Transmitted by expert from Republic of Korea

Proposal for Amendment 3

Submitted by the Chair (Republic of Korea) of the Informal Working Group on the Deployable Pedestrian Protection Systems of UN Global Technical Regulation No. 9.

The text reproduced below was prepared by the experts of the Informal Working Group (IWG) of the Deployable Pedestrian Protection Systems (IWG-DPPS) on UN Global Technical Regulation No. 9 and proposes to complement the working document ECE/TRANS/WP.29/GRSP/2022/02 on DPPS, submitted in May 2022 GRSP by the IWG. The modifications are marked in bold for new or strikethrough for deleted characters. The proposal below consequently aims at revising ECE/TRANS/WP.29/GRSP/2022/02 and submitting a consolidated text for the draft 03 series of amendments to GTR9.

I. Proposal

Part II, Text of the Regulation,

Paragraph 3, amend to read:

"3. Definitions

When performing measurements as described in this Part, the vehicle should be positioned in its normal ride attitude.

In case of the vehicle equipped with a deployable pedestrian protection system as defined in paragraph 3.17., that area shall be defined with the system deactivated.

If the vehicle is fitted with a badge…

…"

Paragraph 3.24. ("Assessment Interval" (AI)), renumber as paragraph 3.3.

Paragraphs 3.3 to 3.14.(former), renumber as paragraphs 3.4 to 3.15.

Paragraph 3.11. (former), renumber as paragraph 3.12 and amend to read:

"**3.12.1.** "Bumper test area **for DPPS detection (BTA)**" means either the front vehicle fascia between the left and right corner of bumper as defined in paragraph **3.16**., minus the areas covered by the distance of 42 mm inboard of each corner of bumper, as measured horizontally and perpendicular to the longitudinal median plane of the vehicle, **[**or between the outermost ends of the bumper beam as defined in paragraph **3.10.** (see Figure 5D), minus the areas covered by the distance of 42 mm inboard of each end of the bumper beam, as measured horizontally and perpendicular to the longitudinal median plane of the vehicle, whichever area is wider**]**."

Paragraphs 3.12. to 3.14. (former), renumber as paragraphs 3.14 to 3.16.

Insert new paragraphs 3.16. to 3.19., to read:

"**3.16. "Deployable Pedestrian Protection System (DPPS)" means a technical system, which is activated for head protection of a pedestrian in the event of a collision with a p. It comprises a deployment module, as defined in paragraph 3.18. below, together with other related components required for its function, such as e.g. bonnet, sensors, or wiring, etc.**

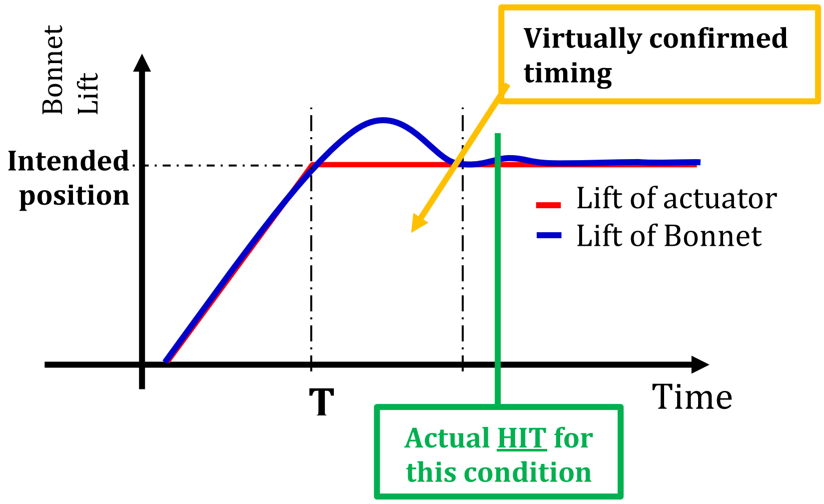
3.17. "Deployment module" means a unit, comprising components, such as airbags, springs, or pyrotechnic actuators etc., that are used to change the vehicle outer surface from a position of normal use in the vehicle to a deployed position, as defined in paragraph 3.19.1.

3.17.1. "Initiation of the deployment module" means, at the option of the manufacturer, either the moment when visible movement of the actuator is initially detected, or the moment when the triggering signal is sent from the electronic control unit to the deployment module.

3.18. "Deployment time (DT)" means the duration from the initiation of the deployment module, as defined in paragraph 3.18.1 until the DPPS reaches for the first time [initially arrives at] its deployed position, as defined in paragraph 3.19.1.

Figure XX

HIC difference between dynamic and static condition

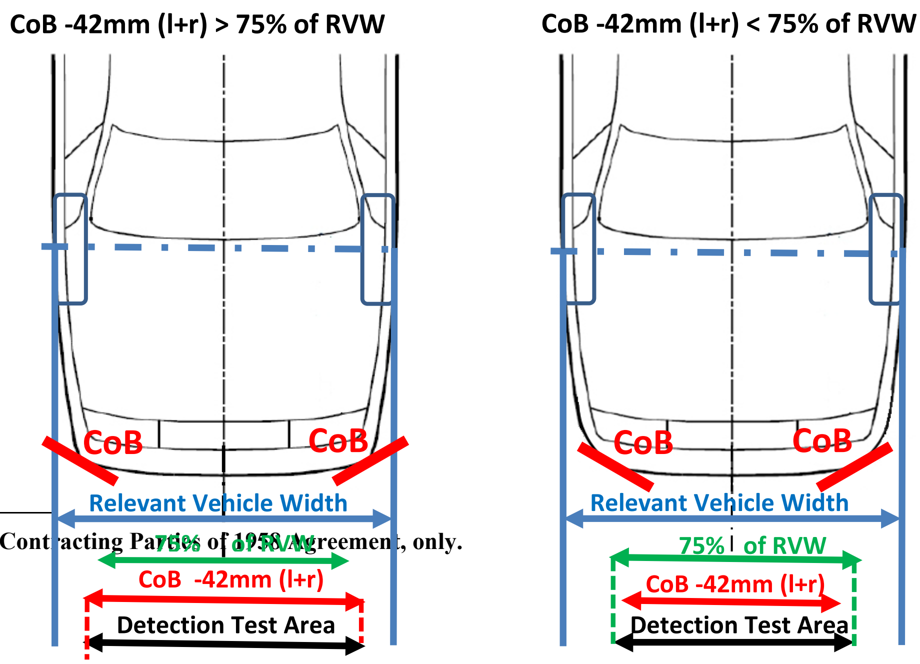


3.18.1. **["Deployed position" means the position of the vehicle outer surface equipped with a DPPS that can be maintained by the system after its activation. For a static test, the Deployed position shall be specified by the manufacturer.]**

3.18.2. **"Un-deployed position" means the position of the vehicle outer surface equipped with a DPPS when the DPPS is not activated.**

3.19. **"Detection test area" is the area designated to detect a pedestrian in order to initiate the activation of the deployable system. The width of the detection test area shall be the relevant vehicle width, minus a distance from each side of 12.5 percent of the relevant vehicle width, but not more than 250mm from each side. The detection test area must not be smaller than the area inboard of the corners of bumper (CoB) - 42mm on each side, as measured horizontally and perpendicular to the longitudinal median plane of the vehicle. At the choice of the manufacturer, a wider detection test area may be declared.[1]**

Figure XX **Detection Test Area**

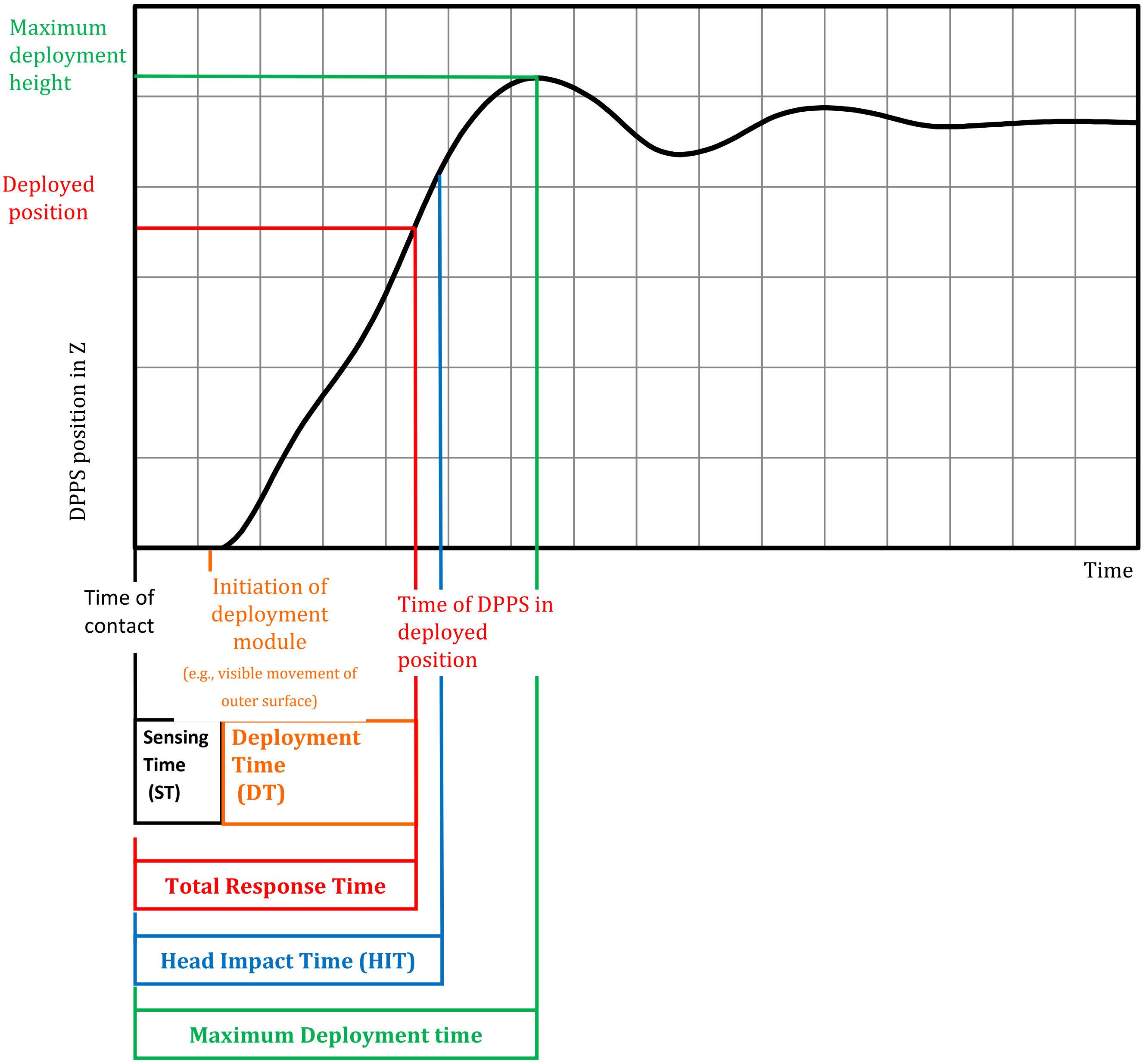


[1] **The choice applies to Contracting Parties of 1958 Agreement, only.**

Paragraphs 3.15. to 3.18.(former), renumber as paragraphs 3.20 to 3.23.

