SIM PROJECT: A WAY FOR PTW INTEGRATED SAFETY

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ABSTRACT

The paper will describe the features and characteristics of the project SIM (Safety In Motion). SIM Project 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, in order to avoid road accidents and/or mitigate their consequences. Main objectives of SIM are:

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

An integrated approach to the complex concept of motorcycle safety shall establish 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). The research will be based on the analysis of motorcycle accident databases from MAIDS, GIDAS and DEKRA. According to that, SIM project focuses on the **vehicle safety aspects**, including the **human-machine-interaction**.
Main results expected are:

- development of electronic active devices (e.g. enhanced anti-lock braking system, traction control and brake-by-wire) for powered two-wheelers;
- development of a passive safety algorithm to activate passive safety devices;
- adaptation of protective inflatable devices located on the rider (garment) and on the vehicle (for lower limbs protection);
- implementation of innovative HMI

On-road and laboratory tests, based on the most relevant accident scenarios, will be conducted in order to evaluate the effectiveness of the safety system devices (e.g. mitigation of injuries via inflatable devices, probability of avoiding accident, etc…) fitted on an integrated concept vehicle.
Innovation aspects are mainly an integrated approach to the issue and the introduction of new safety technologies in PTW field.

PROJECT OBJECTIVES

Project context

Over 6000 among 40,000 fatalities on European roads in 2001 are related to the Powered-Two-Wheelers-vehicles (PTW's). Compared to the overall number of victims on the roads, this figure represents 15% of this dreadful aspect of our society. The European Commission has launched the 3rd European Road Safety Action Plan with the ambitious goal of reducing the fatalities by 50% in 2010. By 2025, the number of persons killed or severely injured on the road shall be reduced by 75%. To this goal, the motorcycle Industry have a role to play in improving the safety features of its products, while keeping their characteristics of versatility.
What are powered-two-wheel-vehicles (PTW's)?
The following is the definition stated in Directive 2002/24/EC that regulates all technical prescriptions for the type-approval of these vehicles:

(a) mopeds, i.e. two-wheel vehicles (category L1e) or three-wheel vehicles (category L2e) with a maximum design speed of not more than 45 km/h and characterised by:
  (i) in the case of the two-wheel type, an engine whose:
    - cylinder capacity does not exceed 50 cm^3 in the case of the internal combustion type, or

- maximum continuous rated power is no more than 4 kW in the case of an electric motor;

(ii) in the case of the three-wheel type, an engine whose:
- cylinder capacity does not exceed 50 cm^3 if of the spark (positive) ignition type, or
- maximum net power output does not exceed 4 kW in the case of other internal combustion engines, or
- maximum continuous rated power does not exceed 4 kW in the case of an electric motor;

(b) motorcycles, i.e. two-wheel vehicles without a sidecar (category L3e) or with a sidecar (category L4e), fitted with an engine having a cylinder capacity of more than 50 cm^3 if of the internal combustion type and/or having a maximum design speed of more than 45 km/h;

(c) motor tricycles, i.e. vehicles with three symmetrically arranged wheels (category L5e) fitted with an engine having a cylinder capacity of more than 50 cm^3 if of the internal combustion type and/or a maximum design speed of more than 45 km/h.

Therefore, when we talk of PTW's, we also have to take into account vehicles with **3 wheels**.

The Motorcycle Industry in Europe, united in ACEM (European Motorcycle Manufacturers' Association) has been active since 1994 in the matter of motorcycle safety, contributing to the establishment of technical European regulations with the highest level of requirements in terms of safety and proposing, launching and managing the first European in-depth study on motorcycle accident (MAIDS, Motorcycle Accident In-Depth Study), which established methodological benchmarking for any similar study.

MAIDS focused on the aetiology of the accidents, identifying the main causative factors distributed in human, mechanical and environmental aspects. The analysis of the causative factors were based on the MAIDS database that contains 921 accidents studied in detail. In order to identify the risk factors, thus identifying the real areas where to intervene for a significant reduction of accidents and casualties, another database of 923 controls (see MAIDS Report, ACEM, 2004, http://www.acembike.org) has been established.

