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**Economic Commission for Europe**

Inland Transport Committee

**World Forum for Harmonization of Vehicle Regulations****Working Party on Passive Safety****Seventy-third session**

Geneva, 15–19 May 2023

Item 2 of the provisional agenda

**UN Global Technical Regulation No. 9 (Pedestrian safety)****Proposal for Amendment 3 to UN Global Technical Regulation No. 9 (Pedestrian safety) \*****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 provisions on DPPS. The modifications to the existing text of the UN Global Technical Regulation No. 9 (ECE/TRANS/180/Add.7, Corrs.1 and 2, Amends.1 and 2) are marked in bold for new or strikethrough for deleted characters.

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\* In accordance with the programme of work of the Inland Transport Committee for 2023 as outlined in proposed programme budget for 2023 (A/77/6 (Sect. 20), table 20.6), the World Forum will develop, harmonize and update UN Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

## I. Proposal

*Section I, Statement of Technical Rationale and Justification,*

*Insert new paragraph 0, to read:*

**"0. FOREWORD: UN Global Technical Regulation (UN GTR) No. 9, Pedestrian Safety, was established in the Global Registry on 12 November 2008. The development of the original GTR was discussed as "Phase 1" beginning with paragraph 0 bis. The GTR was amended by Corrigendum 1 on 12 November 2009, and by Corrigendum 2 and Amendment 1, affecting only the scope of the GTR, on 10 November 2010. Amendment 2 was established on 14 November 2018 and replaced the European Enhanced Vehicle-safety Committee (EEVC) lower legform impactor used for the bumper test with the flexible pedestrian legform impactor (FlexPLI). Development of Amendment 2 is discussed as "Phase 2" beginning with paragraph 133. Amendment 3 was established on [insert date when established] and added new requirements for vehicles equipped with a Deployable Pedestrian Protection System (DPPS). Amendment 3 is discussed as "Phase 3" beginning with paragraph 228. The informal working group that developed Amendment 3/Phase 3 notes that paragraph 122 in the discussion of Phase 1 has been superseded for vehicles equipped with a DPPS."**

*Paragraph 0 (former), renumber as Paragraph 0 bis*

*After paragraph 227, insert new subsection C, to read:*

### "C. Phase 3

**228. Paragraphs 228. to 298. reflect the development of Phase 3 of UN GTR No. 9 and relate to the development of test provisions for vehicles equipped with deployable pedestrian protection systems (DPPS), including prerequisites, without changing the headform impactors and their corresponding parameters for tests to the bonnet top.**

#### 1. Introduction and General Background

**229. During the fifty-sixth session of GRSP (9–12 December 2014) the expert from the Republic of Korea proposed to develop test provisions for active devices to further improve vehicle safety performance. It was noted that guidelines already existed for testing active bonnets (INF GR/PS/141 Rev. 1), however these were considered to be insufficient, and consent was sought from WP.29 and AC.3 to extend the IWG mandate on the development of phase 2 to UN GTR No. 9.**

**230. The proposal from the Republic of Korea to develop an amendment to UN GTR No. 9 on the testing of provisions for deployable systems of the outer surface to ensure an adequate protection of pedestrians was endorsed by AC.3 at its forty-eighth session (17 November 2016) and the IWG mandate on the development of Phase 2 was extended until December 2017.**

**231. The development of the test provisions for deployable systems was initiated by a Task Force under the umbrella of the IWG on phase 2 (TF-DPPS). After four meetings of TF-DPPS, the IWG mandate expired. Subsequently, AC.3 endorsed at its fifty-second session (14 March 2018) the transformation of TF-DPPS into a new Informal Working Group (IWG-DPPS).**

**232. TF-DPPS held the following meetings:**

- (a) 27–28 February 2017: Paris, France;
- (b) 28–29 March 2017: Paris France;
- (c) 7 September 2017: virtual;
- (d) 21–23 November 2017: Berlin, Germany.

**233. IWG-DPPS held the following meetings:**

- (a) 18–20 April 2018: Frankfurt/Main, Germany;
- (b) 5–7 September 2018: Brussels, Belgium;
- (c) 10 December 2018: Geneva, Switzerland;
- (d) 12–14 March 2019: Paris, France;
- (e) 3–4 September 2019: London, United Kingdom;
- (f) 28 November 2019: virtual;
- (g) 4–5 March 2020: virtual;
- (h) 15–17 September 2020: virtual;
- (i) 18 November 2020: virtual;
- (j) 20–21 January 2021: virtual;
- (k) 9–10 March 2021: virtual;
- (l) 27–28 April 2021: virtual;
- (m) 29–30 June 2021: virtual;
- (n) 14–15 September 2021: virtual;
- (o) 16–17 November 2021: virtual;
- (p) 9–10 February 2022: virtual;
- (q) 5–6 April 2022: virtual;
- (r) 2–3 June 2022: hybrid;
- (s) 18–20 October 2022: hybrid, International Organization of Motor Vehicle Manufacturers (OICA)-Paris;
- (t) 8–9 November 2022: virtual;
- (u) 15–16 November 2022: virtual;
- (v) 31 January–2 February 2023: hybrid, Brussels-Netherlands Vehicle Authority (RDW) office.

