Final Report Summary - APROSYS (Advanced Protection Systems)

The goal of the APROSYS project was to offer a significant contribution to the reduction of road victims in Europe and in this way contribute to the road safety goals of the European Commission as defined for instance in the White Paper for transport. The general objective of APROSYS was the development and introduction of critical technologies that improve passive safety for all European road users in all relevant accident types and accident severities. Furthermore, APROSYS aimed to increase the level of competitiveness of the European industry by developing new safety technologies (safety is a proven selling point) and by developing design tools (computer-aided design (CAD)) and evaluation methods that will increase the efficiency of the development process of the involved industries.

Passive safety is one of the most important and effective strategies to reduce the number of road traffic victims. This strategy protects traffic participants in case an accident is happening by reducing the loads on the human body during the accident by technological measures like for instance restraint systems and vehicle designs. Passive safety has proven to be a very effective strategy to reduce the number of casualties among road users. For example, a study in the United Kingdom demonstrated that the greatest contribution to casualty reduction was from passive safety improvements to vehicles in the period 1980-1996. These measures accounted for 15 % reduction in casualties compared to 6.5 % for road safety engineering measures.

The vision of the APROSYS project is that also in the next 30 years not all accidents can and will be prevented, in spite of very impressive developments in accident avoidance (accident-free traffic) and that in case of an accident is happening a significant higher level of protection can be offered though new secondary safety technologies. In particular, technologies that combine active safety and passive safety strategies and more specifically also strategies that use information from the pre-crash phase to affect the crash phase are seen as very promising to reduce to the number of fatalities and the number and severity of injuries. This area is often identified as integrated safety. APROSYS focussed on the scientific and technology development in this area. The field of passive and integrated safety concerns in particular human biomechanics (injury mechanisms and criteria), vehicle and infrastructure crashworthiness, sensing and control and occupant and road user protection systems.
To reach these goals the emphasis in APROSYS has been placed on research and development (R&D) topics with the greatest fatalities / injuries reduction potential. The choice for these topics was based among others on the PSN roadmap, state of the art of technology reviews and extensive discussions with stakeholders. This resulted in the following seven scientific and technological objectives:
1. new injury criteria and injury tolerances;
2. new mathematical models of the human body;
3. new world-wide harmonised crash dummy;
4. new knowledge and tools for intelligent safety systems;
5. enhancement of virtual testing technology;
6. new test methods (for advanced safety systems);
7. advanced protection systems for injury reduction in most relevant accident types.

These seven project objectives have been evaluated on a regular basis. They remained valid until the end of the project.

In case of accidents with pedestrians and pedal cyclists, the focus is on impacts with the front of passenger cars with special emphasis on injuries to children and elderly. Concerning car to car accidents the focus is on the protection of car occupants in front and side impacts. In case of heavy trucks accidents involving vulnerable road users and passenger, cars striking the side of a truck will be considered and for motorcycle accidents the focus is on collisions with passenger cars and the infrastructure.

Based on general European accident data in APROSYS the following accident types have been selected as the most relevant ones for developing new advanced passive and related integrated safety strategies:
- SP1: car accidents concerning the protection of car occupants including improved protection in car to roadside obstacle accidents and improved compatibility in car to car accidents;
- SP2: heavy truck accidents concerning accidents with pedestrians and accidents with passenger cars;
- SP3: pedestrian and cyclist accidents due to impact by a passenger car;
- SP4: motorcycle accidents with infrastructure and passenger cars.

In addition to the four accident type sub-projects, three technology focussed sub-projects have been defined (horizontal activities):
- SP5: injury biomechanics, dealing with new knowledge on injury mechanisms, injury criteria and human substitutes;
- SP6: intelligent safety systems, dealing with advanced sensor (pre-crash sensing) and actuator technologies;
- SP7: virtual testing, dealing new computer simulation technologies.

Within the project, many detailed results were delivered, varying from new protection methods, design tools (CAD) tools to new test and evaluation methods. In order to structure the various results, they were integrated into the so-called 10 main results, all having a large impact on the safety problem. These 10 main results (MR) that together fully address the seven project objectives, were:

MR 1: New human body mathematical models
A number of human body mathematical modelling activities has been performed, dealing among others with active human body models for studying the pre-crash phase and the effect of age and gender on the structural behaviour of the human body, combined with related injury risks for several body parts. The thorax, shoulder, abdomen, neck and leg have been addressed, also for the head, these relations were established. Concerning the brain, based on new animal tests, improved constitutive models were implemented and detailed accident reconstructions were carried out in order to gain a better understanding of the injury mechanisms and to define injury criteria for the brain.

MR 2: WorldSID fifth percentile female dummy for side impacts
A new world-wide harmonised crash dummy has been developed in the framework of APROSYS. This has been deemed as the WorldSID 5th, a small female dummy for side impacts based on the 50th percentile version of this dummy. In 2006, the first prototype was released. After an extended series of evaluation tests and international discussions about harmonisation, a second prototype has been realised recently. This prototype is being under final evaluation now (outside of the APROSYS framework).

MR 3: Side impact protection system for car occupants, using pre-crash sensing
A new side impact protection system for car occupants was developed. Basically, it consists of a sensing and an acting part, linked through a decision logic unit. The sensor system is built around fusion of the data of radar and stereo vision, covering the side of a car. Based on the input from this sensor system, the decision logic can until a minimum of 200 ms ahead of a side crash, release an actuator mechanism based on shape memory alloy in the side structure. This system supports mitigating the severity of the side
impact by reducing the door velocity and intrusion. The side impact protection system has extensively been tested also in full scale test environment.