The findings published in the report show several important topics, which have been used by ACEM to define a Motorcycle Safety Plan for Action, aiming at contributing effectively to the European goal of reducing by 50% casualties on the road. The Plan for Action can be downloaded from ACEM website (www.acembike.org).

Main result of MAIDS is to have identified the causative factors to accident causation from an overall scene point-of-view.

The main findings of MAIDS, as indicated in the MAIDS Report, could be split in aspects related to accident causation and consequences They are synthetically reported below.

Accident causation – Accident statistical analysis about risk factors, collision dynamics and other aspects shown:

- the main primary contributing factors were "human behaviour" related (37.1% for PTW rider and 50.4% for the Opponent Vehicle (OV) driver);
- in 10.6% of all cases, PTW rider inattention was present and contributed to accident causation;
- 3.7% of cases involved a PTW tyre problem and 1.2% a brake problem;
- in 36.6% of all cases, the primary contributing factor was a **perception failure** on the part of the OV driver;
- 27.7% of PTW riders and 62.9% of OV drivers made a **traffic-scan error** which contributed to the accident;
- 32.2% of PTW riders and 40.6% of OV drivers engaged in **faulty traffic strategies** which contributed to the accident.
- considering multi-vehicle accidents (about 85% of overall cases) it also has been pointed out that 73% of all PTW riders attempted some emergency manoeuvre but:
    - in 30% of cases there was a **loss of control** (braking, swerving, etc…);
    - in 32.2% there was **no time available** for PTW rider to complete a collision avoidance manoeuvre.

Accident consequences - Rider injuries, type of rider protection and other post-crash events are considered. It is pointed up:

a total of 3644 injuries were reported. Most injuries were reported to be minor lacerations, abrasions or contusions;

- lower extremity injuries made up 31.8% of all injuries;
- upper extremity injuries made up 23.9% of all injuries;
- head injuries accounted for 18.7% of all reported injuries;
- most upper and lower extremity injuries occurred as a result of impacts with the OV or the roadway;
- in 69% of cases, helmets were found to be effective at preventing or reducing the severity of head injury;

- there were cases of helmets coming off the riders head due to improper fastening of the retention system or helmet damage during the crash sequence.

A plan for action – MAIDS results refuted some commonplaces about PTW risk factors indicating that:

- engine displacement does not represent a risk factor in accident involvement;
- speed is not a contributing factor, especially in multi-vehicle accidents (70% of impact speed less than 50 km/h).

Motorcycle safety is a complex concept involving several aspects (preventive, active and passive safety) and several factors (mechanical, human and infrastructural). A matrix approach (See Figure 1) could help to describe all the different areas in which improvement is possible:

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. the safety matrix

On the basis of MAIDS results and the matrix approach, SIM Project aims at evaluating the effectiveness of an innovative vehicle, equipped with state of the art car-derived safety technologies, in real-life accident scenarios.

Safety In Motion (SIM) project aims to cover some of the cells of the "*safety matrix*" focusing on the vehicle safety aspects, including the human-machine-interaction. Other cells are and will be covered by running projects (like APROSYS SP4, SAFESPOT, WATCH-OVER, PISa).

The most relevant element in SIM is the ambitious objective of developing a comprehensive safety strategy for motorcycles, structuring cooperation with existing research projects in order to cover adequately all the different fields of application.

SIM itself is focussing on **vehicle-based** safety applications.

On preventive safety, SIM is implementing and evaluating Human-Machine Interaction systems, based on ADAS technology.

On active safety, SIM is implementing and evaluating dynamic stability control system based on active (electronic) suspension systems, traction control, enhanced anti-lock braking system.

Finally, SIM is implementing and evaluating an integrated protection system to mitigate the consequences of accident. This system will integrate inflatable devices applied on the vehicle with inflatable device worn by the rider (and passenger).

Scientific and Technological Objectives

Last decade is characterized by a relevant increase in EU countries in the number of registration of Powered Two wheelers. This is due to the spread of an utilitarian use of PTW's. New riders choose this transport mode mainly to cover more quickly home-office trips, avoiding queues and parking issues.