Insert new paragraph 3.24., to read as follows:

"3.24. The pedestrian Head Impact Time (HIT) is defined as the elapsed time subsequent to the time of first contact of the Pedestrian surrogate (neglecting forearms and hands) with the vehicle outer surface and the time of first contact of its head with the vehicle outer surface."



Paragraphs 3.19 to 3.23.(former), renumber as paragraphs 3.25. to 3.29.

Insert new paragraphs 3.30 to 3.31., to read as follows:

"**3.30. "Outer surface" means those components of the vehicle within the headform test areas, which may be contacted by the pedestrian in case of an accident. The outer surface may include the bonnet, the fenders, but also external airbags or other components within the headform test areas.**

3.31. "Sensors" are pedestrian contact sensors that detect a pedestrian contact with the front of the vehicle. These sensors include, but are not limited to, accelerometers, fibre optic sensors, pressure sensors, etc."

Paragraphs 3.25. and 3.26.(former), renumber as paragraphs 3.32 and 3.33.

Insert new paragraphs 3.34 and 3.35., to read:

"**3.34. "Relevant vehicle width (RVW)" is the maximum width of the vehicle without rear view mirrors or rear-view mirror substitute systems, measured on or in front of a vertical transverse plane passing through the front axle of the vehicle.**

3.35. "Sensing time (ST)" means the duration from the time of the first contact of the Flex-PLI with the vehicle outer surface to the initiation of the deployment module ."

Paragraphs 3.27. to 3.29. (former), renumber as paragraphs 3.36 to 3.38.

Insert new paragraphs 3.39. to 3.41., to read:

"**3.39. "Testing of the DPPS":**

The headform impact tests on the DPPS can be performed in three ways: statically, dynamically or combined.

3.39.1. "Static testing" means the launch of the headform on a DPPS being in the deployed position.

3.39.2. "Dynamic testing" means the synchronized launch of the headform onto the deploying DPPS at the appropriate HIT.

3.39.3. "Combined testing" means the set of tests on a DPPS in which a given test is run in either the static mode or the dynamic mode.

3.40. "Testing time" means the timeframe after the DPPS reaches its intended position in which the headform test to the DPPS is to be performed.

3.41. ["Total response time (TRT)" means the duration from the time of first contact of a pedestrian with the vehicle front to the time the DPPS reaches the Deployed Position as defined in 3.19.1. It consists of the sensing time (ST) and the deployment time (DT)."]

Paragraphs 3.30 to 3.32 (former), renumber as paragraph 3.42 to 3.44.

Paragraphs 5.2., 5.2.1. and 5.2.2., amend to read:

"5.2. Headform tests

If the manufacturer stipulates that the vehicle shall be tested as a DPPS, the test conditions and requirements in Annex 1 shall apply.

"5.2.1. Child headform to the front structure:

When tested in accordance with paragraphs 7.2., 7.3. **and, if applicable**, **Annex 1,** the HIC shall comply with paragraph 5.2.3.

5.2.2. Adult headform to the front structure:

When tested in accordance with paragraph 7.2., 7.4. **and, if applicable, Annex 1,** the HIC shall comply with paragraph 5.2.3."

Insert new paragraph 6.2.4., to read:

"6. TEST SPECIFICATIONS

6.2. Preparation of the vehicle

…

6.2.4. If the manufacturer stipulates that the vehicle shall be tested as a DPPS, the vehicle shall be adjusted as specified in the test procedure defined in Annex 1."

Delete all Annex1(former) and insert new Annexes 1 to 3, to read:

"Annex 1

Test procedure for deployable pedestrian protection systems (DPPS)

1. Preliminaries and pre-requisites

Based on a determination by each Contracting Party, a Contracting Party may either allow static tests, dynamic tests, and a combination thereof, or stipulate dynamic tests only.

For DPPS to be assessed statically, dynamically or combined, it will be necessary for the vehicle manufacturer to identify detailed information highlighted in this Annex before any testing begins. The vehicle manufacturer shall identify all necessary information regarding detection of pedestrians and the deployment of the system. Based on the evidence identified, activation of the system in the headform test will be determined.

1.1. If the pre-requisites from 1.2 to 1.6. are not met, the vehicle will be tested in the un-deployed position.

1.2. System specification:

As a Contracting Party option, a technical description of the DPPS components shall be identified by the manufacturer. This shall be accompanied by the following information:

1.2.1. For Sensing system:

(a) Sensor type (e.g., pressure, optical, acceleration, etc.)

(b) Sensor locations

(c) Operation process (including the lower deployment threshold speed of the DPPS)

1.2.2. Deployment information:

(a) Technology of the DPPS (airbag, active bonnet, etc.)

(b) Mechanism explanation

(c) Component description (lifting system (e.g., actuator), hinge, latch, etc.)

(d) Deployed position [Required height or Intended deployment height] information (not required for dynamic testing)

(e) TRT (ST+DT) information (not required for dynamic testing, where only ST is requested)

(f) Evolution of system stability (e.g., pressure or force versus time diagram) (not required for dynamic testing).

1.3. The marking of the head test areas of the DPPS shall always be done in undeployed position, for static, dynamic or combined testing.

1.4. HIT information shall be provided according to Annexes[2] 2 (HBM qualification) and 3 (HIT determination simulation).

1.5. Pre-requisites for deployed static tests

1.5.1. Deployed Position [Required height]

The vehicle outer surface with the DPPS capable of maintaining the deployed position shall reach a position equal to or above the deployed position [required height] during the time between the TRT and the HIT that corresponds to the rear end of the respective headform test area. The position shall not go below the [required height] deployed position after the first overshoot phase [exceeding 10 percent / 10mm tbc below the [required height] deployed position]. If the position does not meet this requirement, then dynamic tests shall be performed.

1.5.2. Verification of the Deployed Position [Required height] in the deployment position versus time history curve.

The values mentioned in 1.5.1. shall be verified by using appropriate tracking means, such as high-speed videos, accelerometer, or laser at the reference points (at the lifting devices).

1.6. Sensing System Verification

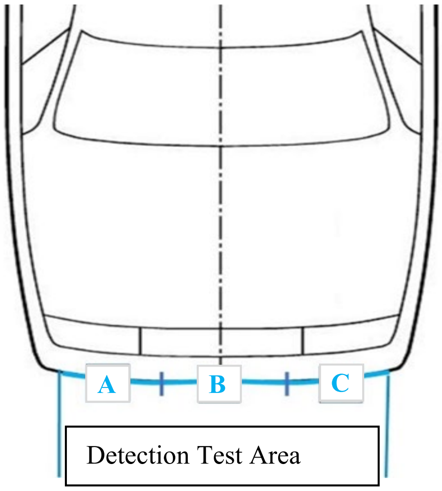
1.6.1. The detection test area, as defined in paragraph 3.20. of this regulation, will be subdivided into three thirds of identical width, whereas one third is the geometrical trace between the left and right end of the detection test area, measured with a flexible tape following the outer contour of the bumper at the upper bumper reference line, equally divided by three. See Figure 2 below.[3]

[2] Will be updated with DPPS Phase 2 (HIT determination by a generic approach option).

[3] Minimum number of tests is specified for Contracting Parties of 1958 Agreement, only.

Figure 2

Scheme of the detection test area subdivision



1.6.2. The vehicle manufacturer shall specify the lowest speed of activation (lower deployment velocity threshold) of the DPPS.

1.6.3. For the system deployment verification, sensor activation tests with the flexible lower legform impactor, as specified in paragraph 6.3.1.1 of this regulation, shall be performed at the DPPS lower deployment velocity threshold.

1.6.4. A minimum of one test per third (A, B and C) shall be performed, maintaining a minimum distance of 50 mm to adjacent tests.[4] Upon request of the manufacturer, additional tests outboard either side of the detection test area may be performed to provide for possible future extensions (e.g. aerodynamic attachments) enlarging the RVW.[5]

1.6.5. Where a test is performed within the tolerances as specified in paragraph 3 of this Annex, but below the nominal lower deployment velocity threshold or outside the detection test area and the system does not deploy, the test must be repeated.

1.6.6. If the system is not activated during any of the verification tests, all headform tests shall be conducted in un-deployed position according to paragraphs 7.2. to 7.4. of this regulation.

1.6.7 For tests with stationary vehicle: the vehicle should be set to the normal running condition as specified by the manufacturer for a vehicle speed corresponding to the particular use case.

2. Verification of TRT and /or ST at nominal velocity

2.1. The TRT shall be confirmed by using the Flex-PLI at the vehicle speed at 11.1 m/s and at the centre line of the vehicle.

2.2. The ST is measured either independently, or during a TRT measurement test, at the vehicle speed as specified in this regulation and at the centre of the bonnet.

2.2.1 For dynamic testing, only ST shall be verified. If the measured ST is within a tolerance of -5ms/+3ms, the value specified by the

[4] Minimum number of tests is specified for Contracting Parties of 1958 Agreement, only.

[5] The choice applies to Contracting Parties of 1958 Agreement, only.

manufacturer shall be used. Otherwise, the measured value shall be used for the test.