234. The meetings were attended by representatives of: European Commission, France, Germany, Italy, Japan, Republic of Korea, the Netherlands, Spain, United Kingdom of Great Britain and Northern Ireland, United States of America, European Association of Automotive Suppliers (CLEPA) and OICA.

235. The meetings were chaired by the expert of the Republic of Korea, while the secretariat has been provided by the experts of OICA since February 2017 (TF-DPPS1).

236. ECE/TRANS/WP.29/GRSP/2023/6 was proposed at the seventy-third session of GRSP as a complete draft of Amendment 3 to the UN GTR No. 9, including Part 1 and Part 2 and supersedes the other drafts previously submitted.

## 2. Principle of Deployable Pedestrian Protection Systems

237. DPPS should be activated as intended for pedestrian protection when the pedestrian is hit by a vehicle. To achieve this goal, the IWG agreed that requirements were needed to ensure that:

- (a) The collision with the pedestrian is detected; and
- (b) The existing headform requirements in the GTR are met for a 35km/h head impact velocity as well as for vehicle speeds below the deployment threshold of the DPPS.

Only contact sensors are taken into consideration for detection on current DPPS. It was discussed that in a possible "DPPS phase 2", non-contact sensors could be explored and comprehended.

238. This Regulation aims to improve protection from injury caused by a collision between the vehicle front and the pedestrian. To assure that a DPPS operates properly and offers at least the same level of pedestrian protection as a conventional passive system, the IWG agreed that the system provisions listed in paragraph 237 are a minimum requirement. Additionally, the IWG discussed the need for two other system requirements:

- (a) Higher speeds - Assurance that a DPPS system will deploy safely at pedestrian impact speeds above 40 km/h;
- (b) Body loading - Assurance that pedestrian body loading of a DPPS will not compromise its effectiveness prior to head impact.

These needs may exist for DPPS systems in particular, as opposed to conventional passive systems. Members of the IWG expressed their concerns that at higher speeds, actuator limitations may prevent the timely deployment of a DPPS, while the negative effects of body loading may be exacerbated by a deployed system without sufficient support. Some IWG members found that a reasonable bonnet clearance at the location and prior to the head impact is needed to prevent a hard head contact due to a collapsing bonnet.

239. At this time, the IWG agreed that a regulatory need is not known with enough certainty to warrant the development of test procedures and requirements related to higher impact speeds and body loading. In other words, current DPPS systems that meet the requirements listed in paragraph 237 may also account for higher impact speeds and body loading. However, further research or the development of future DPPS may result in insights for which the effect of pedestrian body loading and protection at higher speeds may be required. Additionally, future accidentology may reveal a prominent safety need exists in current DPPS systems due to body loading and impacts at higher speeds. In either case, the GTR will be reviewed and adapted if and where necessary.

240. At the request of the United States, the IWG decided that, based on a determination by each Contracting Party or regional economic integration organization, the fulfilment of all provisions may be required to be demonstrated using the dynamic test option of Annex 1.

241. Since the expressions "static test" and "dynamic test" are not uniformly used within different Regulations and their test procedures, the IWG DPPS discussed about how to define static and dynamic tests for the purpose of testing DPPS. In this context, the IWG agreed upon defining a "static test" as a headform impact on the DPPS in the deployed position. A "dynamic test", on the other hand, is defined as a synchronised headform impact on the DPPS during its deployment.

### 3. Detection test area, lateral offset leg versus head

242. As one of the fundamental prerequisites to account for the potential safety benefits of DPPS, the pedestrian needs to be detected during an accident prior to head impact on the vehicle. IWG discussed the required width of the area on the vehicle front where a pedestrian needs to be detected in order to purposefully initiate the system.

243. An earlier Task Force study was recalled by the expert from Germany in which it was shown that pedestrian impacts take place over the entire vehicle width (TF-BTA-6-07). In a later IWG meeting, Laboratoire d'Accidentologie et Biomécanique (LAB) presented an analysis of fatal French accidents contained within the Etudes Détaillées d'Accidents (EDA) database (IWG-DPPS-18-08). The LAB analysis revealed that for all cases in which a pedestrian was struck outside the longitudinal frame rails of the vehicle, accounting for approximately 15–20 per cent of the vehicle width, there were no subsequent head impacts to the bonnet (though about one-third of the cases did result in pelvis impacts to the bonnet). Thus, in principle and ideally, a detection of pedestrians in nowadays DPPS should be required accordingly.

