OSCCAR:

FUTURE OCCUPANT SAFETY FOR CRASHES IN CARS

Report on implementation effects, impact and benefits through use of HBMs for future interior development using fully integrated occupant assessment throughout the complete accident scenario

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1 EXECUTIVE SUMMARY

This report summarizes three cases which were done in the OSCCAR project and which contribute to the OSCCAR goals in terms of virtual assessment, occupant diversity, new accident scenarios, new restraint principles and improved injury prediction. An overview is given in Table 1, followed by a description for each case and a benefit and impact description of the cases. Each of the demonstrated cases can be found in more detail in two of the OSCCAR deliverables (Deliverable Deliverable D2.4 [1] and Deliverable D4.3 [2]).

2 OBJECTIVES

OSCCAR aims to contribute to a number of upcoming aspects in the development of occupant safety strategies:

- Automated driving causes new accident scenarios
- New sitting positions will be possible, and therefore restraint principles need to be enhanced
- Enhance injury prediction (study injury mechanisms on a tissue level) and therefore injury prevention capablity
- Occupant diversity should be considered
- The development of harmonized continuous virtual assessment processes

Human Body Models (HBM) are an enabler (and currently the only possiblilty) to study most of the mentioned points and are therefore used throughout the project.

To demonstrate the impact, benefit and the contribution to these topics by the OSCCAR project, three OSCCAR cases were selected for this report. Finally, an estimation for market penetration of automated driving related aspects like new sitting positions is given.

3 DESCRIPTION OF WORK

OSCCAR aims to contribute to the further development of vehicle occupant safety, by enhancing the knowledge, methods and principles in the following points.

The possible new accident scenarios which will happen due to automated driving were determined (WP 1). Further, new sitting positions will be possible, which was also considered. That leads to the need of new restraint principles. The diversity of the population, the possibility to assess injury risk on a tissue level and allowing a continuous assessment are advantages of HBMs, which play a major role in the OSCCAR project. To demonstrate the benefit and the impact of the developments in OSCCAR, three cases were chosen as examples. The following table gives an overview, how the chosen examples contribute to the complete OSCCAR story.

	Homologation test case	**WP 2 – Protection Principle 3 (Reclined occupant)**	**WP 2 – Protection Principles 6 (Far Side)**
Application of OSCCAR Tools / Methods	Comparable simulations due to agreed methods (aligned assessment approach) Continuous assessment approach	Selection of cases (Deliverable D2.1 [7])	Selection of seat positions (Deliverable D 2.1 [7])
Diversity	-	Obese	-
New sitting postures	48 degress reclined	Variety of sitting postures (25, 48, 60 degrees reclined)	No centre console → living room / camp fire configuration possible → see OSCCAR Deliverable D2.1 [7]
Enhanced restraint systems	SOTA DLPT	Seat integrated countermeasures for submarining (energy absorption)	Seat mounted protective measures SOTA DLPT + seat side support, inverted belt
Outlook to improved injury prediction	Rib injury risk	Submarining – loading to pelvis and lumbar spine	Rib deflections, section forces for upper/lower neck + L5. Skeleton fractures for platic strain > 2%

	Homologation test case	WP 2 – Protection Principle 3 (Reclined occupant)	WP 2 – Protection Principles 6 (Far Side)
New accident scenarios / Scaling to future prospective accident expectations	OSCCAR: LTAP OD2 (WP 1)	Use case evaluation with Deliverable D2.1 [7] Urban areas (year 2030), L4/L5 vehicle Remaining crossing intersection determined in Deliverable D1.3[10]	Remaining crossing intersection determined in Deliverable D1.1 [4] using Swedish database
Additional information			THUMS / WorldSID comparison

Table 1 Contribution to the OSCCAR story

3.1 OSCCAR Homologation test case

3.1.1 OSCCAR Homologation test case overview

To consider the pre-crash phase for the in-crash simulation requires virtual assessment, since both phases can not be tested in real world crash tests within a single test run. That means, that a continuous assessment approach also needs to be applicable for ratings and homologations. Therefore, a clear defined virtual homologation procedure will be needed. The OSCCAR project did a homolgation test case scenario which contains a continuous assessment with several participating project partners. To achieve that, boundaries and assessment procedures were defined to ensure comparable results. The chosen sitting posture was a 48° reclined sitting posture, which requires the usage of HBMs, since currently available crash test dummies are validated for upright sitting positions.