2.2.2 For tests with stationary vehicle: the vehicle should be set to the normal running condition as specified by the manufacturer.

3. For verification tests of paragraphs 1 and 2 of Annex 1 with the flexible lower legform impactor the following tolerances shall apply:

3.1. For tests with a moving vehicle impacting the stationary impactor: Target speed: ± 0.6 m/s; impact accuracy: ± 50 mm.

3.2. For tests with a propulsion system propelling the impactor against the stationary vehicle:

Target speed, impact accuracy, angle tolerances are those of the performance tests, as in paragraph 7.1. of the regulation.

4. Headform test for protection below the lower deployment threshold speed of the DPPS

4.1. The vehicle outer surface shall remain in un-deployed position.

4.2. The test procedures specified in paragraphs 7.2. to 7.4. of this regulation shall apply with the impact speed specified at 0.9 times the lower deployment threshold speed. The allocation of the HIC 1700 and HIC 1000 zones may differ from those at nominal velocity (9.7 m/s) head impact tests according to paragraph 5.2.4 of this regulation.

5. Headform Test Procedure at nominal velocity (9.7m/s)

The impact points and the allocation of the HIC 1700 and HIC 1000 zones shall always be based on and related to the test area where the DPPS is deactivated.

5.1. Static test option:

If the vehicle manufacturer supports the static test [alternative], provided the following conditions are fulfilled, the requirements for an impact test [shall] be demonstrated using the static test.

If any of the following conditions are not met, then the dynamic test option shall be performed.

5.1.1. The HIT determined on the deployed DPPS, as described in Annex 3, at the impact point WAD shall be greater than or equal to the TRT (HIT≥TRT).

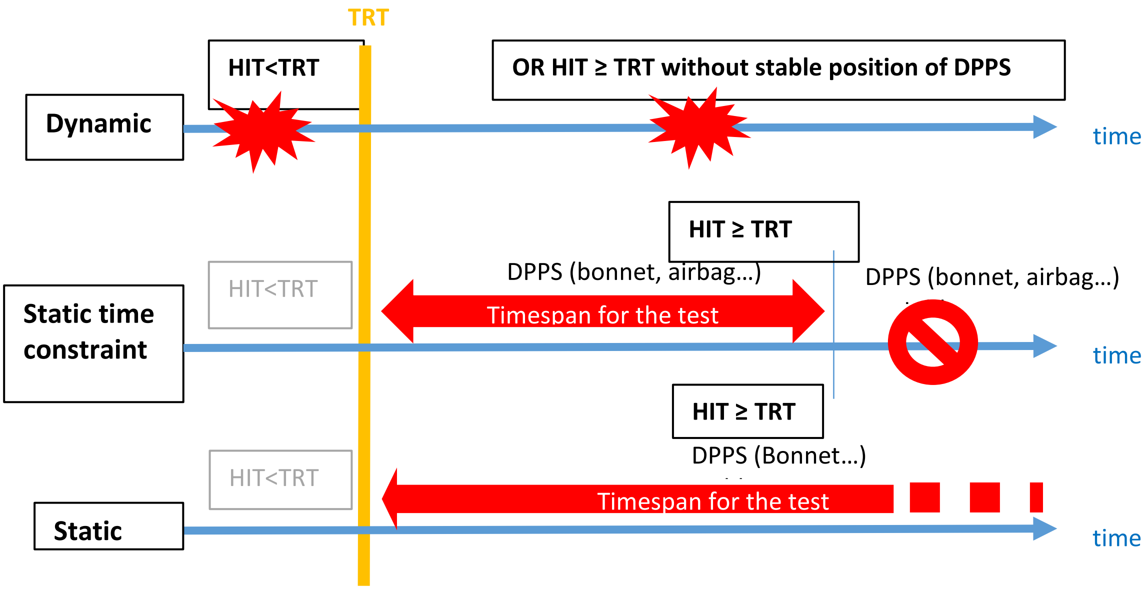
5.1.2. The vehicle outer surface shall represent the deployed position and the resisting force. [The outer surface of the vehicle shall be set to that position and its resisting force by appropriate means.]

5.1.2.1. Static time constraint condition, linked to the resisting force:

When there is a constraint on time for the stability of the system and HIT≥TRT, the launching time of the headform test shall ensure that the system remains stable (tolerance ±10 per cent of corresponding resisting force), as identified by the manufacturer (pre-requisite in paragraph 1.2. of Annex 1).

Based on the evolution of system stability (see Fig. 1), a decision can be made on how to perform the test. During the static tests it shall be ensured that the resisting force of the DPPS is equivalent to the actual situation at the real HIT.

Figure 1: Testing time aim = LAB tests represent real life



5.1.2.2. Appropriate means (e.g., actuator surrogates) shall ensure the corresponding resisting force of the DPPS can be used.

5.1.3. The test procedures specified in paragraphs 7.2. to 7.4. of this regulation shall apply.

5.1.4 Test accuracy at impact location

5.1.4.1. Prior to conducting the static tests at 9.7 m/s, one headform test at the discretion of the test laboratory may be conducted on the undeployed DPPS to confirm that impact velocity and impact location are within tolerances.

5.1.4.2. If the tolerances for impact speed and location are met during the test on the undeployed DPPS, there is no requirement to prove that these tolerances are still met during the static tests, provided that test inputs remain the same.

5.1.4.3. Alternative methods to demonstrate the test accuracy may also be accepted.

5.2. **Dynamic test option:**

5.2.1. **The dynamic verification of a DPPS is based on a headform test performed on the DPPS, where the headform launch device and DPPS deployment are synchronized to achieve the correct HIT.**

The following steps are conducted:

5.2.1.1. **Test accuracy at impact location**

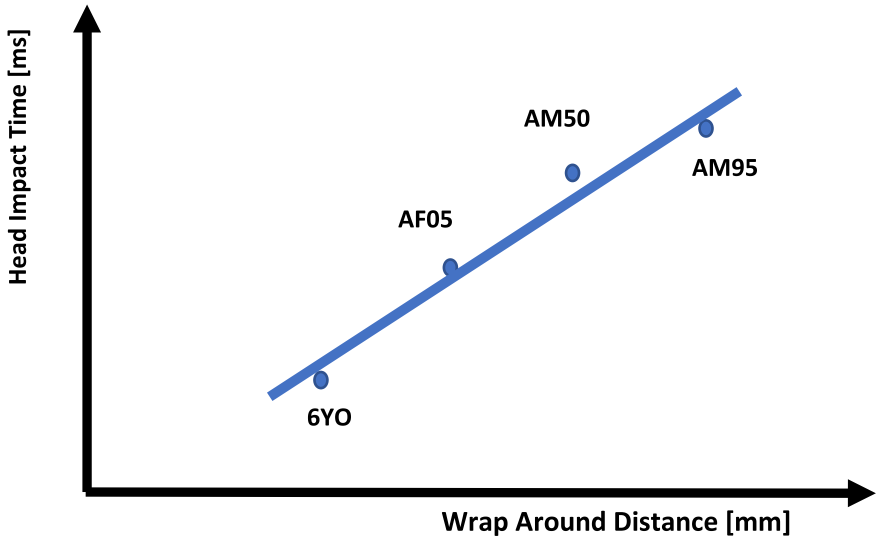
Prior to conducting the dynamic tests at 9.7m/s, one headform test at the discretion of the test laboratory shall be conducted on the undeployed bonnet to confirm that impact velocity and impact location are within tolerances.

If the tolerances for impact speed and location are met during the undeployed test, there is no requirement to meet these tolerances during dynamic tests, provided test inputs remain the same.

5.2.1.2. **To enable dynamic testing to be conducted, HIT and sensing time (ST) are required inputs, which shall be established by the following:**

(a) HIT is obtained from Annex 3, Figure 2.

Figure xx

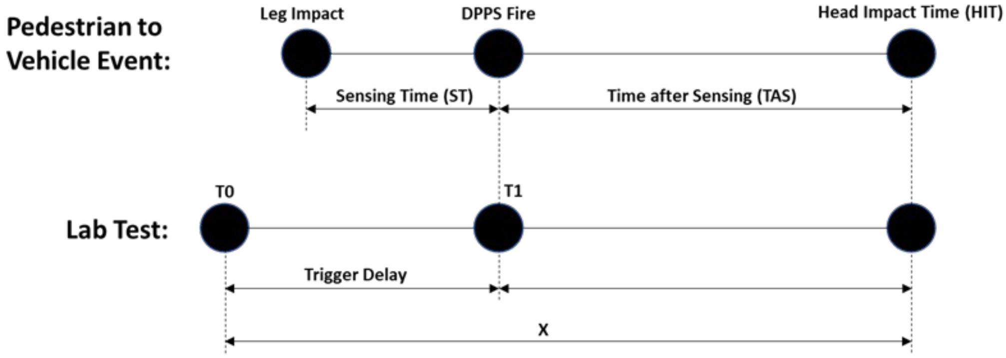


(b) ST is determined from manufacturer pre-requisite or sensor verification test., carried out at the center of the bonnet (Y0).

The test facility shall ensure that the head impact occurs at the correct time relative to the deployment of the DPPS, taking into account the HIT and ST, as shown in Figure 2 below.

Figure 2: Example of test rig synchronisation

[



X is rig-specific and is the time period between T0 and the time of head impact.to the undeployed bonnet

T1 is the delay between T0 and the firing of the DPPS

Time after sensing (TAS) is calculated by deducting the sensing time (ST) from the HIT at that particular test point

T1 shall be adjusted such that the period of time between the firing of the DPPS and the impact of the headform on the undeployed bonnet is identical to the TAS.]