This new category of riders is not necessarily interested in riding characteristics neither is fully aware of risks related to improper use.

Focusing on vehicle peculiarities it should be stressed that riding a PTW is a **complex task** and every rider should keep in mind these points:

- PTW rider's are one of the most vulnerable road users;
- PTW balance conditions can be obtained only in dynamic way;
- path change is more complex than a 4-wheelers (by actions involving the whole rider-plus-vehicle system).

On the other side complexity of on-board instrumentation is rising and there is an amount of information to be managed (perception, comprehension and decision tasks are involved), so workload (and risk of distraction) increases and the risk level of having an accident grows.

SIM project would focus on **active** and **passive safety** aspects mainly from a **PTW-point-of-view**. **Preventive safety** will also be covered, especially in considering **Human-Vehicle interaction**.

Active safety – On active safety, SIM is implementing and evaluating a dynamic stability control system based on active (electronic) suspension systems, traction control, enhanced anti-lock braking system. This is because the MAIDS Project has highlighted that loss of control is one of the main problems in motorcycle accidents.

The objective of active safety devices on-board is to improve substantially all elements contributing to vehicle stability and balance. This is required in all riding conditions.

In order to achieve this objective, SIM wants to improve all vehicle subsystems designed to keep wheels rolling with no slither and with optimal grip in the most critical motion conditions:

- acceleration and braking;
- cornering and steering.

Further to that, a new generation Anti-lock Braking System is considered, with a better behaviour in cornering and steering and adaptable on wet road surface conditions.
Electronically controlled suspensions for the optimisation of load-shift in acceleration and deceleration will be implemented, together with a traction control system.

Passive safety – SIM is implementing and evaluating an integrated protection system to mitigate the consequences of accident. This system will integrate inflatable devices applied on the vehicle with inflatable device worn by the rider (and passenger).
Even if main aim of SIM is to avoid accidents, passive safety systems are essential to mitigate consequence in case of inevitable precipitating events.
In order to achieve that, SIM is developing and validating a tailor-made integrated passive system for PTW's.
Algorithms for the activation of the passive system will be adapted and sensors and actuators will be implemented on-board.
Protective devices, located on the rider (e.g. inflatable garment) and on the vehicle (for limbs protection) will be adapted.

Preventive safety – Based on reasons above described, SIM will implement and evaluate Human-Machine Interaction systems, based on ADAS (Advanced Driver Assistance System) technology.
Special focus will be devoted to the innovative dashboard that will be designed to help the rider in getting the correct and adequate information with no workload in excess. The objective is the development of a dashboard providing information on the basis of hierarchical logic that provides the rider with information instantaneously important. The prototype will be compared in effectiveness (reduction of the workload, reduction in reaction time) with an equivalent traditional-design dashboard, available from high-end vehicles.
Helmet will be an integral part of the system, helping in the exchange of information and in control operation, through a radio link. This allows information flow from vehicle to rider and voice-operated controls in opposite way to inquire on-board information system (e.g. phone activation, menu scrolling, and so on…).
In this context, an analysis of existing wireless technologies (e.g. Radio Frequency, Ultra Wide Band, Bluetooth, etc.) will be carried over, as well as an evaluation of technical-economic feasibility.
Also "augmented reality" aspects will be considered, only at theoretical level, as well as non-conventional controls (haptic controls) and non-conventional information display.
The study and development of the above-described devices is based on cognitive ergonomics, bearing in mind the *dual-task paradigm* for the evaluation of the proposed solution effectiveness.
Preventive, active and passive safety aspects will be integrated into the same prototype in order to develop and validate a comprehensive safety strategy for PTW's.