244. Also, it was agreed that in many cases the pedestrian may tend to spin off at the outer widths of typically angled or V-shaped vehicle front-end surfaces, without a head-to-bonnet impact. This effect is even more present when using a leg impactor as pedestrian surrogate without attaching any mass of a pedestrian hip, torso, arms, neck, and head, consequently limiting the load on the sensing system and therefore not being representative for a pedestrian.

245. In the light of these observations, IWG investigated further definitions of a detection area.

246. The expert from Japan proposed that the detection area – which would differ from the leg test area – be the area in the lateral direction of the vehicle in which activation of the DPPS is ensured in a vehicle-to-pedestrian impact (Task Force Document DPPS-3-03). The reason given was that: only in this area a head impact test would be allowed with activated DPPS, while outside this area the DPPS was supposed to remain deactivated.

247. The expert from Germany suggested to use the bumper test area (BTA) as already defined for the lower extremity injury risk assessment based on the tests with the lower legform impactor. Since the flexible pedestrian legform impactor (FlexPLI) was also chosen as verification impactor (compare Chapter 4) and the BTA is well elaborated and established, the expert from Germany reasoned that existing definitions could be applied.

248. The expert from European Automobile Manufacturers' Association (ACEA) also referred to current regulatory definitions and proposed to apply the lower leg test area defined in Amendment 2 to UN GTR No. 9 as required confirmation of sensing capabilities for DPPS homologation or self-certification (IWG-DPPS-1-08).

249. The expert from OICA suggested to define the outer boundaries of the detection area by the width between the corner reference points (CRPs) (CRPs, the intersections of the side reference lines and the bonnet leading edge reference line), projected to the upper bumper reference line (IWG-DPPS-4-05). It was noted by IWG participants that when a vehicle has multiple or continuous intersections between the bonnet leading edge reference line (BLERL) and the side reference line (SRL), the most outboard point is used as the CRP. It was also noted that the distance between right and left CRPs can be narrowed easily by a minor, cosmetic redesign of the vehicle front end. Such a redesign would have no effect on the legform test zone but could lead to large differences in CRP locations and thus greatly affect the DPPS detection test area. Therefore, the IWG abstained from further discussions on the use of the CRP in defining the detection test area.

250. An independent expert proposed a required percentage of the vehicle width (around the longitudinal vertical centreplane as its centre) as detection test area, with a subtraction of no more than 12.5 per cent of the vehicle width but a maximum of 250mm at each side of the vehicle. The independent expert's ~~The BGS~~ proposal also stated that the detection test area should be no less than the BTA (IWG-DPPS-5-09). It was explained that with a percentage all vehicles would be equally treated, regardless their effective width: however, big cars should not be allowed to further reduce the detection area, beyond 250mm on each side.

251. The expert from Germany subsequently provided an update to the independent expert's ~~BGS~~ proposal wherein the vehicle width was defined as the width at the cross-section of the front axle, without rear view mirrors or rear-view mirror substitute systems, so that the proposed detection test area was not linked to the width of the deployed area of the DPPS (IWG-DPPS-7-10). Examples of four current vehicle models were displayed to show how the detection test area based on the 12.5 per cent stipulation was greater than the BTA.

252. Japan investigated the outer most boundary of the detection area proposed by Germany and confirmed that it covers the headform test area for vehicles equipped with DPPS currently available on the market in Japan. Thus, Japan accepted the detection area proposed by Germany. However, it was suggested that in cases where

the sensing width is narrower than the width of the detection area, the DPPS would be allowed to only be activated within the sensing width (IWG-DPPS-9-09). The rationale was that the lateral offset between the lower extremity impact and the pedestrian head impact after wrap around would be considered as rather small.

253. The group examined indications regarding the possible lateral offset between lower extremities and head in pedestrian accidents with passenger cars.

254. The expert from Japan presented post-mortem-human-subject (PMHS) tests, Human Body Models (HBM) finite element simulations and dummy tests where the lateral movement of the pedestrian's head until the head impact on the vehicle front was small. It was concluded that the impact locations of the head and the leg would not differ a lot (IWG-DPPS-10-04).

255. The expert from Germany examined some cases from the German In-Depth Accident Study (GIDAS) database for real world trajectories of pedestrians. The sample showed in several cases a significant lateral offset between the first leg impact and the subsequent pedestrian head impact. They concluded that laboratory test conditions with stationary test specimen do not always reflect real world impact conditions in an appropriate way (IWG-DPPS-10-09).