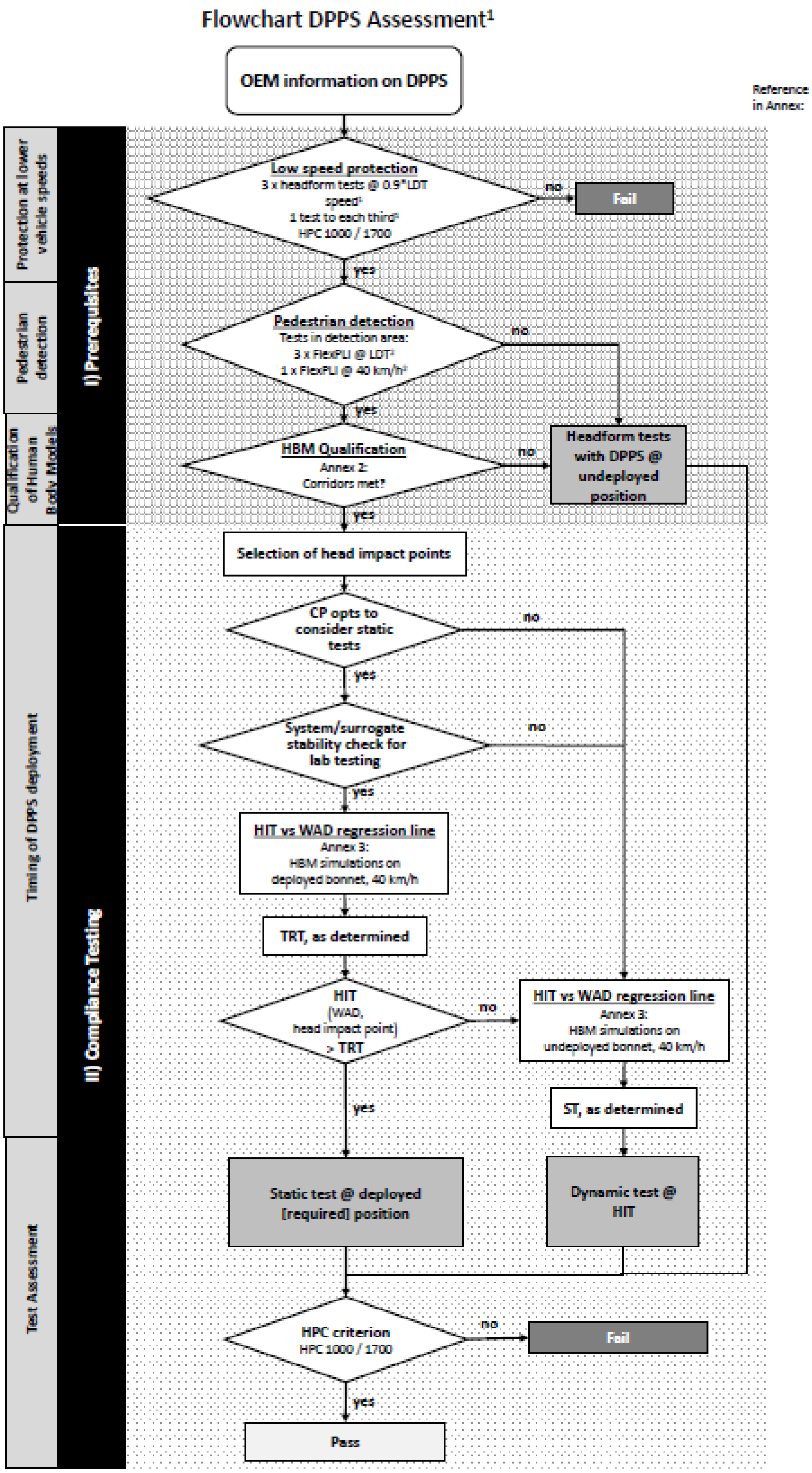
5.3. **"Combined" test option:**

Combined static and dynamic tests may apply, at manufacturer's choice.

If the bonnet top test area consists of sections where the HIT of the HBM at the corresponding impact point is less than TRT (HIT<TRT) and sections where the HIT of the HBM at the corresponding impact point is greater than or equal to TRT (HIT≥TRT, then all test points forwards of the corresponding wrap around distance WAD (HIT < TRT) shall be tested dynamically. The remaining section of the bonnet top test area may be tested statically. The undeployed marking procedure shall be used for this combined option. (see Figure 4 below).

Figure 4
Scheme of HIT vs WAD for combined testing

Annex 1 Appendix 1: Flowchart DPPS Assessment guideline[6]



¹: Will be updated with DPPS Phase 2 (Generic approach)
²: Minimum number of tests specified for Contracting Parties of the 1958 Agreement, only

[6] The flowchart in Figure 3 illustrates the decision process for Contracting Parties (1958 Agreement) that allow both static and dynamic options. For Contracting Parties that allow only dynamic option, this flow chart is also useful, but not all steps will be considered.

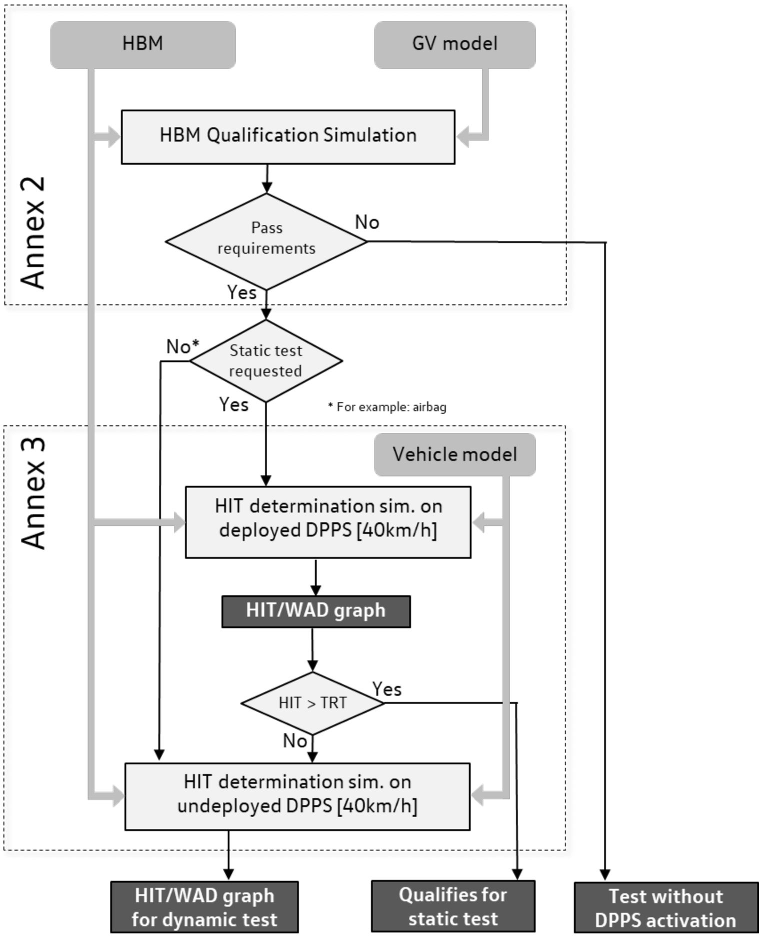
Annex 2

Qualification Process of Human Body Models for Pedestrian HIT-Determination

1 INTRODUCTION

[Annex 1 describes the test procedure for the Deployable Pedestrian Protection System. Based on the evidence provided by the vehicle manufacturer, the authority may decide whether subsystem testing for head impact assessment is conducted in either the deployed or undeployed position of the Deployable Pedestrian Protection System or if dynamic tests are required.]

HBM compliance must be demonstrated by the vehicle manufacturer in accordance with the procedure in this document. All requirements which are specified within this document have to be fulfilled to qualify a HBM to be used in Annex 3.



1.1 Limitations

As mentioned in the preamble of UN-GTR No.9, the qualification procedure described in this text is simplified and therefore limited to the purpose of pedestrian Head Impact Time (HIT) and Wrap Around Distance (WAD) calculation and is not suited to qualify for injury assessment in this or any other crashworthiness regulation. Only measures relevant for these outputs are included in the qualification procedure (Klug et al. 2021[7])

[7] Klug, Corina; Ellway, James (2021): Euro NCAP TB 024 - Pedestrian Human Model Certification v3.0.1.

and have been determined within sensitivity studies and round robin simulations (Klug et al. 2017, Klug et al. 2019[8]).

1.2 Definitions

Throughout this document, the following definitions are used:

- **A Human Body Model (HBM) is understood as a virtual geometric and mechanical representation of the human body, which takes the human anatomy into consideration. The procedure described in this document refers to HBMs used for the simulation of pedestrian impacts. Pedestrian models which are required for Annex 3 shall be selected from the following statures, a six year old (6YO), 5th percentile female (AF05), 50th percentile male (AM50) and 95th percentile male (AM95).**
- **Generic Vehicle (GV) Models are generic replications of car fronts representing three vehicle categories: Family Cars (FCR), Roadsters (RDS), Sports Utility Vehicles (SUV). (The shape of the generic Multi Purpose Vehicle (MPVs) was found to lay in between the generic FCR and generic SUV and is therefore covered already.) The GVs are available on the UNECE website [tbd]. The vehicle models provide representative shapes for the selected vehicle categories as well as median structural response upon pedestrian impact in terms of force-deflection characteristics and are modelled to be robust and transferable to all considered explicit Finite Element (FE) codes.**
- **HBM vs. GV simulation: A computer simulation providing evidence that the specific Human Body Model simulation is comparable with reference simulations and shows consistent results – in particular referring to HIT and WAD. The reference simulations are based on models which have been validated by comparing their simulation response with PMHS tests (see Appendix B). Another purpose is to make sure that models give comparable results with varying hardware or software environments when applied for a specific purpose.**
- **HIT-Determination simulation: A computer simulation for determination of HIT as a function of WAD in the DPPS vehicle model for deriving the test conditions for the assessment of deployable systems as specified in the Annex 1.**

[8] Klug, Corina; Feist, Florian; Raffler, Marco; Sinz, Wolfgang; Petit, Philippe; Ellway, James; van Ratingen, Michiel (2017): Development of a Procedure to Compare Kinematics of Human Body Models for Pedestrian Simulations. In: 2017 IRCOBI Conference Proceedings.
Klug, Corina; Feist, Florian; Schneider, Bernd; Sinz, Wolfgang; Ellway, James; van Ratingen, Michiel (2019): Development of a Certification Procedure for Numerical Pedestrian Models. In: The 26th ESV Conference Proceedings. International Technical Conference on the Enhanced Safety of Vehicles.