3.1.2 Case summary

The OSCCAR Homologation test case is performed in a pre-defined (and validated) environment for three different solvers codes (LS-Dyna, VPS, Madymo). The environment consists of a model of the LAB seat [1] and a partly encrypted belt model which was provided by Autoliv. Validation tests and simulations for all codes were done in Workpackage (WP) 2 and documented in Deliverable D2.5 [5].

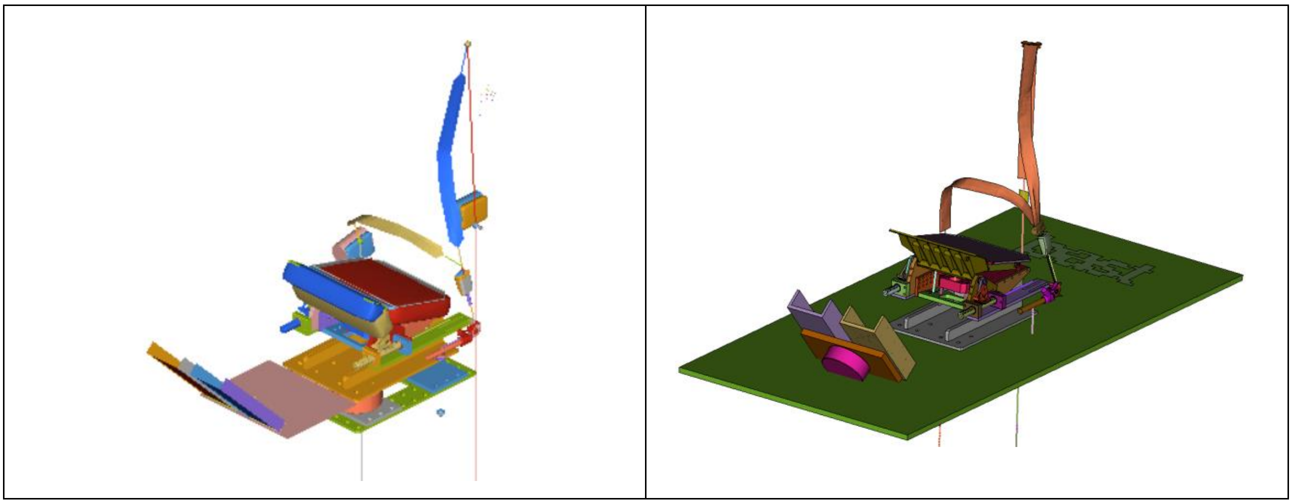

Figure 1 LAB CEESAR seat models (FE / MB)

For the Homologation test case, the partners positioned their 50% male HBMs to a pre-defined 48° reclined seat back, using the positioning tool and method developed in Task 4.2. and reported in Deliverable D4.2.[11]. The target positions for the anatomical landmarks were taken from literature [8].

Two pulses were used for in-crash simulations. In a first step, the partners used the same pulse as in the validation simulations, which was a 50 kph full-frontal pulse defined in [3]. The second pulse was determined in WP 1 and is a “Left Turn Across Path – Opposite Direction” (LTAP OD2, OSCCAR Deliverable D1.3 [10]). That pulse was used for a standalone in-crash simulation and in addition a pre-crash pulse (OSCCAR WP 2) was added, to demonstrate a continuous assessment approach.