256. The expert from Japan proposed that the pedestrian accidents scenario assumed under the current UN GTR No. 9 is the case when the vehicle impacts the stationary pedestrian from the side, and the pedestrian accidents scenario assumed in the test for DPPS should be the same as the current UN GTR No. 9. Japan found that, for consistency reasons, a consideration of the pedestrian kinematics with significant lateral offset between the pedestrian's leg impact and the subsequent head impact would require such a consideration with modified impact angles also during component tests. However, Japan also showed that this would not be in the scope of the IWG and beyond the minimum requirements as specified in the GTR (IWG-DPPS-11-03).

257. The expert from Germany clarified the objective of the IWG, which was not limited to clarification of the current practice, but also to develop new and more detailed requirements, where needed, to ensure a correct activation and design for vulnerable road user protection. Since the detection of pedestrians is one of the indispensable prerequisites and DPPS needs to be correctly activated, real world conditions under consideration of pedestrian trajectories with a considerable offset between leg and head impact need to be taken into account to provide for at least the same level of protection as conventional systems without DPPS (IWG-DPPS-11-05).

258. The expert from Japan presented a literature review of real-world accident data and concluded that a walking pedestrian hit laterally by a vehicle would be a representative accident scenario (IWG-DPPS-12-07) which is reflected by the current UN GTR No. 9 test procedures. The expert from Germany found that also a large number of oblique impacts were included in the share of given lateral impacts which need to be taken into consideration with respect to the leg versus head offset. It was added that UN GTR No. 9 would not only cover lateral but also oblique impacts, since the outer skin of the vehicle front would be, in most cases, not parallel to the moving trajectory of the crossing pedestrian and thus not perpendicular to the velocity vector of the impactor during the impact. Regarding the pedestrian accidents scenario assumed for DPPS, other contracting parties supported Germany's proposal, but Japan did not accept it. However, because the detection area proposed by Germany covers the headform test area for vehicles equipped with DPPS currently available on the market in Japan, Japan accepted the detection area proposed by Germany regardless the difference of assumption for the pedestrian accidents' scenario for the tests.

259. The expert from Association of the Automotive Industry (VDA) explained possible shortcomings of the BTA definition when applied to the DPPS detection test area. For the lower leg injury assessment, the BTA is defined by the greatest of the following areas: (a) the area limited by the corners of bumper, moving on either side 42mm inboard; (b) the outermost ends of the bumper beam, moving on either side 42mm inboard. The expert from VDA took exception to the use of the bumper beam in defining the detection test area for DPPS applications (IWG-DPPS-14-04). They

presented conditions that exist on two production vehicles, in which structures are appended to the bumper beam, but only for certain markets, in order to fulfil corresponding crash test requirements. These structures have the effect of extending the BTA. Hence, if the structures were used to stipulate the DPPS detection test area, there would exist different detection test areas for different markets.

260. Further discussion on bumper beam structures ensued. The expert from OICA described the structures as "optional" and insufficient to serve as a pressure tube backstop. Additionally, they extend outboard into an area in which the fascia covering is curved (outboard to the corners of bumper as defined by the 30° gauge). These two factors preclude the ability to install a sensing tube that could generate enough signal to trigger a DPPS actuator as described in a previous VDA analysis (IWG-DPPS-12-08).

261. A working subgroup of the IWG analysed current examples of DPPS on the market to guide a decision on how to proceed with a suitable definition for the detection test area. This survey included twelve production vehicles with different sizes and body styles. For each vehicle, following widths were noted: the car manufacturer-reported width of sensing, a possible detection test area determined by the 12.5 per cent/250mm stipulation, and a possible detection test area determined via the lower leg Bumper Test Area (BTA) criteria: the 30° gauge and the bumper beam (IWG-DPPS-18-07).

262. The survey revealed that the width of sensing can also extend outboard of the detection test area when defined by the relevant 30° corner gauge contact points and into an area where a glancing blow will occur. In the vehicle survey, the 12.5 per cent-based width of the detection test area was wider than the corner gauge-based "geometry" in most of the vehicles surveyed. This shows that – at least to a certain extent – it is feasible to overcome the "spin off/low signal" issue brought up in IWG-DPPS-12-08.

263. The vehicle survey showed one instance where the corner gauge-based detection test area was greater than the 12.5 per cent-based detection test area. In this case, the reported width of sensing was even greater. This shows that it is feasible to enforce the corner gauge-based detection test area when it is wider than the 12.5 per cent-based width.