1.3 General Requirements

Only those HBM statures have to be qualified which are required for the HIT determination simulations described in Annex 3, paragraph 2.2.

The pedestrian Human Body Model that is qualified is the very same model as used for HIT-Determination simulations. This applies to:

- **Version of the Human Body Model;**
- **Node-Position of every single node of the Human Body Model;**
- **If available:**
  - **identical initial element stresses/strains;**
  - **identical initial contact penetrations/contact forces;**
- **Identical material cards (including fracture mode), contact cards, control cards and constraints.**

Furthermore, it is important that all simulations (qualification and HIT-Determination) are performed with consistent settings. This applies to:

- **Solver-Version;**
- **Solver-Platform (SMP, MPP);**
- **Solver-Precision (Single, Double Precision);**
- **The time-step used for simulations;**
- **Time-step settings (relating to initial and dynamic mass scaling);**
- **Contact settings (between Human Body Model and Vehicle);**
- **Control settings which are affecting the pedestrian model.**

2 Procedure

2.1 HBM Pre-processing

Shoes

The HBM may be fitted with a pair of shoes, featuring a sole thickness (at the heels) of 20 to 30 mm.

Positioning

The car manufacturer has the freedom to choose a positioning tool. Positioning can be achieved through pre-simulation (pulling/pushing the limbs of the HBM to the desired position) or by re- meshing/morphing. The target posture of the AM 50 model is specified in Table 1.

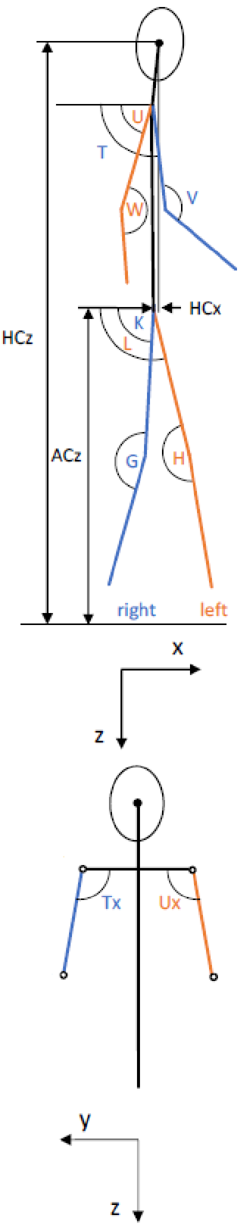
All other model sizes have to meet the required initial posture defined in Table 2.

For all abbreviations and reference point description (HC, AC etc.) see Appendix A.

Table 1

Initial Posture AM 50.

Abbrev.	Measure	Ref. Value	Tolerance (+/-)	Angle Definition
Px	Heel to heel distance	310 mm	5.0%	
Py	Heel to heel distance lateral	185 mm	15.0%	
ACz	Height of AC relative to the ground level	949 mm	2.0%	
K	Right Upper Leg Angle (around Y w.r.t.	89°	5°	
L	Left Upper Leg Angle (around Y w.r.t. the horizontal)	106°	5°	
G	Right Knee flexion Angle (Y)	164°	5°	
H	Left Knee flexion Angle (Y)	175°	5°	
Ty	Right Upper Arm Angle (Y w.r.t. horizontal)	98°	5°	
Uy	Left Upper Arm Angle (Y w.r.t. horizontal)	70°	5°	
Tx	Right Upper Arm Angle (X w.r.t. horizontal)	100°	10°	
Ux	Left Upper Arm Angle (X w.r.t. horizontal)	100°	10°	
V	Right Elbow flexion Angle	140°	5°	
W	Left Elbow flexion Angle Left	160°	10°	
HCx	x-Position of HC relative to AC	44 mm	15 mm	
HCz	Height of HC relative to the ground level	1686 mm	1.5%	
M	Total mass	76.7kg[9]	5%	



The angles should be measured using the reference axis as defined in Appendix A. The reference measures for the other sizes of models are listed in Table 2.

[9] Schneider, Lawrence W.; Robbins, D. H.; Pflueg, M. A.; Snyder, R. G.; Corporate Author: University of Michigan, Ann Arbor, Transportation Research Institute: **"Development of anthropometrically based design specifications for an advanced adult anthropomorphic dummy family, volume 1. Final report"**

Table 2

Reference Posture of other pedestrian sizes.

Abbrev.	Unit	Reference	Reference	Reference	Tolerance
		6YO	AF05	AM95	
Px	mm	199	243	340	5.0%
Py	mm	152	164	265	15.0%
ACz	mm	613	831	1043	2.0%
K	°	89°	89°	89°	5°
L	°	106°	106°	106°	5°
G	°	164°	164°	164°	5°
H	°	175°	175°	175°	5°
Ty	°	98°	98°	98°	5°
Uy	°	70°	70°	70°	5°
Tx	°	100°	100°	100°	10°
Ux	°	100°	100°	100°	10°
V	°	140°	140°	140°	5°
W	°	160°	160°	160°	10°
HCx	mm	6.5	27	16	15 mm
HCz	mm	1100	1468	1836	1.5%
M	kg	22.8	46.9	102.6	5%

The right side in viewing/walking direction of the HBM is defined as the struck side. The z-direction is defined as the vertical axis, positive in inferior direction. The local HBM x-axis is the frontal axis, facing anterior. (Both shoe soles should ideally contact the ground – if ACz cannot be achieved with ground contact, a z-offset of the HBM is permitted).

None of the limbs, i.e. arms/legs shall be artificially connected, tied or constrained to each other (e.g. wrists tied) The HBM should be exposed to a vertical acceleration field constituting the gravitational loading for HBM qualification and HIT determination simulation.

Output Parameters

The HBM must be equipped with "sensors" and other output definitions, which allow tracking the trajectories of selected body parts. The centre specifies the centre of all nodes; i.e. the node with averaged coordinates.
Node histories must be output at the HC and AC. Outputs must be in the global coordinate system, with the x-direction parallel to the vehicle longitudinal axis in driving direction and the z- direction parallel to the vehicle height axis facing upwards. The sensor shall be constrained to the structure, which was used for the definition of the geometric centre (at least 10 nodes of the cortical bone for HBMs with skeleton and all related bodies for HBMs without skeleton).

2.2 Impact Simulations

According to tables 3-5 the HBM must be impacted by the provided generic vehicle models at three different impact velocities (30 km/h, 40 km/h and 50 km/h). The simulation time must be higher than the expected Head Impact Time.

The static and dynamic coefficient of friction between the car and the HBM should be set to 0.3.

The Head Centre of Gravity (CoG) of the HBM must be positioned in line with the vehicle centreline (y=0 in the global coordinate system).

2.3 Output Requirements

It should be confirmed that the following outputs have been generated from each simulation:
Time history curves of:

- **x and z coordinate of HC and AC in the global coordinate system**
- **x displacement of vehicle COG in the global coordinate system**
- **Resultant acceleration of HC**
- **Contact forces (between vehicle and HBM without upper extremities, vehicle and HBM head and total contact force)**
- **Total hourglass and internal energies of the total setup**
- **Mass increase,**

all plotted every 0.1ms.

Furthermore, animations of the simulations should be generated with an output interval of 1ms.

2.4 Quality Checks

The following Quality Checks shall be performed:

- **Contact force (between HBM and vehicle) is zero at simulation start.**
- **Total energy remains constant within a 15% tolerance.**
- **Hourglass energy ≤ 10% of the total energy.**
- **Artificial mass increase is less than 3%.**

2.5 Reference Results for Qualification Simulations

From the qualification simulations with the generic vehicle models, HIT values and the location of AC and HC at the time of head impact should be compared with the references in Table 3-5.
These tables have been created using simulations with validated HBMs (see Appendix B).

The trajectories are measured relative to the generic vehicle model, which means that the x-displacement of the generic vehicle has to be subtracted from the measured x coordinates HCx and ACx in the global coordinate system. For HCz and ACz the global z-coordinates are used.

[Table 3
AM50

GV Type	Velocity [km/h]	HIT [ms]		ACx [mm]		ACz [mm]		HCx [mm]		HCz [mm]	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
FCR	30										
	40										
	50										
RDS	30										
	40										
	50										
SUV	30										
	40										
	50										

Table 4
6YO

GV Type	Velocity [km/h]	HIT [ms]		ACx [mm]		ACz [mm]		HCx [mm]		HCz [mm]	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
FCR	30										
	40										
	50										
RDS	30										
	40										
	50										
SUV	30										
	40										
	50										

Table 5
AF05

GV Type	Velocity [km/h]	HIT [ms]		ACx [mm]		ACz [mm]		HCx [mm]		HCz [mm]	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
SUV	30										
	40										
	50										

]

AM95

The AM95 does not need to be specifically qualified. AM95 models which can be used are all derived from AM50 models and therefore the AM95 only has to meet the positioning requirements and no specific qualification simulations need to be performed.

3 Documentation

3.1 General

The following information should be provided:

- **Date of report**
- **Name of car manufacturer**
- **Type and release version of software (FE-software package name, revision and version)**
- **Name and version of Human Body Model**
- **Version of Generic Vehicle models applied**

Images showing the front view and side view of the pedestrian, at t0 and at the time of head impact should be added to the report.

3.2 Quality Checks

For all simulations Table 6 should be filled in

Table 6
Quality Checks

Verification evaluation criteria	Allowed	Observed	Pass?
Coefficient of friction between GV and Human Body Model	0.3		Y/N
Head centre of gravity is positioned at vehicle centreline	Y=0 mm		Y/N
Contact force between HBM and vehicle at simulation start	0		Y/N
Change in total energy throughout simulation	≤15%		Y/N
Amount of hourglass energy relative to total energy	≤10%		Y/N
Artificial mass increase relative to total mass of the setup	≤3%		Y/N

3.3 Calculation of Head Impact Time

Time of first contact is defined as the first time at which the contact force is no longer 0 anymore.
The Head Impact Time (HIT) is defined as the elapsed time subsequent to the time of first contact of the HBM (neglecting forearms and hands) with the vehicle outer surface and the time of first contact of its head with the vehicle outer surface.

If this method is for any reason not applicable, an appropriate alternative method should be applied and documented.

3.4 Initial Posture of Pedestrian Model

The following table has to be filled in for all statures using the references from Table 1 and 2.