Based on harmonized definitions for HBM outputs and aligned post-processing, it is possible to conduct an injury risk prediction. Therefore steps for a harmonized rib fracture risk assessment were considered as reported in OSCCAR Deliverable D3.3. [15]

Head injury risk assessment was done with the SUFEHM tool, which also requires a certain (and therefore harmonized) definition of the HBM kinematic outputs.

Further the influence of the pre-crash phase to the in-crash phase was analyzed. A detailed documentation can be found in Deliverable D4.3 [14].

3.1.3 Contributions / enhancements in OSCCAR

The homologation test case contributes to the OSCCAR storyline mainly in two points:

- **Impact of demonstrating a continuous assessment approach**
    - The OSCCAR homologation test case showcases a possible continuous virtual assessment approach. That allows to consider occupant kinematics in the pre-crash phase for in-crash simulations,
    - Restraint systems can be enhanced, and pre-crash functionalities can demonstrate their benefit on protecting the occupant during the in-crash phase,
    - As this is not possible in a real world test case with crash test dummies, virtual assessment is necessary.
- **Impact of “Aligned harmonized assessment approach”**
    - A procedure was demonstrated which shows a possible way how comparable HBM simulations could be achieved. That requires a harmonized environment (seat, belt, pulses) and a harmonized assessment of the HBM kinematics (landmark trajectories), and its interaction with the environment (contact forces) as well as the environment behavior itself (e.g. belt pull in/out),
    - For any kind of virtual assessment approach, certified HBMs would be useful. Certifying an HBM requires the same boundaries as it was shown for the Homologation test case. Hence, the demonstrated procedure can also be seen as a basis for a HBM certification process.

3.2 Protection Principle 3 – Variety of sitting postures with an obese occupant

3.2.1 PP3 overview

The Protection Principle (PP) 3 used in the investigation focuses mainly on seat pan or seat belt-integrated protection principles, addressing the risk of submarining. It is assumed that when the seat is positioned away from the instrument panel or in a living room layout, the risk of submarining will increase especially in the reclined occupant position, and even if submarining is avoided the consequences will be increased loading to the pelvis from the lap belt, and increased lumbar spine loading due to unfavourable kinematics, with the upper body loading the lumbar spine when pitching forward. To address these issues, multiple innovative solutions and studies were conducted by various partners like influence of seat and lap belt load limiting for upright and reclined occupant postures, avoidance of submarining in a reclined seating position and reduction of pelvis and lumbar spine loads, double lap belt pre-tensioning, energy absorbing seat structure and influence of different postures on occupant loading and kinematics. In the section below, one of studies focusing on energy absorbing seat structures showcased to address the risk to normal and obese occupants travelling in reclined seating configurations.

3.2.2 Case summary

In the baseline studies conducted in Deliverable D2.1 [7] these two perspectives are discussed in Case 3, which comprises an obese occupant in a reclined seating posture. It is observed that in such a seating configuration, high loading on the thorax and lumbar spine is one of the major concerns for obese occupants. Therefore, the aim of this study performed by Mercedes is to develop a concept to reduce loads in the thoracic and lumbar regions by the introduction of a seat track load limiting (LL) system based on the generic vehicle environment developed in Deliverable D2.1 [7] for both 50th percentile male and obese occupants. The seat track load limiting function was incorporated in the OSCCAR generic seat system [7] by modelling it as simplified one-dimensional elements. The characteristics of these one dimensional elements are intended to represent a mechanical device which dissipates energy by shearing action in the metallic structure. The seat track LL system was represented by two modules in left and right seat track proximity. The seat was then integrated into the sled environment developed and discussed in Deliverable D2.1 [7]. Seat pan and backrest were rotated by 60° relative to the floor of the generic vehicle. The generic full-frontal crash pulse defined in WP 1 was used to evaluate the seat track LL system characteristics where the collision velocity was 40 km/h (FF40). No airbag system was deployed in the seat track LL system and contact settings regarding the instrumentation panel were deactivated. In this study a seat-integrated belt system with a belt load limiting of 2.1 kN and of 4 kN was used for the 50th percentile male occupant and for the 50th percentile obese occupant respectively. Figure 1 shows the sled set-up with the 50th percentile obese occupant in the reclined seating posture and the pulse used.