Project Approach

SIM's aim consists in the development and realisation of a **new concept vehicle** that intrinsically enhances PTW safety, merging the **handling** of classic PTW and the **stability** of passenger cars, by developing and implementing **active**, **preventive** and **passive safety** devices.
The project plan deals with the following:

Strategic vision – the Safety Strategy in Motorcycles will be appraised by means of a first identification of the most important (in terms of frequency and severity) accident scenarios that involve this type of vehicles to focus on the worst cases. We will be able to identify problems and needs through the analysis of those scenarios: the project starts from **accident analysis** and main findings performed in the MAIDS project (1999-2004) that is the most relevant research project on motorcycle accidents and the only in-depth analysis at European level.
Nowadays PTW offers an effective solution to problems related to urban transport and leisure. Its diffusion is desirable and useful in terms of quality of life, environmental impact and fuel consumption. So, the flexibility of use and the easiness in handling, especially developed on recent models, attract new customers, unused to the risks of motorcycles: running a motorcycle is a complex task, involving a level of risk of having an accident that cannot be underestimated.
However, the development and realisation of a new concept vehicle that intrinsically enhance PTW safety, merging the handling of classic PTW and the stability of passenger cars, will positively affect, in the SIM consortium opinion, this share of PTW accidents reducing drastically its negative consequences in terms of injuries and fatalities.

Technical targets – SIM will focus on **Active, Preventive and Passive Safety** systems on-board of the motorcycle deploying innovative technologies in order to bring the development of an enhanced-safety vehicle, contributing to the fatalities reduction on European roads.
This will be managed by studying and implementing Powered Two Wheelers (PTW) dynamic systems for what concerns active and preventive safety, while passive safety will focus on rider protection systems fitted both on the

vehicle and on those rider protection systems worn by the motorcyclists but operated by devices fitted on the vehicle.
The state of the art in passenger car will be implemented in SIM's new concept, studying an "ad hoc" design for PTW's, especially for **active safety** technologies.
The aim is the development of an Integral Dynamic Stability Control that integrates and manages single electronically controlled subsystems (ABS system, traction control and suspension systems) in order to optimise vehicle control and stability performances, acting on grip, load transfer, avoiding slither and so on. Although SIM will do all the effort to reduce the event of a crash, it cannot simply dismiss it.
SIM will include also the implementation of innovative **passive safety** devices on the concept vehicle such as airbag, inflatable garments and lower limb protective devices, taking into account potential benefit of airbag technologies in selected scenarios, considering problems related to the wide range of possible outcomes of a two-wheeler accident. The injury mechanisms involved differ very considerably form those found in car accidents. SIM will carefully consider the critical importance for the successful development of any safety device of the study of all impact configurations, not only those likely to give rise to the sort of injuries under study, but also all other configurations, so to ensure that there is no increase in the risk of other types of injuries.
The use of innovative technologies and systems will open new opportunities in the development of Human-Machine Interaction (HMI) for a **preventive safety** issue, which is a relevant concern, and almost undeveloped in motorcycles and scooters.
SIM will study and develop an HMI design, aiming mainly to minimize workload and distraction imposed by In-vehicle Information Systems (navigation systems, vehicle-to-vehicle communication systems, phone systems). Maximisation of the safety benefits of new Advanced Driver Assistance Systems will be considered, by establishing links with other running projects focused on Intelligent Transportation Systems (ITS), with specific development on motorcycles: this communication flow between the rider and the motorcycle systems will be established through the helmet.
The use of ITS applications which can influence the behavior of a motorcycle - for example by applying the brakes or regulating the fuel management system - should always be optional, and only considered when it has been demonstrated that they will not destabilize a motorcycle in a range of conditions and circumstances. Because of PTW's dynamics, some ITS applications will not be able to be adapted to motorcycles, or may not be cost effective. Traffic management applications of ITS should be developed to include motorcycles and could usefully be adapted to give them priority over other vehicles.

Prototype development – All the devices and systems studied and implemented in the first phases of the project, will be integrated, as it is intended to generate a prototype as **Integral Safety Solution** that will be further tested to prove its structural integrity and to ensure its capability of contributing to the European Commission goal of reducing fatalities in the European roads;
An **integrated safety approach** is followed and addressed in two ways:

(a) In order to give a contribution to the spread of PTW, the aim of SIM consists in making PTW safer, by following the philosophy of "maximum control with minimum effort". SIM will provide an "easy" vehicle in every sense, letting the pilot pay attention only to the traffic and the way. SIM expects to intervene and provide solutions from *before the precipitating event* (i.e. the time from which the crash is inevitable) until *after the crash*, mitigating its consequence.
(b) All above is related to on-vehicle technologies and devices. However, the consortium endeavours to establish links with all on-going, past and present projects related to motorcycle safety in order to guarantee a 360° outlook for improving motorcycle safety records.