Table 7
Initial Posture Check

Abbrev.	Unit	Measured Value (for Stature …)	Deviation to Reference	Tolerance	Pass?
Px	mm			5.0%	Y/N
Py	mm			15.0%	
ACz	mm			2.0%	
K	°			5°	
L	°			5°	
G	°			5°	
H	°			5°	
Ty	°			5°	
Uy	°			5°	
Tx	°			10°	
Ux	°			10°	
V	°			5°	
W	°			10°	
HCx	mm			15 mm	
HCz	mm			1.5%	
Total weight	kg			5%	

3.5 Results of Qualification Simulations

To qualify one HBM stature the following table has to be filled in including all GV shapes and collisions speeds where reference values are provided in the corresponding tables 3, 4 or 5. To pass the requirements the values of the respective HBM have to be within the min/max values of table 3-5.

Table 8
Results of Qualification Simulation

GV Type	Velocity [km/h]	HIT [ms]		ACx [mm]		ACz [mm]		HCx [mm]		HCz [mm]	
		Measured	Pass?	Measured	Pass?	Measured	Pass?	Measured	Pass?	Measured	Pass?
FCR	30										
	40										
	50										
RDS	30										
	40										
	50										
SUV	30										
	40										
	50										

For each simulation, the following diagrams should be provided:

- **ACx and HCx as a function of time**
- **ACz and HCz as a function of time**
- **HCz as a function of HCx and ACz as a function of ACx**
- **Total Contact Force between HBM and GV as a function of time**
- **Total, kinetic, internal and hourglass energy as a function of time**

APPENDIX A: REFERENCE SYSTEMS

Global Coordinate System

The global coordinate system is defined as shown in Figure A.1:

- **X direction is the driving direction of the vehicle (longitudinal axis) and X=0 at the foremost point of the vehicle at t=0.**
- **Y direction is the vehicle lateral axis with Y=0 at the vehicle centreline.**
- **Z direction is parallel to the vehicle height axis facing upwards, Z=0 at the ground level.**

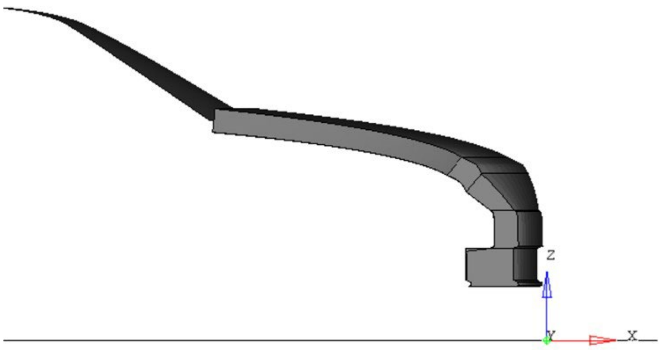


Figure A.1: Global Coordinate System

Note: All Generic Vehicle models are already positioned correctly – no transformation of the vehicle is required

HBM Reference Axis

The HBM reference coordinate system is defined as: The x-axis of the local HBM is defined in the sagittal plane, oriented in the anterior direction. The y-axis is the one defined in the coronal plane, pointing to the right of the HBM and the z-direction is defined as the cross product of the aforementioned axis, this being the vertical axis oriented in the inferior direction.

The local axes describing the initial posture with the corresponding landmarks are shown in Figure A.2 (small capital r stands for right and l for left side of the body)

HBM with skeleton

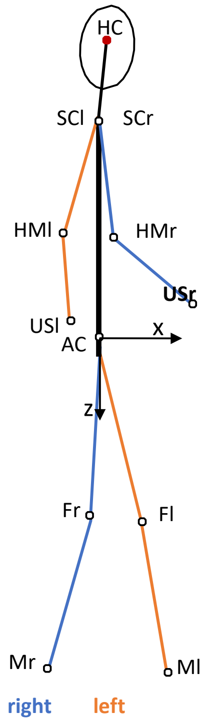


Figure A.2: Local HBM axes for angle definitions

- **Centre of gravity of the head (hereafter called HC) is defined as the mass centre of all parts of skull, scalp, face, brain, intracranial space, scalp. It should be connected to all nodes of inner cranium for the dynamic output.**
- **AC is defined as the geometric centre of the right and left acetabulum centres. The geometric centre of all nodes within the concave surface of each acetabulum has to be determined as averaged coordinate of all nodes on the pelvic bone surface within the boundaries defined as sharp edge where the bone changes its curvature shown in Figure A.3. This has to be done at the left and the right Acetabulum. The midpoint of the left and right acetabulum centred is AC and should be connected to all nodes of the right and left acetabulum.**

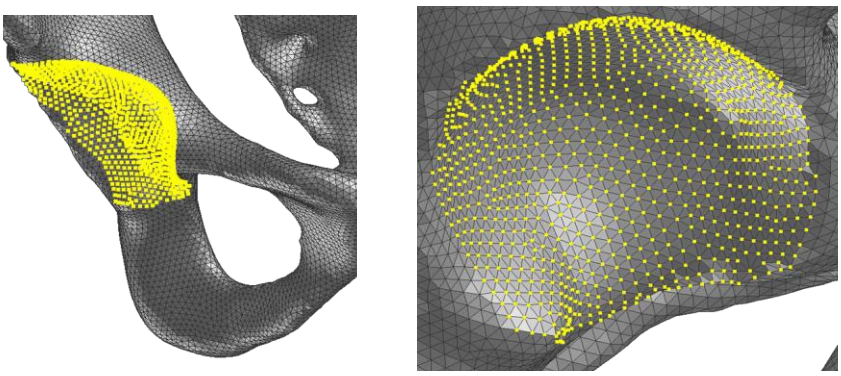


Figure A.3: Definition of Acetabulum Centre (all nodes up to sharp edge where the bone changes curvature)

- **The Upper Leg Angle is defined as the angle about Y between the femur reference axis and the horizontal.**

- The femur reference axis is defined as the connection between the centre of the nodes of the acetabulum and the midpoint (F) between Epicondylus femoralis medialis (FEM) and Epicondylus femoralis lateralis (FEL). If FEM and FEL are not clearly identifiable from the bony structure, the approach shown in Figure A.3 can be used. For this approach the femur model has to be positioned such that the lateral and medial epicondyle are overlaying as much as possible, as seen in the left image in Figure A.4. Then a cylinder is created from the contour of femoral condyle. The points of intersection of the axis of a longitudinal cylinder along the femoral condyle and the outer surface of the bone should be used as FEM and FEL. This point has to be determined on the left (Fl) and the right femur (Fr) of the HBM.

Figure A.4: Construction of FEL and FEM

- The Knee Flexion Angle is defined between the femur reference axis and the connection between the midpoint of the femoral epicondyles and the inter-malleolar point (M) located midway between the tip of the medial malleolus (MM) on the tibia bone and tip of the lateral malleolus (LM) on the fibula as shown in Figure A.5. These points have to be defined on the left (Ml) and right side (Mr) of the HBM.

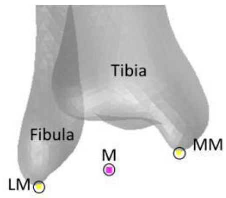


Figure A.5: The right inter-malleolar point (MR) located midway between MM and LM

- The Upper Arm Angle is defined as angle around the Y axis between the horizontal plane and the humerus reference axis. The humerus reference axis is defined as the connection between the shoulder reference point (SC) and the Humerus reference point (HM). SC is determined as the midpoint of the most laterodorsal point of the Angulus Acromialis (AA) and the most ventral point of processus coracoideus on the scapula (PC), both on the scapula. HM is defined as the midpoint of the most caudal-lateral point on lateral epicondyle (EL) and the most caudal-medial point on medial epicondyle (EM). These points have to be defined on the left (SCl, HMl) and right side (SCr, HMr) of the HBM.

- The Elbow Flexion Angle is defined as angle between the humerus reference axis and the connection between HM and the most caudal-medial point on the ulnar styloid (US). This axis has to be defined on the left (HMl, USl) and right side (HMr, USr) of the HBM.

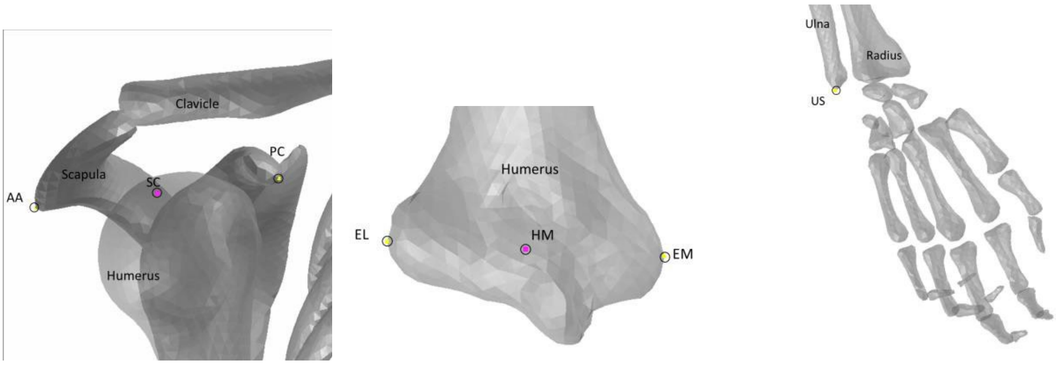


Figure A.5: Anatomic Landmarks of upper extremities

- The Heel to Heel distance is defined as the distance between the centre of all nodes of the right and the left calcaneus. If this cannot be determined, the distance between the most posterior node of the left heel to the most posterior node of the right heel of the shoe sole has to be used.

HBM without skeleton

Wherever the landmarks described in the previous section cannot be identified in an HBM, points according to the definition in Table 10 should be used.