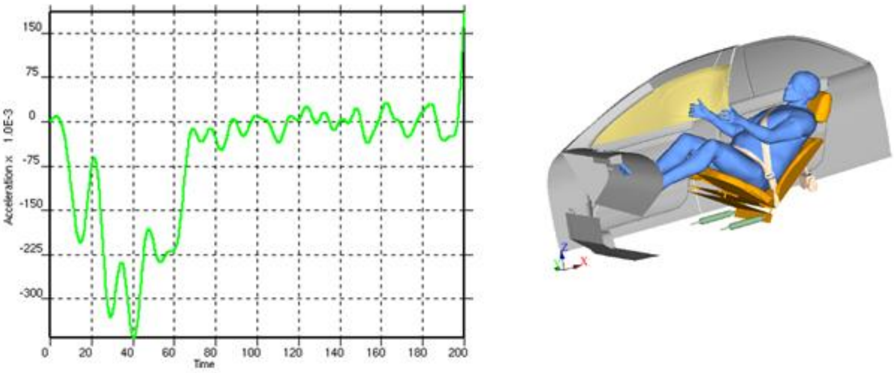

Figure 2 Sled set-up and pulse used for 50 %ile obese occupant

Based on harmonized definitions for HBM outputs and aligned post-processing, it was possible to conduct an injury risk prediction.

3.2.3 Contributions / enhancements in OSCCAR

The PP3 contributes to the OSCCAR storyline mainly from the perspective of conducting virtual assessments for diverse populations with the use of human body models. Within OSCCAR, in Deliverable D3.1 [13][13] 50th percentile male Obese model (THUMS-D v4 Obese HBM) was updated and validated. The modeling aspects focused on distinct representation of Visceral Adipose Tissue (VAT) layer and Subcutaneous Adipose Tissue (SAT) layer and additionally on the skin properties. In PP3, this updated model is used for conducting virtual evaluations for reclined seating configurations. The updates in the model and harmonized approach to monitor and post-process lumbar section forces enabled to showcase the benefit of the energy absorbing seat structure concept. The modified obese model also helps to address limitations of existing restraint systems and areas where new concepts can be explored for diverse populations.

3.3 Protection Principle 6 – Far-side load case

3.3.1 PP6 overview

The PP6 aims at evaluating a seat-mounted protection measure that would allow different seat positionings as expected in future AD vehicle interiors. Depending on the vehicle interior seat configurations (different seat orientations, seat track adjustements, seat back inclination…), the occupant interaction inside the car may vary and it would be important to confirm the same safety level as in nowadays cars for standard seat and occupant positions in the case of a crash.

3.3.2 Case Summary

OSCCAR Deliverable D1.1 [4] highlighted intersection collisions in urban and rural areas as the most frequent remaining accident scenarios after filtering out the avoided accidents by AD cars and running pre-crash simulations with activation of an automatic emergency manoeuvre. Using Swedish data, VCC (Volvo Car Company) showed that side impact collisions for AD cars would represent 20% of the remaining intersection collisions. This crash configuration was picked-up to investigate possible protection principles considering as well the current focus on the far-side occupants in Euro NCAP assessment.

PP6 test case selected by OSCCAR combined a side load case and a “living room” interior use case as shown in Figure 3. The protection of a rear-seat occupant sitting on the non-struck side and restrained with PP6 was assessed.