MR 4: Generic assessment methodology for advanced pre-crash safety systems
A clear trend in automotive safety is towards integrated safety, and towards application of adaptive safety systems. However, there is not yet a well-established test procedure for evaluation of such systems available. To cover this need, APROSYS has developed a generic assessment methodology for adaptive safety systems, taking into account the accident scenarios the system is intended for, the types of sensors used, etc. Using this assessment methodology gives a clear and independent insight in the effectiveness and efficiency of the system under evaluation.

MR 5: Generic car mathematical models
In developing new safety measures for all road users, application of computer modelling for analysing the crash has become common practice in many companies and institutes. However, vehicle models used for such studies are usually in-house developed models representing a specific single vehicle type. There is a clear need for a set of generic vehicles models representing various vehicle classes that can be applied in a range of accident conditions and scenarios, including vehicle to vehicle, truck to vehicle, vehicle to pedestrian and vehicle to motorcyclist impacts. Such a set of models has been successfully developed within the framework of APROSYS for different types of techniques, such as finite elements and multi-body models.

MR 6: Virtual testing methodology
Certainly, the future of vehicle and component testing for regulatory purposes will include virtual testing. The enhancement of the actual virtual testing technology for passive safety and the discussion and preparation of virtual testing tools for future regulatory purposes, have been major objectives for APROSYS. Virtual testing in vehicle safety is nowadays used very extensively in the vehicle design process, including the development of safety features. APROSYS has developed guidelines how to implement virtual testing in the regulatory environment and which analysis criteria to be used. This has been done, using demonstrators for analysing pedestrian safety based on a hybrid approach using a multi-body model for overall kinematics and a finite element (FE) modelling approach for detailed local injury prediction. In a virtual testing roadmap, the path to implement virtual testing in current and new regulations has been described.

MR 7: Test methods for vulnerable road users
For vulnerable road users, i.e. pedestrians and (motor) cyclists, the main focus was on new evaluation methods. These evaluation methods include:

1. Vulnerable road users impacted by heavy vehicles. For this, a heavy vehicle aggressivity index (HVAI) has been developed. This index gives an indication of the risk of a heavy vehicle truck in case of an impact with other road users. There are three subjects in this index: a run-over factor, a vehicle structural factor and a field of view factor.
2. Vulnerable road users impacted by passenger cars. This includes new test procedures for pedestrian safety, including virtual and experimental testing and new impactors for head impact testing. In the work done here, it has become apparent that cyclist cannot be seen as a subgroup of pedestrians.
3. Motorcyclists. This includes the development of a reviewed standard for helmet testing, a road and misuse test standard for the deployment of active safety systems and a proposal for test procedures to evaluate road infrastructure in terms of motorcyclist safety.

MR 8: Full width frontal impact test for Europe
To assess the car's frontal impact crashworthiness, including its compatibility, an integrated set of test procedures is required. The European Enhanced Vehicle-safety Committee (EEVC) compatibility and frontal impact working group has recommended that this set of test procedures should contain both a full overlap test and an offset (partial overlap) test. Currently in Europe, only an offset test exists in regulation and consumer test programmes (EuroNCAP). Within APROSYS, a full overlap test protocol appropriate for be used within Europe has been developed and evaluated. The evaluation considered issues such as the effect of having a deformable element in the test compared to a rigid wall and potential assessment of the rear seat positions.

MR 9: New side impact test methods
In 2005 the International Harmonisation of Research Activities (IHRA) side impact working group proposed a four part suite of test procedures, to form the basis of harmonisation of side impact regulation world-wide and to help advances in car occupant protection. The four parts of the proposed procedures were: a mobile deformable barrier test, an oblique car to pole side impact test, an interior headform tests and a series of side out-of-position tests. APROSYS has evaluated and developed this procedure further focus on a European perspective. One of the main achievements of the APROSYS work was the development of a new advanced European mobile
deformable barrier (AE-MDB), a test including a new deformable barrier and the use of the WorldSID dummy.

MR 10: New protection systems for vulnerable road users
A large number of new protection systems for vulnerable road users have been developed within the framework of APROSYS. Examples are a safety bar add-on for trucks, active bumper strategies and pedestrian airbags on the windshield, an improved helmet design for motorcyclists and a thorax protector for motorcyclists. The commercial version of this thorax protector is planned to enter the market mid 2009. It therefore is a very good example of how international cooperation in EU projects leads to new, innovative products.

The impact of the results and the research carried out in APROSYS on the European safety problem will become visible only to a small extent before 2010. The long lead time for the introduction of safety systems normally applicable in the automotive market and the slow renewal of the vehicle fleet, makes accordingly the impact of APROSYS largely to be expected in the period after 2010. General estimates on the future effect of passive safety measures have been made in the roadmap of future automotive passive safety technology development. Estimates made by vehicle safety experts here are dependent on the collision type. The largest effects are predicted for frontal impacts namely a 50 % fatality reduction due to new passive and integrated safety measures. For frontal impacts this is due to, among others, compatibility measures and the large scale introduction of intelligent safety systems. For side impacts a fatality reduction due to passive safety measures of 40 % is predicted and for motorcycles and pedestrians, respectively 25 % and 30 % in this roadmap.

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