must be able to adapt to the road condition and to the instantaneous brake/acceleration request, providing the highest tire adherence and force stability achievable in each situation (**Figure 15**), so assuring the maximum effectiveness respect to accident avoidance.

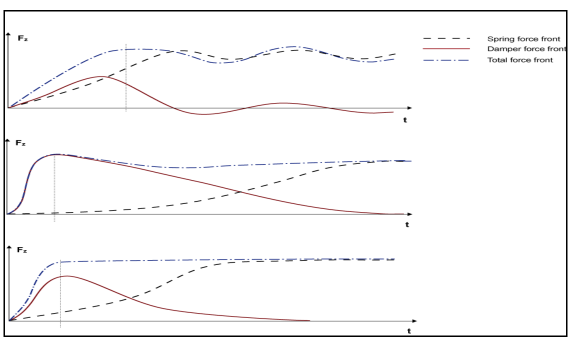

Figure 15. Damping modulation effect on tire force

In order to realize that, the SIM **suspension system** must provide a real time variable damping in order to allow instantaneous self-adaptation by means of fast electronic valves and programmable ECU for suspension management algorithms implementation.

In case the accident can not be avoided at all, a protection strategy for vehicle occupants must be investigated. Due to the highly variable rider motion during a crash event, a cooperative strategy between protective devices fitted on the vehicle and worn by the rider could be needed.

In this respect, SIM prototype must be provided at least of one specifically designed **airbag** and an inflatable wearable device **(airjacket)**.

From a technical point of view, the real challenge is the integration of the airbag in the limited spaces available on a motorcycle and the setup of an effective deployment strategy of inflatable devices.

In order to set-up the passive safety devices, extensive virtual tests coupled with a limited number of real crashes are performed both in standalone and cooperative configuration. Because of the intrinsic active safety enhancement assured by the innovative front suspension the Piaggio Mp3 (**Figure 16**) vehicle have been chosen as the ideal platform for the test of SIM advanced safety features.

Figure 16. Piaggio Three Wheeler Motorcycle (Mp3).

Active And Preventive Safety Systems

After an in-depth analysis of the most promising active and preventive safety devices, it is pointed out that the most advanced technologies could lead to a significant reduction of accidents or at least to a mitigation of eventual consequences in terms of rider injuries, for example avoiding the rider's loss of vehicle control or significantly reducing the kinetic energy at the impact. In addition to that an efficient human machine interface represents an effective preventive safety feature reducing possible distraction in riding activity.

In such vision, the following active and preventive safety devices have been selected in order to be implemented and tested taking into account the architecture and the dynamic behaviour of the vehicle chosen as technological platform for SIM prototype, the PIAGGIO MP3 motorcycle:

- Semi-Active electronic suspension system
- Traction control system
- Enhanced anti-lock braking system
- HMI management concept for motorbike
- Enhanced HMI (ergonomic handlebar controls, wireless communication, Head-Up Display)

Active safety systems

Regarding the active safety systems that are developed inside the SIM project, an electronic suspension system and an enhanced anti-lock braking system are studied and implemented.

It is noticeable that the effectiveness of braking system and traction management could be improved by integrating the suspension control system.

The suspension system for the project have been developed in order to guarantee a semi-active function. This kind of implementation requires a very fast modulation of suspension damping in order adapt the vehicle to the driving conditions but also to the driver's behaviour. In fact the characteristics are modified by using sensors to continuously detect vehicle and environmental parameters such as movement of the suspension parts, brake pressure, throttle angle and vehicle roll. The sensor signals are transferred to the suspension ECU which according to control algorithms transforms the signals into an electric signal.

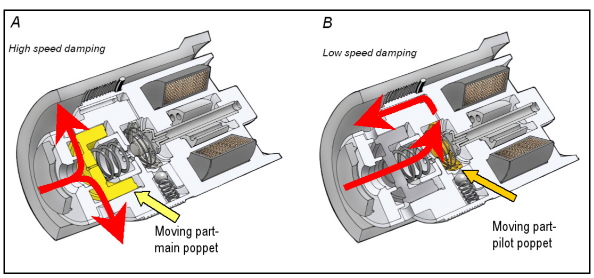

Figure 17. Continually Electronically Steered (CES) valve.

The fast damping modulation is granted by a continuously variable electronic valve specifically designed for Mp3 application (**Figure 17**).

In order to adapt the PTW suspension to the driver's behaviour, a setting switch has been used to allow the rider to choose between pre-programmed suspension behaviour (comfort, sport, normal).