Not only the tests will be used as **dissemination** mean but also intermediate and final results will be disseminated in conferences, workshops, publications, sharing of information with the main stakeholders involved in the field and the creation of a web site.

Overall description of the project plan

The work in SIM project will be divided in six Workpackages (WP). A brief description of their contents is described in the table below (See Table 1):

Table 1.

Project structure and description

WP#	Title and short description
WP1	**Project management** To manage and coordinate consortium activities.
WP2	**Safety Strategy** To identify main parameters affecting PTW accident dynamics in main accident scenarios and establish a "safety strategy" for motorcyclist and links with other R&D projects about road safety.

WP3	**PTW Active safety** To focus on an improved motorbike concept design in order to enhance the motorcyclist's safety through the improvement of active safety devices (suspensions, brakes, traction control). Further, preventive safety will be considered in terms of HMI and improved comfort.
WP4	**PTW Passive safety** To develop effective passive safety systems for motorcycles that act in case of accident, mitigating the consequences of the crash event.
WP5	**Integral Safety solution** To demonstrate the feasibility of integrated safety concepts applied on motorcycle through definition of test bed. Technical tests will be run and evaluation of cost/benefit ratio in terms of potential reduction of accidents and mitigation of consequences will be performed.
WP6	**Dissemination and Exploitation** To organize and harmonize the spreading of information and results generated with regard to integrated safety on motorcycles; To evaluate guidelines for standardisation activities and market acceptance of the innovative devices analysed and implemented during the project.

Methodology approach

The activities of the project are carried out by six workpackages:

WP1 Project Management – The first work package will take in charge the overall co-ordination of the project, in order to ensure the management of the activities regarding Financial and Technical Administration of the Project, establishing an Executive Committee and including an activity of Quality Assurance.

WP2 Safety Strategy – WP2 will start at the beginning of the project and last 6 months with the goal of identifying accident scenarios and to evaluate technical solutions and potential improvements effectiveness. Moreover, activities that will be carried out in this work package will be devoted to links and collaboration with other R&D projects focusing on motorcyclists safety.
DEKRA will be the leader of the work package with the participation of PIAGGIO across all the activities and the support of CIDAUT in the accident analysis.

WP3 PTW Active Safety – The work package has an overall duration of 14 months and deals with the identification of the most promising technical solutions related to active and preventive safety.
Main work package activities will consist in the definition of active and preventive safety, vehicle dynamic systems, electronic control of active systems implementation, HMI and comfort, active and preventive safety systems integration.
CRF will be the leader of this project, being involved in the design and development of the specific preventive safety applications and of the related HMI Systems, with the participation of several partners for the definition of the concept (PIAGGIO), for the vehicle system definition (UNIPI, CONTI), for the electronic system (CIDAUT, CONTI, OHLINS) for the HMI and comfort (PIAGGIO, NZI) and for the integration (PIAGGIO, CRF, CONTI).

WP4 PTW Passive Safety – The work will begin focusing on the development of highly effective passive safety systems for motorcycles that act in case of crash event. The main actors in the field of passive safety, during a period of 14 months and led by CIDAUT, will work each one on their specific field of knowledge: vehicle, helmet, electronic control unit and airbag. DALPHIM and UNIPI will provide their contribution in the definition of the concept, rider protection system and system integration; CONTI will take part in the definition of the electronic control system and provide sensors and actuators. PIAGGIO will cooperate in the definition of the concept.

WP5 Integral Safety Solution – This work package will establish the feasibility of integrated safety concepts applied on motorcycle, defining technical tests to be run, technical assessment of the overall integrated system and the HMI strategies, evaluating in terms of potential reduction of accident events and potential mitigation of their consequences. Within a total period of 22 months, PIAGGIO will lead this part of the project, with the support of UNIPI in Integrated System Specification, of CRF for the integration of active and preventive safety systems on-board, of CIDAUT for the integration of passive safety systems, and of DEKRA for the activity of testing and evaluation.