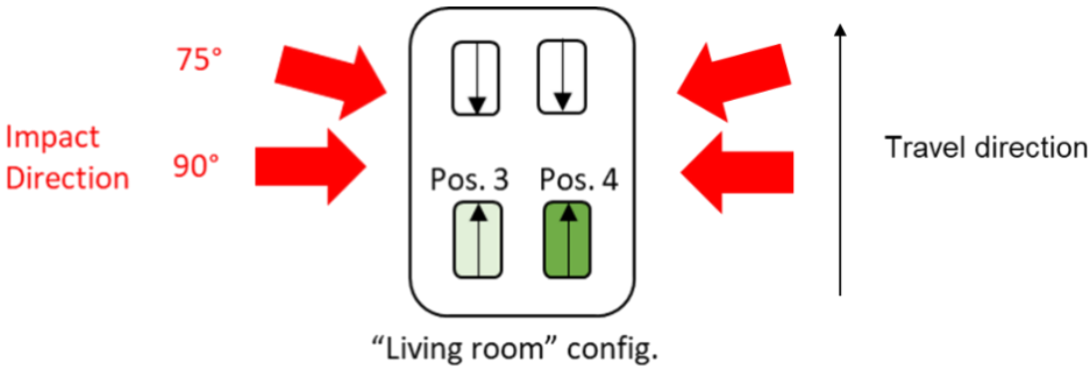

Figure 3 Far-side test case

PP6 integrated a double lap belt pretensioning and seat side supports. An inverted belt was also investigated but the combination of the double lap belt pretensioning and the seat side supports was found to best compromise the occupant excursion and the occupant injury assessment values. Further details on the simulation and sled test results can be found in Deliverables D2.4 [1] and D2.5 [5] respectively.

The test environment used at CTAG-IDIADA and the corresponding simulations run under LS-Dyna and Madymo are shown in Figure 4. The environment used to evaluate the PP6 consisted of a rigid inclined seat pan, a rigid frame as backrest, a rigid footrest, rigid belt anchorage points adjusted to simulate a seat-mounted belt. The PP6 included the double lap belt pretensioning, also used in the homologation test case, and seat side supports. The latter were simulated by two rigid plates covered by a 50 mm layer of Ethafoam TM 180 (Figure 4).

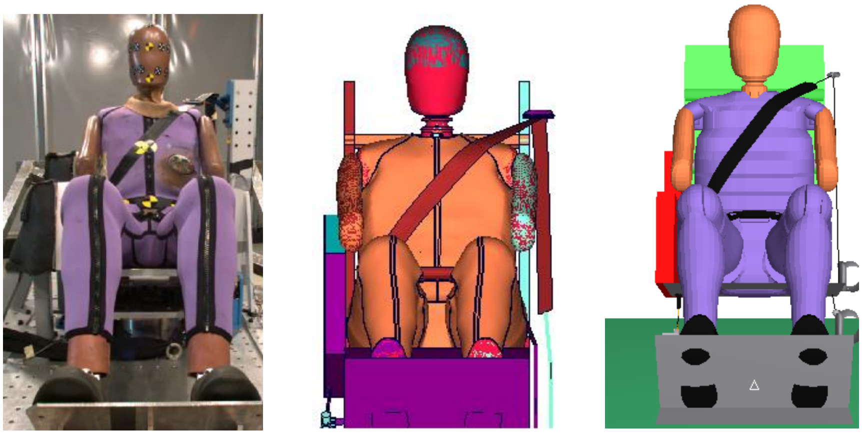

Figure 4 Test set-up (left), corresponding LS-Dyna (middle) and Madymo (right) models for PP6 evaluation

The pulse applied to the environment was identical to [6]. The pulse direction and magnitude are shown in Figure 5 and Figure 6.