264. The vehicle survey also showed that some of the vehicles had reported widths of sensing that would not have met the width requirement of the detection test area as determined by the 12.5 per cent stipulation or the corner gauge. This means that with phase 3 of UN GRT No. 9, new vehicles will have a greater width of sensing relative to many vehicles not fulfilling this requirement.

265. Based on the discussions, the bumper beam has been excluded from the stipulation for the DPPS detection test area. Furthermore, the exclusion is consistent with a performance-based standard. If it was included, it would partly act to prescribe the sensing tube technology and the form of the bumper beam itself. Originally, the bumper beam was considered because sensing technology that uses a pressure tube typically operates by using the beam as a hard surface to "back up" the tube. It was reasoned that if the beam is of a certain length, it is feasible to require the tube (and the sensing area) to be the same length: in three vehicles of the survey, the width of the bumper beam underlying the fascia exceeded the 75 per cent stipulation. However, this misleadingly assumes that the beam will always be made of a rigid, tubular structure and that pressure tube technology is used. In fact, the survey showed that accelerometers were used in four of the vehicles. A Regulation should not prescribe a particular technology or stand in the way of new technologies, such as different sensing technologies or bumper beams that take on different materials, shapes and functions.

266. The IWG finally agreed upon the minimum width of the detection test area being the vehicle width minus 12.5 per cent (but not more than 250mm) on each side but extending at least up to the points 42 mm inboard of each corner of bumper.

#### 4. Test procedures for the sensing systems of Deployable Pedestrian Protection Systems and selection of the verification impactor

267. For verification of the functionality of the DPPS sensing system, component tests will be performed with the flexible pedestrian legform impactor (FlexPLI), representing the lower extremities of a 50th percentile male for injury assessment of knee and tibia injuries. The use of the flexible pedestrian legform impactor (FlexPLI) as sensing impactor was agreed following extensive investigations.

268. Contact biofidelity was considered to be an indispensable property of such a sensing impactor. The IWG-DPPS found that, when verifying the ability of a contact sensor to detect a pedestrian, the relevant properties of an impactor are the total mass, mass distribution, moments of inertia, centre of gravity, impactor width, bending stiffness and the local stiffness / compression behaviour in impact direction were highly relevant properties of an impactor for the signals in use with contact sensors. While most properties of the flexible pedestrian legform impactor (FlexPLI) were accepted to be very reliable due to its design specifications, two complementary studies were carried out to ensure its biofidelic and repeatable local stiffness.

269. The first study, carried out by Concept Tech, investigated time histories of different pedestrian surrogates and human body models for identical load cases. It concluded the flexible pedestrian legform impactor (FlexPLI) had, in principle, an appropriate contact biofidelity to work as a representative pedestrian surrogate for sensing issues (IWG-DPPS-3-03).

270. The second study, carried out by The Federal Highway Research Institute (BAST) and an independent expert in cooperation with ACEA members, focused on the intrusion during inverse tests at impact speeds typical for the lower deployment threshold of DPPS within the typical time interval for detection of pedestrians. Here, two different setups were used, covering the height dimensions as required by Research Council for Automobile Repairs and UN Regulation No. 42 (Front and rear protection devices) which need to be fulfilled by a high number of vehicles. It could be shown that the double integral of the filtered impactor acceleration signal, representing the intrusion, was within a small range with satisfactory coefficients of variation (IWG-DPPS-6-04, IWG-DPPS-7-09 and IWG-DPPS-9-11).

271. The IWG-DPPS concluded that the flexible pedestrian legform impactor (FlexPLI) was currently the best available pedestrian surrogate which could be used as an impactor for the sensing verification of the system for the time being.

272. The IWG emphasized that, due to the complexity of testing the DPPS, the test provisions laid down represent a limited range of typical load cases. It is therefore seen as due care of the vehicle manufacturer that any DPPS would ensure the necessary protection (e.g. for a variation of speeds and pedestrian statures) in order to act as intended in the event of a collision with a pedestrian for a variety of pedestrian statures.

#### 5. Determination of Head Impact Time and wrap around distance

273. 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. IWG decided to use two kinds of HIT determination depending on the application (static or dynamic test) as a compromise of technical feasibility (i.e. for pedestrian airbags) and the consideration of worst-case scenarios:

(a) "HIT\_for decision" (HIT\_d) represents the worst case and is determined with the deployed DPPS. The HIT\_d is compared to the total response time and used to decide whether a test on the DPPS is to be done on a deploying (dynamic test) or on a statically deployed system (static test).

(b) HIT\_s (s for synchronisation) is determined with the undeployed DPPS, as for airbags a deployed position is difficult to define. HIT\_s is used to synchronise the test trigger time of a dynamic test in the case of a deploying system.