Table 10
Reference nodes used for determination of the initial posture for HBMs where anatomic landmarks cannot be defined

HBM with full skeleton	HBM without skeleton
HC	Centre of gravity of the body/bodies representing the full head moving with the head
Scl/SCr	Geometric centre of shoulder joint connecting the Thorax with the body representing the upper arm
HMl/HMr	Geometric centre of elbow joint connecting the body representing the upper arm with the body representing the lower arm
USl/USr	Geometric centre of wrist joint connecting the body representing the hand with the body representing the lower arm (on the posterior side / side of the pinkie)
AC	Geometric centre of hip joint connecting the body representing the pelvis with the body representing the upper leg
Fr/Fl	Geometric centre of knee joint connecting the body representing the upper leg with the body representing the lower leg

Mr / Ml	**Geometric centre of ankle joint connecting the body representing the foot with the body representing the lower leg bones**

[APPENDIX B: Documentation of validation of reference Human Body Models

This Section contains a description of the validation of the reference AM50 human body models that were used for the definition of the qualification corridors, as depicted in Chapter 2.5 of Annex 2.

The validation procedure, in contrast to the previously described qualification simulations, describes the process towards a determination of the degree to which the reference models represent the pedestrian kinematics during real world crashes.

For their individual validations the different models had to undergo a harmonized procedure. This procedure consisted of simulations of the HBM against a model representing a generic vehicle frontend (SAE buck[10]) used in post mortem human subject (PMHS) experiments[11]. The SAE buck is part of the THUMS User Community validation repository[12]. The HBM responses were compared to scaled corridors[11] derived from three tests with PMHS.

The procedure used for the validation of those models that were used for the qualification corridors is kept simple and therefore limited to the purpose of pedestrian Head Impact Time (HIT) and Wrap Around Distance (WAD) calculation. It is not suited to qualify for injury assessment in this or any other crashworthiness regulation. If HBMs are intended for extended usage, more enhanced validations are needed[13].

The impact of the simplicity of this procedure compared to a more detailed validation procedure on the established qualification corridors related to HIT and WAD is expected to be neglectable. [However, the potential influence on WAD and HIT results for human body models subjected to a more stringent validation procedure should be further evaluated during phase 2 of the IWG on DPPS.]

To validate exactly the same model, which is used for the qualification simulations, the HBM posture is not aligned with the PMHS tests, but corresponds to Table 1 of this document instead. The main difference between the posture from the PMHS tests and Table 1 is the arm posture (the PMHS leg position and the proposed HBM position both

[10] Pipkorn, Bengt; Forsberg, Christian; Takahashi, Yukou; Ikeda, Miwako; Fredriksson, Rikard; Svensson, Christian; Thesleff, Alexander (2014): Development and component validation of a generic vehicle front buck for pedestrian impact evaluation. In: International Research Council on the Biomechanics of Injury (Hg.): 2014 IRCOBI Conference Proceedings. IRCOBI Conference. Berlin, Germany, 10.-12.9.2014: IRCOBI (IRCOBI Conference Proceedings), S. 718–729.

[11] Forman, J. L.; Hamed Joodaki; Ali Forghani; Patrick Riley; Varun Bollapragada; David Lessley et al. (Hg.) (2015): Biofidelity Corridors for Whole-Body Pedestrian Impact with a Generic Buck. International Research Council on the Biomechanics of Injury. Lyon, France. Online verfügbar unter http://www.ircobi.org/wordpress/downloads/irc15/pdf_files/49.pdf.

[12] https://tuc-project.org/whole-body-pedestrian-impact/

[13] Wu, Taotao; Kim, Taewung; Bollapragada, Varun; Poulard, David; Chen, Huipeng; Panzer, Matthew B. et al. (2017): Evaluation of biofidelity of THUMS pedestrian model under a whole-body impact conditions with a generic sedan buck. In: *Traffic Inj Prev* 18 (1), 148-154. DOI: 10.1080/15389588.2017.1318435.

target the SAE J2782 measures and are therefore comparable). Previous studies have shown that the arm posture effects HIT by roughly ±3 ms[14] which is smaller than the range of results observed in the PMHS study.

The HBM is positioned vertically relative to the SAE buck such that AC (as defined in Fig. A.3) is positioned at a height of 932 mm. (Based on the offset between H-Point and pelvis reference point used for tracking defined in SAE J2782, the provided location of the pelvis reference point[11] was offset by 73 mm to convert it to the H-Point location. The minimum value of the pelvis reference point from the corridor was taken to ensure that HC requirements from Table 1 are not contradicted.)
For the lateral position, AC is aligned with the vehicle centerline.

The unchanged SAE buck model Error! Bookmark not defined. **has an initial velocity of 40 km/h. The same contact settings as defined in 2.2 are used (i.e. the static and dynamic coefficient of friction between the car and the HBM is set to 0.3.). No ground floor is modelled. Gravity is applied and the HBM is positioned as close as possible to the vehicle model.**
All outputs as described in 2.3. are generated. From the simulations, the HIT is calculated according to 3.3. The model fulfills the validation, if the criteria defined in Table 11, based on the scaled corridors defined in Forman et al. (2015), are met and all quality checks defined in 2.4. are fulfilled. For the HIT, the mean from the PMHS test was taken as reference value, allowing a deviation of +/- 15%, which corresponds to the average deviation between HIT and TRT in DPPS cars observed in previous studies[15].

Table 11
Validation of AM50 HBMs

	HIT [ms]		HCx [mm]		HCz [mm]	
	Min	Max	Min	Max	Min	Max
Reference from PMHS Tests	117	159	1402	1653	1020	1271
HBM 1						
HBM 2						
HBM 3						

]

[14] Klug, Corina; Feist, Florian; Raffler, Marco; Sinz, Wolfgang; Petit, Philippe; Ellway, James; van Ratingen, Michiel (2017): Development of a Procedure to Compare Kinematics of Human Body Models for Pedestrian Simulations. In: 2017 IRCOBI Conference Proceedings, IRC-17-64. IRCOBI. Antwerp, Belgium, 13.-15.9.2017. http://www.ircobi.org/wordpress/downloads/irc17/pdf-files/64.pdf.

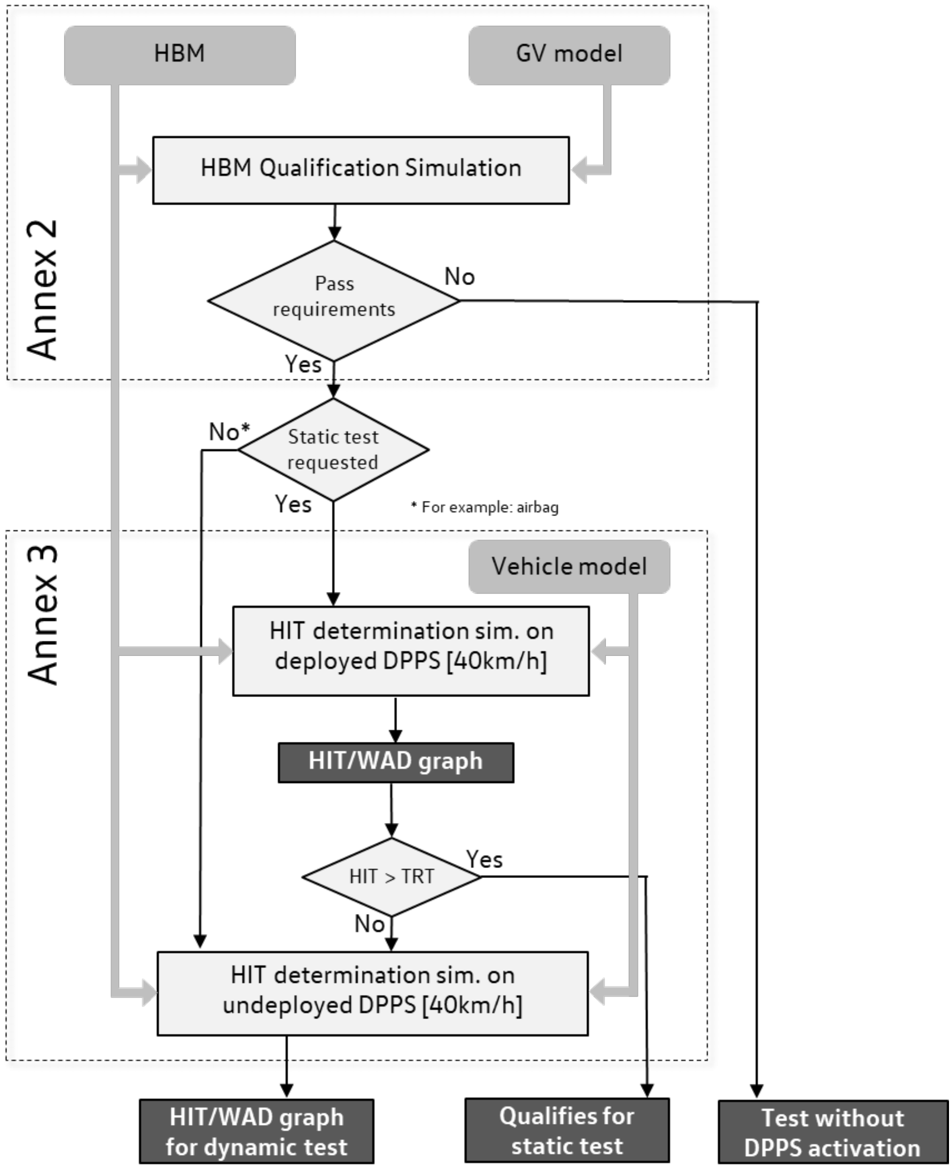
[15] Klug, Corina; Feist, Florian; Schneider, Bernd; Sinz, Wolfgang; Ellway, James; van Ratingen, Michiel (2019): Development of a Certification Procedure for Numerical Pedestrian Models. In The 26th ESV Conference Proceedings. Eindhoven, Netherlands, 10-13 June: NHTSA, Paper No.19-0310-O. https://www-esv.nhtsa.dot.gov/Proceedings/26/26ESV-000310.pdf.

Annex 3

HIT-Determination Simulation

1 INTRODUCTION

A HIT-Determination simulation is a computer simulation for determination of HIT over WAD in the DPPS vehicle model for deriving the test conditions for the assessment of deployable systems as specified in the Annex 1.



1.1 General Requirements

The Human Body Models (HBMs) that are used for HIT-Determination simulations have to be qualified according to Annex 2. The HBMs have to be the very same unchanged HBMs that are qualified in Annex 2. All simulations (qualification and HIT-Determination) have to be performed with consistent settings as described in paragraph 1.3 of Annex 2.