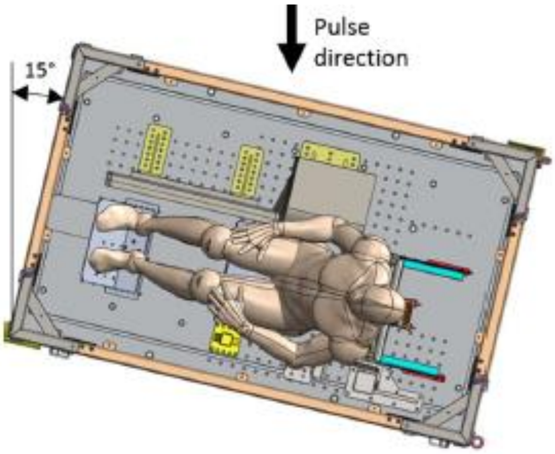

Figure 5 Test set-up

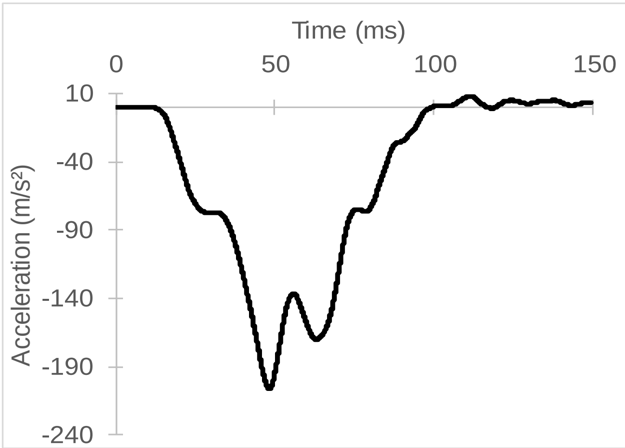

Figure 6 Pulse at 8 m/s [1]

PP6 was evaluated using the Total Human Model for Safety (THUMS) v4.1 50th percentile male. THUMS head COG excursion, rib deflections and section forces at upper and lower neck, and at the 5th lumbar spine vertebra were extracted. Fractures of the skeleton were also assessed.

The head excursion and the injury prediction given in sled tests using the WorldSID dummy and in simulations using THUMS correlated well for the double lap belt pretensioning and seat side support configuration of PP6. This configuration limited the excursion of the occupant and therefore little difference between WorldSID and THUMS kinematics was observed. In other PP6 configurations (with the double lap belt pretensioning only), the difference in head excursion between the two human surrogates was significant (more than 150 mm).

3.3.3 Contributions / enhancements in OSCCAR

OSCCAR developed a methodology that allows the definition of new protection principles for automated driving (AD) cars considering future relevant accident scenarios as well as future use cases predicting AD vehicle interior configurations:

- Starting from today accidents, a prospective approach was applied to define the future accident scenarios as defined in Deliverable D1.1 [4],
- The results were combined with the use cases of future AD cars defined in Deliverable D2.1 [7].

This approach was also demonstrated for PP6 which was assessed in sled tests using WorldSID ATD but also virtually using THUMS HBM.

Different from the homologation test case, where all approach steps were demonstrated including the pulse definition, the PP6 demonstrator used a generic pulse provided by [6] and applied for their Post Mortem Human Subject experiments.

Still, PP6 demonstrator gives an overview of OSCCAR Virtual Testing tool chain approach including HBM and broadens the scope of OSCCAR in terms of covered accident scenarios (frontal and frontal-oblique load case for the homologation test case, side load case for PP6 test case) and used tools for environment model validation (THOR ATD for the homologation test case, WorldSID ATD for the PP6 test case).

Additionally, PP6 test case gives reference data that are used for on-going discussions at Euro NCAP regarding Virtual Testing.

3.4 Market penetration

The discussed aspects which are directly related to automated driving will penetrate the market, as automated vehicles will do. That applies to new accident scenarios, new sitting positions and therefore new restraint principles which require new injury risk parameters. Deliverable D1.1 [4] demonstrated an estimation on market penetration of automated vehicles (Figure 7). It shows, that roughly in the year 2045 a market penetration of 50% will be reached in the fleet.