274. The IWG discussed three methods of determining HIT:

- (a) Use of HBM simulations;
- (b) Use test dummies and physical testing;
- (c) Use of a "generic" approach.

275. IWG ultimately agreed to propose a procedure using HBM simulations based upon a procedure on Euro New Car Assessment Programme No. TB024, as an initial DPPS amendment.

276. For deployable pedestrian protection systems to work as intended, it is necessary that the system in question is activated in due time.

277. The HIT<sub>d</sub> of pedestrians of the relevant statures needs to be compared with the total response time (TRT) of the DPPS.

278. This comparison provides the basis for whether headform tests to the vehicle front are performed with the DPPS either statically in undeployed or in deployed position, or dynamically onto a deploying system.

279. The IWG DPPS understood that HBM simulations were the common method for determination of the HIT. In order to ensure comparability and applicability of HBM for that purpose, a qualification procedure for HBMs was developed within a subgroup of the IWG DPPS, [led by the experts of Austria and OICA. All Generic Vehicle models used for the qualification are made available [as Addendum 4 of Mutual Resolution No. 1 (M.R.1) of the 1958 and the 1998 Agreements ECE/TRANS/WP.29/1101].]

280. Given its limitations, the IWG recognized the qualification procedure being applicable for the determination of HIT and wrap around distance (WAD) only. The simulation procedure described is limited to HBM qualification for the determination of HIT and related WAD and not suited to qualify for injury assessment in any pedestrian or other crashworthiness regulations.

281. In order to create an independent baseline, reference simulations have been used to determine requirements and tolerances described in the Annex 2 "Qualification Process of HBMs for Pedestrian HIT-Determination". The HBMs that were used for these reference simulations have been validated by comparing their simulation responses (HIT, kinematics) with PMHS tests. [The background concerning the validation of reference HBMs are submitted at the seventy-third session of GRSP (GRSP-73-03.)]

282. However, the injury assessment abilities of HBMs are not validated. Therefore, and as of now, HBMs may not be used for injury assessment in any pedestrian or other crashworthiness regulation.

283. The simulation procedures with the qualified HBMs and the actual vehicle model for HIT determination are described in Annex 3 "HIT determination simulation".

284. Concerning the linear regression explanation, IWG has discussed different options to determine HIT versus WAD graphs for the decision of a static or a dynamic test mode and a system triggering for the dynamic testing. IWG considered two methods – the "linear regression method" and the "dot-to-dot method" – and recognized that each method has pros and cons. Both Japan and Korea preferred the "dot-to-dot method" because the method is mathematically more accurate, by using the simulated HIT values as agreed upon in annexes 2 and 3, and the linear regression method may have low correlation (IWG-DPPS-5bis-04 (Japan), IWG-DPPS-6-05 (Korea)). Other Contracting Parties and NGOs were in favour of the "linear regression method", because the method is practical to figure out the corresponding HIT values to WADs and may also be used to extrapolate HIT for WADs lower than 6 years old or higher than 95th percentile adults (IWG-DPPS-6-06 (OICA)). Finally, the IWG agreed on the "linear regression method" to figure out HIT values after extensive discussions on both methods.

285. Japan proposed to allow the use of physical test tools to predict HIT in addition to numerical tools. Performance requirements and test procedures for full scale pedestrian dummies have been specified in a published Society of Automotive Engineers (SAE) technical standard (SAE J 2782) and test results for an existing pedestrian dummy have been reported in SAE J 2868. Due to the availability issue of the SAE standards and the upcoming update of J 2868, Japan also proposed to seek a way to transpose the contents of the SAE standards into UN GTR No. 9. As a result of discussion, IWG agreed to consider developing further modifications to this amendment to incorporate the allowance of the use of physical test tools to predict HIT after the phase 1 of this activity is complete.

6. Protection at speeds below lower deployment velocity threshold

286. To protect the head of a pedestrian in the event of a collision, DPPS usually provide additional clearance between the bonnet and underlying hard structure. However, since DPPS are only activated at and above a lower deployment velocity threshold, head protection at head impact velocities equivalent to the vehicle speed below this threshold must be demonstrated in order to ensure the same level of protection as conventional passive systems. For that purpose, headform tests are performed at these impact velocities on the undeployed DPPS and their results compared to the biomechanical limits which also apply for the compliance tests.

287. Members of the IWG found wide variations of the ratio between head impact velocity and vehicle impact speed (between 0.68 and 1.5 for a car impact speed of 40km/h) in former studies. When taking into account the ratio for the legal requirements (head impact velocity of 35 km/h corresponding to a vehicle speed of 40km/h), the IWG finally decided to use a rounded ratio of 0.9 for the verification tests at lower deployment velocity threshold. Thus, for the DPPS to demonstrate the fulfilment of this prerequisite, head impact tests are to be performed at an impact velocity which is 0.9 times the vehicle lower deployment velocity threshold.