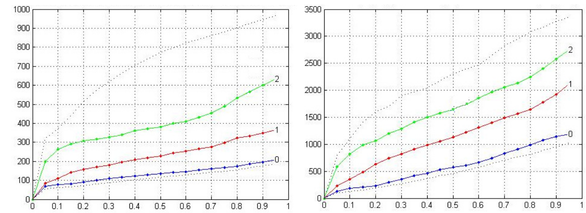

Figure 18. SIM suspensions settings.

During SIM project development an automatic safety system control is foreseen in order to maximize comfort, performance and safety. With the safety system active, the suspension is adapted to minimize braking distance, to prevent high side situations, smoothening the suspension behaviour when in fully extended or compressed state and to optimize the damping setting in order to achieve optimal stability and handling of the vehicle. In order to achieve the goal Sky-Hook and Ground Hook control algorithms will, be implemented in the dedicated suspension ECU.

Apart from the suspension system, for increasing rider stability control and preventing MP3 wheels from locking, an enhanced anti-lock braking system, based on two independent hydraulic circuits has been developed (**Figure 19**). The system is developed also in order to integrate further functionalities like FIB (Full Integral Brake) ABD (Active Brakeforce Distribution), RLP (Rear wheel Lift off Protection) and TCS (Traction Control System) able to ensure a good performance of the overall braking system.

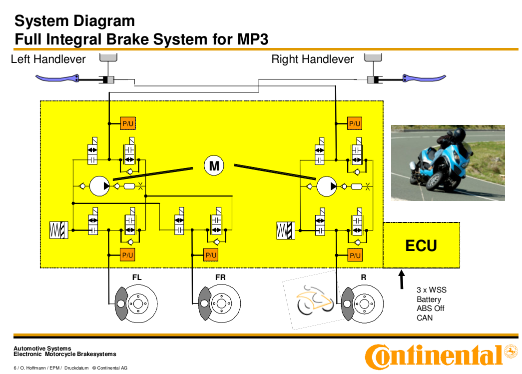

Figure 19. Electro Hydraulic scheme for SIM innovative brake system.

In order to set-up the main parameters for active safety systems management a complete vehicle model and virtual driver have been developed in virtual environment (**Figure 20**).

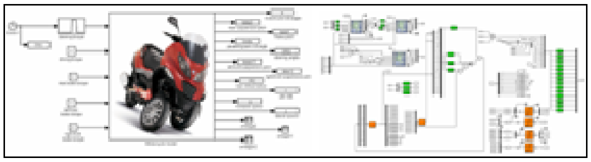

Figure 20. Mp3 virtual model with integrated active safety systems.

In such a manner, the virtual vehicle (validated with experimental tests) has been used in order to collect an extended database of simulation results with different sets of suspension characteristics and brake system logics both on flat and uneven road surfaces, also assessing the possible active systems effectiveness in terms of comfort and performances [7].

Preventive safety systems

An important role of support to active safety systems is played inside the SIM project by the preventive safety concept of HMI improvements.

The basic idea is to reduce road accidents possibility by the optimization of information flow from vehicle to rider that can greatly improve rider awareness. In order to reach this goal, a system have been developed able to redistribute the information, generally shown only in the central dashboard, to other communication channels. In this way the rider is informed about possible failures, incoming calls or navigations messages thought ad-hoc acoustic, visual and vocal signals. In such a manner the rider do not need to put off the eyes from the road, nor to take the hands away from the handlebar, remaining in the meantime focused on driving task.

HMI information management concept

The motorcycle rider receives several information referred on one hand to vehicle status and on the other hand to personal infotainment devices.

In fact, nowadays riders are interested not only to diagnosis information about vehicle functionality but also to data related to user's devices like mobile phone and PDA or to integrated applications like navigation system or media player. An easy access to this kind of information is strongly desired by the rider and so the need of communication management becomes a fundamental topic .

With the aim "to reduce the rider distraction concentrating his/her attention on the driving manoeuvres" is therefore designed and developed an HMI Information Management concept for motorBikes (IMB).

The significant information that the dashboard, the mobile phone and the navigation system provide are structured, prioritized and assessed in terms of riding safety by the IMB: the signals are handled in order to create the proper balance among the different elements of the motorbike-rider-protective equipment system.

While the output information is distributed to the rider using visual and acoustic modality, the IMB receive input commands by the rider through the vocal and the tactile modality.