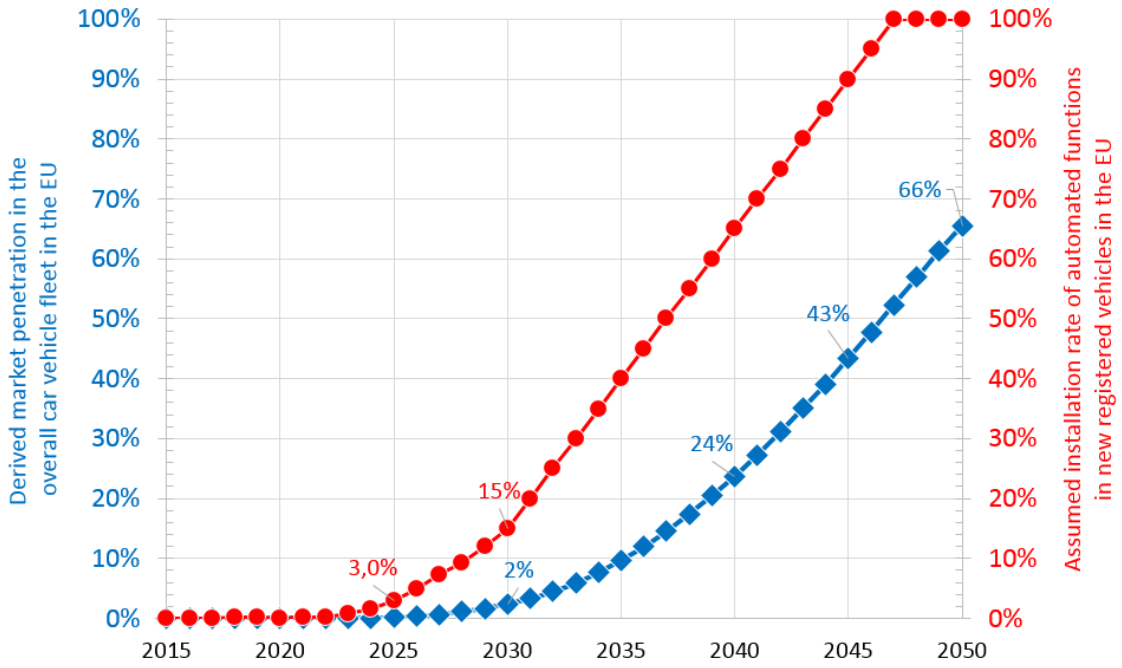

Figure 7 Market penetration as presented in OSCCAR Deliverable D1.1 [4], Figure 13

Concerning the usage of Human Body Models for virtual assessment in consumer ratings, it is already allowed to use them according to the TB024 [9]. EuroNCAP currently discusses a further usage of Human Body Models for occupant protection in selected scenarios (harmonized assessment approach). That will also be a possibility to take the diversity of the occupant population into account.

4 DISSEMINATION, EXPLOITATION AND STANDARDISATION

The presented cases are described in detail in the OSCCAR delivrables D2.4 [1] and D4.3 [14]. This Report is the last deliverable of Workpackage 4 and additionally it is public available. Therefore, no further publication is planned for this document.

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6 ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
AD	Automated Driving
ATD	Anthropomorphic Test Device
CPU	Central Processing Unit
D	Deliverable
FF	Full Frontal
HBM	Human Body Model
LL	Load Limiting
LTAP OD	Left Turn Across Path – Opposite Direction
PP	Protection Principle
SAT	Subcutaneous Adipose Tissue
SOTA DLPT	SOTA belt with Double Lap belt Pre-Tensioning
SUFEHM	Strasbourg University Finite Element Head Model
THOR	Test device for Human Occupant Restraint
THUMS	Total Human Model for Safety
THUMS-D	Total Human Model for Safety Daimler AG
VAT	Visceral Adipose Tissue
VPS	Virtual Performance Solution
VCC	Volvo Car Company
WP	Work Package
WorldSID	Worldwide Harmonized Side Impact Dummy