7. Total Response Time measurement

288. Since it is critical that the DPPS is deployed before the pedestrian's head contacts the vehicle for pedestrian protection in a pedestrian-to-vehicle collision, how to measure TRT (ST+DT) needs to be verified. The specific conditions for the verification test were reviewed. The impact speed and location were decided as equal to the conditions for defining HIT, and the flexible pedestrian legform impactor (FlexPLI), which is the same impactor for sensing system verification, was selected for the test.

289. There were concerns about how to conduct a headform test when the bonnet is still deploying towards its maximum height. Whereas static tests are able to save time but may differ from actual test results with moving DPPS, dynamic tests can be performed in actual conditions but may take a longer time. The IWG concluded that dynamic tests should be conducted for the case, subsequently, TRT should be measured from the time of first contact of the flexible pedestrian legform impactor (FlexPLI) with the vehicle outer surface to the time that DPPS reaches its maximum deployment height first.

8. Headform test options

290. Depending on the degree of fulfilment of the prerequisites, the compliance tests with adult and child headform impactors are performed on the static DPPS in either the undeployed or the deployed state, or on the deploying DPPS.

291. A protection at speeds below the lower deployment velocity threshold and the appropriate detection of a pedestrian are both indispensable requirements for vehicle approval or compliance.

292. Furthermore, only those headform tests qualify for being performed on the deployed DPPS, where during simulations with qualified HBM on the deployed DPPS, the HIT<sub>d</sub> is proven to be greater than the TRT.

293. Where a pedestrian is not detected or any relevant HBM fails the qualification procedure, all tests are to be performed on the undeployed DPPS.

294. In the remaining cases, where the HIT<sub>d</sub> is smaller than or equals the TRT, or when requested by the contracting party, dynamic tests are to be performed on the deploying DPPS. Synchronisation of the headform impactor and the DPPS during dynamic tests are to be derived from the generated regression line out of HIT<sub>s</sub> as a function of WAD during simulations on the undeployed DPPS.

## 9. Head test area

295. Two approaches to define the head test area for vehicles fitted with DPPS were discussed, either in an undeployed position, or in a deployed position.

296. First of all, all IWG members agreed on defining the area in an undeployed position for dynamic testing of DPPS, including pedestrian airbag systems.

297. The expert from Korea proposed that the head test area should always be defined in an undeployed position for consistency. The Korean expert was concerned about an inconsistent test area depending on the test mode (static or dynamic), and also pointed out that there might be pragmatic issues to define the test area in the deployed position for a static headform test, especially, when the static test has to be partially conducted. On the other hand, manufacturers claimed that the test area defined in a deployed position makes more sense because the headform actually contacts a deployed bonnet in case of the static test.

298. After extensive discussions, the IWG decided to define the head test area in an undeployed position at all times.

*Part II, Text of the Regulation,*

*Paragraph 3, amend to read:*

## "3. Definitions

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

**In case of the vehicle equipped with a deployable pedestrian protection system (DPPS) as defined in paragraph 3.16., [the measurements shall be taken] with the system undeployed.**

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.*

*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 of the vehicle with a pedestrian. It comprises a deployment module, 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.**

**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(s) until the DPPS reaches its maximum deployment height for the first time. Measurement shall be done on the outer surface of the DPPS, in the area above the lifting device(s).
- 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, as shown in Figure 1-1 of Annex 1.
- 3.18.2.** "Undeployed 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 per cent 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) minus 42mm on each side, as measured horizontally and perpendicular to the longitudinal median plane of the vehicle.<sup>1</sup> (see Figure 11)

*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.

There are two kinds of HIT :

- 3.24.1.** HIT<sub>d</sub> : to decide whether the physical head test on the deployable system can be done dynamically or statically. The HIT<sub>d</sub> is determined with the deployed DPPS.
- 3.24.2.** HIT<sub>s</sub> : to synchronise the test rig for dynamic testing. The HIT<sub>s</sub> is determined with the undeployed DPPS."

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

*Insert new paragraph 3.30., 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.]"

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

*Insert new paragraphs 3.34 to 3.36., to read:*

- "3.34.** "Relevant vehicle width (RVW)" is the maximum width of the vehicle without devices for indirect vision, measured on or in front of a vertical transverse plane passing through the front axle of the vehicle.

<sup>1</sup> A contracting party may allow application of these requirements in its domestic legislation if it decides that such extension is appropriate.