Summarising, the Information Management Board picks up:

- Rider input (by voice or by handlebar controls)
- Vehicle information (like for example specific ECU malfunction, ECU settings and vehicle alerts)
- Mobile phone information including media player, SMS reader and hands-free Bluetooth
- Navigation system information

and redistributes them through the SIM enhanced HMI, that includes an additional display mounted on the handlebar and an head up display mounted in the helmet (**Figure 21**).

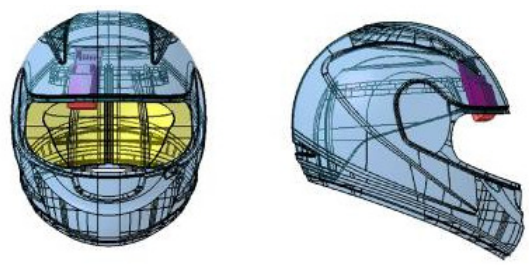

Figure 21. Helmet head up display placement.

The helmet is also equipped with a microphone and headsets wireless connected to the IMB through which the audio communication is permitted.

It is important to highlight that the SIM HMI displays does not substitute the conventional dashboard because its role is to enhance some critical messages about the vehicle status. Moreover, in order to ensure that the surrounding ambient noise is being perceived by the rider since his safety depends also on such an information, the solution with only one active earphone in the helmet is implemented.

Passive Safety Systems

In order to develop a passive safety system, the first step is related to the definition of most relevant crash scenarios used in order to evaluate its effectiveness. In [8], based on kind of injuries sustained by the rider in similar crashes and complexity of rider motion during the event, two main scenarios have been selected from ISO 13232 standard: configuration 413 and 114 (**Figure 22**).

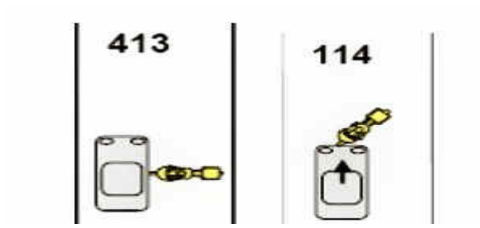

Figure 22. Crash configuration analysed in SIM project

In fact, in those configurations, previous full scale crash tests shown that a frontal airbag totally avoids the contact with the car in 431 situation drastically reducing the injuries suffered by the rider, specially in head and neck. Otherwise the ISO 114 configuration can be considered the worst case scenario on which the airbag, also if it do not cause additional damages, can not avoid the contact with the other vehicle nor the ground. For this kind of accidents where the rider separates from the PTW, the only effective protection can be provided by protective devices located on the rider garment.

Based on this analysis, the passive safety system for SIM project have been designed as a cooperative architecture composed by:

- frontal airbag system
- wearable inflatable device

In the next research and development phases, each subsystem has been tested as standalone and/or in combination with the other module in simulation environment by multibody codes (**Figure 23**).

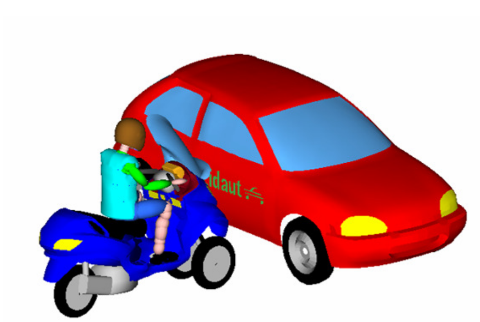

Figure 23. Multibody model for passive safety systems assessment.

In addition to multibody analysis that give a preliminary estimate of rider and dynamic and interaction with protective devices during crash sequence, a finite element model has been developed in order to obtain a more detailed simulation of energy absorption and rider injury level (**Figure 24**).

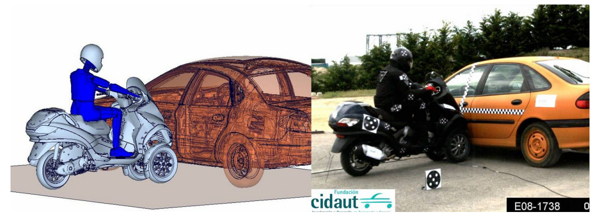

Figure 24. Mp3 FE model and simulation of 114 configuration crash test.

The FE model has been set-up by acceleration data collect on specific vehicle position during full scale tests against rigid wall performed in cooperation with Aprosys Project (**Figure 25**)

Figure 25. Mp3 full scale crash test (from Aprosys project).