WP6 Dissemination and exploitation – It is responsible for correct and widespread dissemination of information and results generated with regard to integrated safety on motorcycles. CTUP will be the leader of this work package, with the participation of PIAGGIO in both of the tasks.

THE CONSORTIUM AND PROJECT RESOURCES

Consortium Overview

Table 2.
List of participants

Organisation legal name (Short name)	Experiences
PIAGGIO & C. SpA (PIAGGIO)	World motorcycle manufacturer and project coordinator
Foundation for the Research and Development in Transport and Energy (CIDAUT)	Centre of excellence in the Transport and Energy sectors with high specialization in Technological R&D, Diffusion, Transfer and Training
Continental Teves AG&Co. oHG (CONTI)	World's leading manufacturer of brake and stability control systems and major electronic supplier
Centro Ricerche Fiat ScpA (CRF)	European car manufacturer
Technical University of Prague (CTUP)	European research institute with competencies in design, organisation and control of transportation processes
DALPHIMETAL ESPAÑA S.A. (DALPHIM)	European airbag supplier
DEKRA e.V. (DEKRA)	International service provider for Accident Research and Crash Test
NZI HELMETS (NZI)	Small OEM focused in helmets design and production
OHLINS RACING AB (OHLINS)	Leading manufacturer of suspension for cars and motorcycles
Savatech d.o.o., Industrial Rubber Products and Tyres (SAVA)	Rubber compounds and tyres manufacturer for motorcycles and industrial vehicles
University of Pisa (UNIPI)	European research institute with expertise in vehicle dynamics analysis and design
University of West Bohemia – New Technologies Research Centre (UWB)	European research institute with high compentencies in CFD simulation and impact dynamics analysis

A complementary and self-consistent Consortium

The participants in SIM represent a well-balanced consortium, including representatives of all relevant actors involved in the development and integration of systems for road safety as well as representatives of the scientific and academic world.

Within the consortium, Piaggio, as leading motorcycle manufacturer, guarantees the integration of the different systems for active, preventive and passive safety on a motorcycle concept for innovative and advanced rider safety, also providing the specifications for the actual implementation of the systems; Continental Teves and Ohlins, respectively leaders in braking systems and semi-active suspensions, provide expertise and scientific knowledge on the specific devices, while Sava contributes with its competencies in design, development and testing of motorcycle tyres.

CIDAUT, Centro Ricerche Fiat and Dekra support the consortium with their methodological expertise and technological knowledge. The three institutes will have specific tasks to perform in the project:

- CIDAUT supports the Coordinator in his tasks having an operational and administrative role. Its main contribution to the project is the leadership of WP4 “Passive Safety”. In this WP, passive safety systems located on the rider and fitted on the vehicle will be investigated as well as the correct performance of the integral system.
- CRF main contribution to the project is the overall management of WP3 “Active Safety” as well as the active participation in WP2 “Safety Strategy” for the definition of the application scenarios that will become the reference scenarios for the system implementation to improve the safety of PTW.
- Dekra ensures the leadership of WP2 “Safety Strategy”, with the development of the knowledge foundation of the project. The identification of safety scenarios will provide the consortium with the elements of investigation related to the safety technologies to be implemented on motorcycles.

The Universities of Pisa, Prague and West Bohemia provide the scientific background as well as the expertise in modelisation of dynamic systems and the study of biomechanics for the rider protection systems. Furthermore, Prague and West Bohemia

are responsible for the implementation of the dissemination activity, in cooperation with the coordinator.
Dalphimetal provides the necessary expertise in the development and implementation of passive safety devices, while NZI contributes its expertise in helmets both in terms of passive safety improvement and, more important, the study of ergonomics (physical and cognitive) to improve preventive and active safety.
This unique blend of expertise and knowledge guarantees consistency in the implementation of the project, robust results and real exploitation of the findings.