2 Procedure

2.1 Impact Simulations

There are two kinds of numerical simulations:

HIT Simulations on deployed DPPS
Simulations on the deployed DPPS to decide whether the physical head test on the deployable system can be done dynamically or statically.

HIT Simulations on undeployed DPPS
Simulations on the undeployed DPPS to determine HIT (needed for dynamic test time triggering) and WAD values.

Pedestrian models shall be selected from the following statures, a six year old (6YO), 5th percentile female (AF05), 50th percentile male (AM50) and 95th percentile male (AM95). The pedestrian position and stance to be used in the model is defined in Annex 2. The pedestrian model has to be positioned, such that the head CoG is aligned with the vehicle centreline.

The vehicle model has to be positioned in the setup such that the vehicle ground level is aligned with the ground level used in the qualification simulations.
As described in Annex 2 the HBM should be exposed to a vertical acceleration field constituting the gravitational loading.
A local vehicle coordinate system has to be initially aligned with the global coordinate system defined in Annex 2, Appendix A and should be connected to the vehicle model CoG.

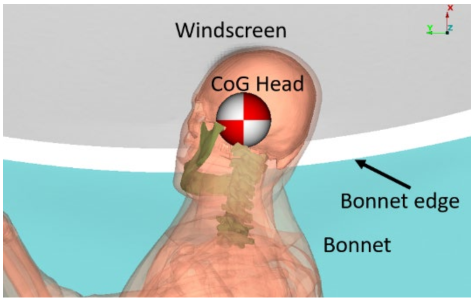
The initial speed of the vehicle model has to be prescribed and is 40 km/h for all simulations. The y and z motion of the car has to be constrained and the motion in x-direction must not be constrained.

2.2 Selection of HBMs

The selected HBMs (needed to draw the WAD/HIT-line in the evaluation) are those HBMs where the head hits the DPPS properly, which is when:

- There is a contact between head and the DPPS
- At time of this contact the x-coordinate of the CoG of the head is smaller than the largest x-coordinate of the DPPS at y=0.

See picture with an example, where the CoG of the head lies behind the DPPS at time of contact. This HBM does not hit the DPPS properly (only contact with chin of HBM).



Simulations with the next tallest HBM should also be performed, but only to prove that this HBM does not hit the DPPS properly.

If only one HBM should hit the DPPS properly, the next tallest HBM should also belong to the selected HBMs.

2.3 Output Requirements

It should be confirmed that the following outputs have been generated from each simulation:
Time history curves of:

- **x and z coordinate of HC and AC in the global coordinate system**
- **x displacement of vehicle CoG in the global coordinate system**
- **Resultant acceleration of HC**
- **Contact forces (between vehicle and HBM without upper extremities, vehicle and HBM head and total contact force)**
- **Total hourglass and internal energies of the total setup**
- **Mass increase,**

all plotted every 0.1ms or less.

Furthermore, animations of the simulations should be generated with an output interval of 1ms.

2.4 Quality Checks

The following Quality Checks shall be performed:

- **Contact force (between HBM and vehicle) is zero at simulation start.**
- **Total energy remains constant within a 15% tolerance.**
- **Hourglass energy ≤ 10% of the total energy.**
- **Artificial mass increase is less than 3%.**

3 Documentation

3.1 General

The following information should be provided:

- **Date of report**
- **Name of car manufacturer**
- **Type and release version of software (FE-software package name, revision and version)**
- **Name and version of Human Body Model**
- **Specification of car**

Images showing the front view and side view of the pedestrian, at t0 and at the time of head impact should be added to the report.

3.2 Consistency with Qualification Simulations

For all simulations Table 1 should be filled in

Table 1

Checklist for simulation settings	Consistent between Qualification and HIT determination Simulation?
Identical Human Body Model	Y/N
Solver Version	Y/N
Timestep	Y/N
All other control settings	Y/N

3.3 Quality Checks

For all simulations Table 2 should be filled in

Table 2

Verification evaluation criteria	Allowed	Observed	Pass?
Coefficient of friction between Vehicle and Human Body Model	0.3		Y/N
Head centre of gravity is positioned at vehicle centreline	Y=0 mm		Y/N
Contact force between HBM and vehicle at simulation start	0		Y/N
Change in total energy throughout simulation	≤15%		Y/N
Amount of hourglass energy relative to total energy	≤10%		Y/N
Artificial mass increase relative to total mass of the setup	≤3%		Y/N

3.4 Calculation of Head Impact Time

Time of first contact is defined as the first time where the contact force is not 0 anymore. The Head Impact Time (HIT) is defined as the elapsed time subsequent to the time of first contact of the HBM (neglecting forearms and hands) with the vehicle outer surface and the time of first contact of its head with the vehicle outer surface.

If this method is for any reason not applicable, an appropriate alternative method should be applied and documented.

3.5 Determination of WAD corresponding to HIT

For the determination of the wrap around distance (WAD) a point on the surface of the vehicle is necessary. This point is defined as follows (all coordinates relative to the local vehicle coordinate system):

At time of head contact with the DPPS the point

$$(x_{head}, 0, z_{head})$$

where

x_{head} is the x-coordinate and
z_{head} is the z-coordinate of the CoG of the head

will be projected orthogonally onto the surface of the undeployed vehicle. (If there are multiple projection points take the one with the highest x value.)

Compute the WAD for this point rounded the nearest full millimetre.

3.6 Results of HIT-Determination

For those HBMs that are selected according to 2.2 the computed HIT-Values and corresponding WADs have to be filled into the following tables
If HIT>TRT for all HBMs, simulations on the undeployed DPPS are not required.

Table 3 HIT Simulations on deployed DPPS

HBM	WAD [mm]	HIT [ms]
6YO		
AF05		
AM50		
AM95		

Table 4 HIT Simulations on undeployed DPPS

HBM	WAD [mm]	HIT [ms]
6YO		
AF05		
AM50		
AM95		

For each simulation, the following diagrams should be provided:

- ACx and HCx as a function of time
- ACz and HCz as a function of time
- HCz as a function of HCx and ACz as a function of ACx
- Total Contact Force between HBM and vehicle as a function of time
- Total, kinetic, internal and hourglass energy as a function of time

4 Evaluation

4.1 HIT Simulations on deployed DPPS

Based on the results of table 3 a graph shall be plotted using a linear regression line for comparison with TRT in the diagram as shown in Figure 1.

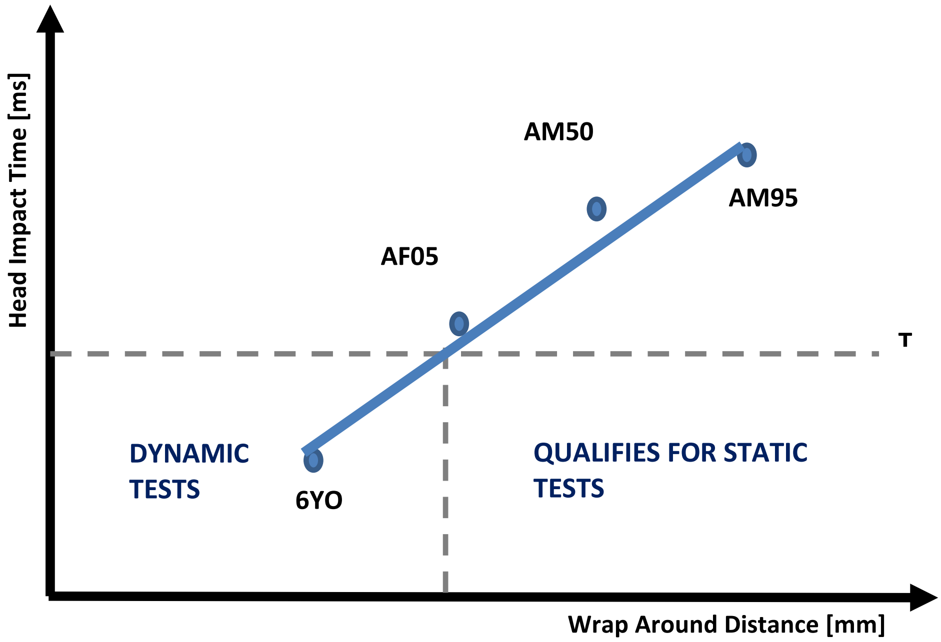


Figure 1: WAD vs HIT

4.2 HIT Simulations on undeployed DPPS

Based on the results of table 4 a graph shall be plotted using a linear regression line as shown in Figure 2. The lines have to be extrapolated in both directions.

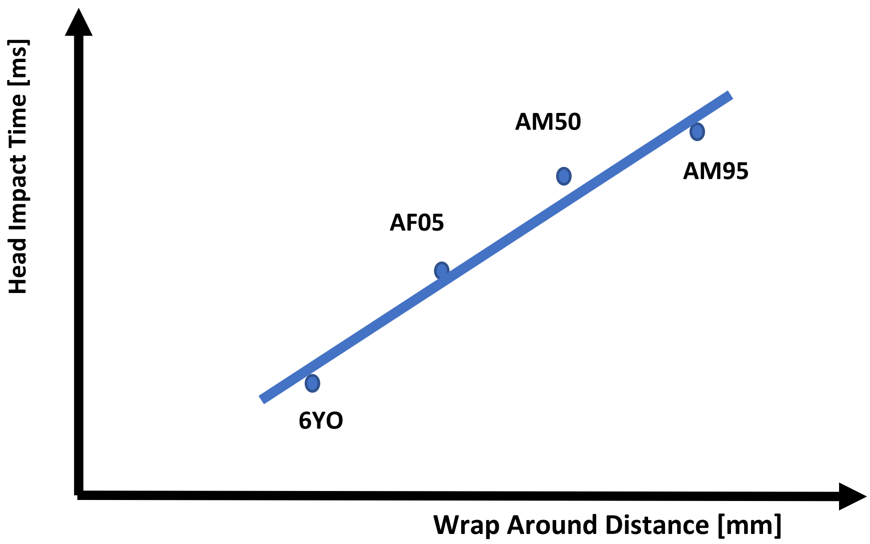


Figure 2: WAD vs HIT