As preliminary strategy, the main functionality of the airbag should be to restrain the rider (protecting/damping the rider from the primary impact), while the major benefits from the wearable module are expected in case of separation between rider and PTW (secondary impact). The effectiveness of the wearable module on the primary impact and the potential side-effects when used in combination with airbag module has also been evaluated by multibody code without harmful results.

In detail the defined PTW airbag functions are:

- To hold back the rider and avoid handlebar contact.
- To guarantee a large volume able to dissipate rider kinetic energy.
- To reduce rider forward displacement.

The wearable safety system used and tested in SIM project consists of an inflatable jacket which provides a better level of protection for the rider. The airbag jacket is expected to have more benefits for the secondary impact injuries, even if it will be tested also in combination with the frontal airbag module (**Figure 26**).

Figure 26. Rider protection air-jacket.

Using the data collected during real crash tests between PTW and passenger cars, from the accelerometers placed along the MP3, an algorithm has been programmed in order to have the decision-making ability of crash event recognition for safety systems activation. The “no fire” thresholds for the algorithm have been set by an experimental campaign of signal registration during normal vehicle operation conditions and also some “misuse” tests (e.g. potholes or drop tests). From further videos and deceleration diagrams analysis of full scale tests, the preliminary set of parameters for the activation of the passive safety system and satellite sensor position has been decided.

The frontal airbag shape and volume and inflator pressure levels have been empirically developed by static bench tests on physical prototypes in order to provide an overall energy absorption similar to the one coming into play in the real crash (**Figure 27**).

Figure 27. Frontal airbag prototype.

Final optimization of airbag prototype have been realized through sled tests that reproduce on a one axis configuration the decelerations felt by the rider during full scale crash. In such a manner it is possible to perform several set-up runs for bag, inflator and firing strategy without significant damages on vehicle structure (**Figure 28**).

Figure 28. Sled test for frontal airbag development.

CONCLUSIONS

As a whole, the PTW overall safety strategy followed in SIM project started from findings of the MAIDS project and from the current situation of PTW accidents and fatalities trends in EU roads.

The main factors that contribute to accident causation have been categorized and crossed with the safety areas (active, preventive and passive). By such an approach, the topics in which PTW safety improvement is feasible are identified for each cell of the Safety Matrix.

SIM project does not expect to cover all aspects of the Safety Matrix, however since the consortium is well-balanced in terms of industrial partners, universities and research centres and it is led by a PTW manufacturer, the efforts are focused on PTW safety improvement and PTW rider protection and comfort.

Further accident analyses were conducted on in-depth databases and results were compared with ones obtained in previous EU projects (i.e. APROSYS SP4). The outcomes are reported in [6].

In [3] the most promising safety enhanced technologies have been selected based on partners’ expertise and by evaluating their effectiveness in real accident scenarios.

The safety devices to be developed and tested within the project have been selected taking into account also the real market perspectives. Summarizing SIM activities, at the end of the second year, the design and development of the active safety systems have been completed and system prototypes have been realized:

-stability management system based on a three-channel advanced braking system

-semi-active suspension system with three setting levels (normal, sport, comfort)

Also a Human-Machine Interface concept has been realized by an Information Management Board that gathers data from vehicle via CAN bus and sends ad-hoc messages to HMI display and in helmet audio speakers.

Some additional information (like RPM and speed) are provided to rider via Head-up Display integrated into the helmet housing.

Beside the great challenge represented by the implementation of rider protection system on a scooter and the strong effort needed for validation of results, passive safety devices characteristics have been selected by several simulation both in FE and multibody environment.

Currently a frontal airbag is installed on vehicle and its preliminary set-up and effectiveness evaluation has been performed by experimental sled tests.

The actuation logic of protection system has been selected and first set of parameters for firing strategy has been set-up from vehicle "misuse" tests, as well as sensor position from full scale crash tests.

To conclude, powered-two-wheelers rider safety is a complex phenomenon that requires a comprehensive approach and the aim and responsibility of SIM project can only be addressed within design and development of new products featuring advanced technologies in all field of safety, related to vehicle and rider helmet and clothing.

Nevertheless it should be underlined that road safety can be achieved in a structural way only with the support and common effort of all stakeholders, first of all road users that have to make the most out of the new technologies available today and in the foreseeable future on the market.

In such a vision the major effort of road operators should be oriented to improvement of passive safety performances of the infrastructure and in a long term, to effectively make the infrastructure cooperative with vehicles within a common communication architecture for safety and traffic management issues.

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