**3.35.** "Sensing time (ST)" means the duration from the time of the first contact of the flexible lower legform impactor with the vehicle outer surface to the initiation of the deployment module.

**3.36.** "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 3.27. to 3.29. (former), renumber as paragraphs 3.37 to 3.39.*

*Insert new paragraphs 3.40. to 3.42., to read:*

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

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

**3.40.2.** "Dynamic testing" means the synchronised launch of the headform onto the deploying DPPS at the appropriate HIT\_s.

**3.40.3.** "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.

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

**3.42.** "Total Response Time (TRT)" means the duration from the time of first contact of the flexible lower legform impactor with the vehicle outer surface to the time the DPPS reaches its Maximum Deployment Height first. It is the sum of the Sensing Time and the Deployment Time."

*Paragraphs 3.30 to 3.32 (former), renumber as paragraph 3.43 to 3.45.*

*Figure 1, the title, amend to read:*

"Figure 1.  
Bonnet leading edge reference line (see paragraph **3.6.** ~~3-5.~~)"

*Figure 2, the title, amend to read:*

"Figure 2.  
Bonnet rear reference line. (see paragraph **3.7.** ~~3-6.~~)"

*Figure 3, the title, amend to read:*

"Figure 3.  
Template (see paragraph **3.7.** ~~3-6.~~)"

*Figure 4, the title, amend to read:*

"Figure 4.  
Marking of intersection between bonnet rear and side reference lines (see paragraph **3.7.** ~~3-6.~~)"

*Figure 5A, the title, amend to read:*

"Figure 5A.  
Corner of bumper example (see paragraph **3.15.** ~~3-14.~~, note that the corner gauge is to be moved in vertical and horizontal directions to enable contact with the outer contour /front fascia of the vehicle)"

*Figure 6, the title, amend to read:*

"Figure 6.  
Impact and target point (see paragraphs **3.26.** ~~3-20.~~ and **3.38.** ~~3-28.~~)"

Figure 7, the title, amend to read:

"Figure 7.  
Lower bumper reference line, LBRL (see paragraph 3.28. 3.22.)"

Figure 8, the title, amend to read:

"Figure 8.  
Side reference line (see paragraph 3.37. 3.27.)"

Figure 9, the title, amend to read:

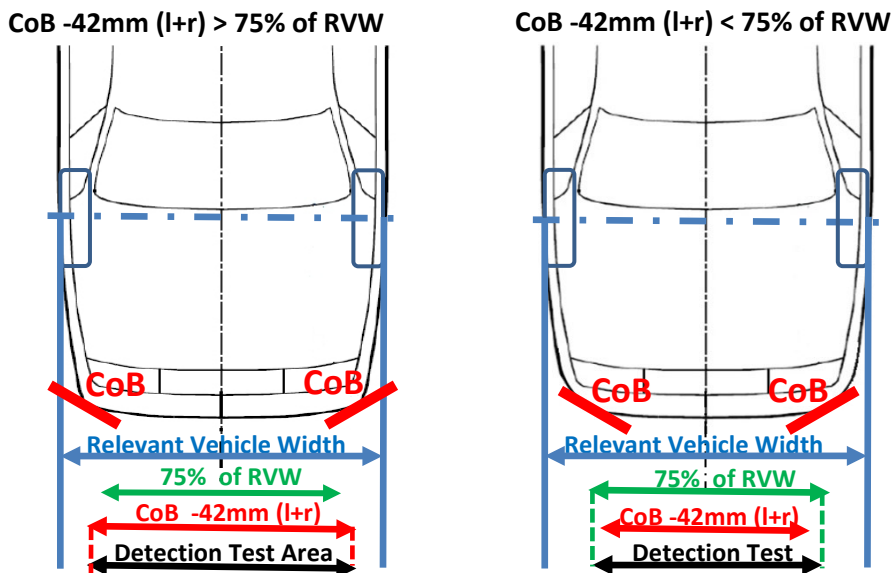
"Figure 9.  
Upper bumper reference line, UBRL (see paragraph 3.43. 3.30.)"

Figure 10, the title, amend to read:

"Figure 10.  
Wrap around distance measurement (see paragraph 3.44. 3.31.)"

Insert new Figure 11, to read:

"Figure 11  
**Detection Test Area (see paragraph 3.19)**



Figures 11 to 30 (former), renumber as Figures 12 to 31.

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

"5.2. Headform tests  
[When/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. ~~[When/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."

*Insert new Annexes 1 to 3, to read:*

## **"Annex 1**

### **Test Procedure for the Deployable Pedestrian Protection Systems**

#### **1. Preliminaries and Prerequisites**

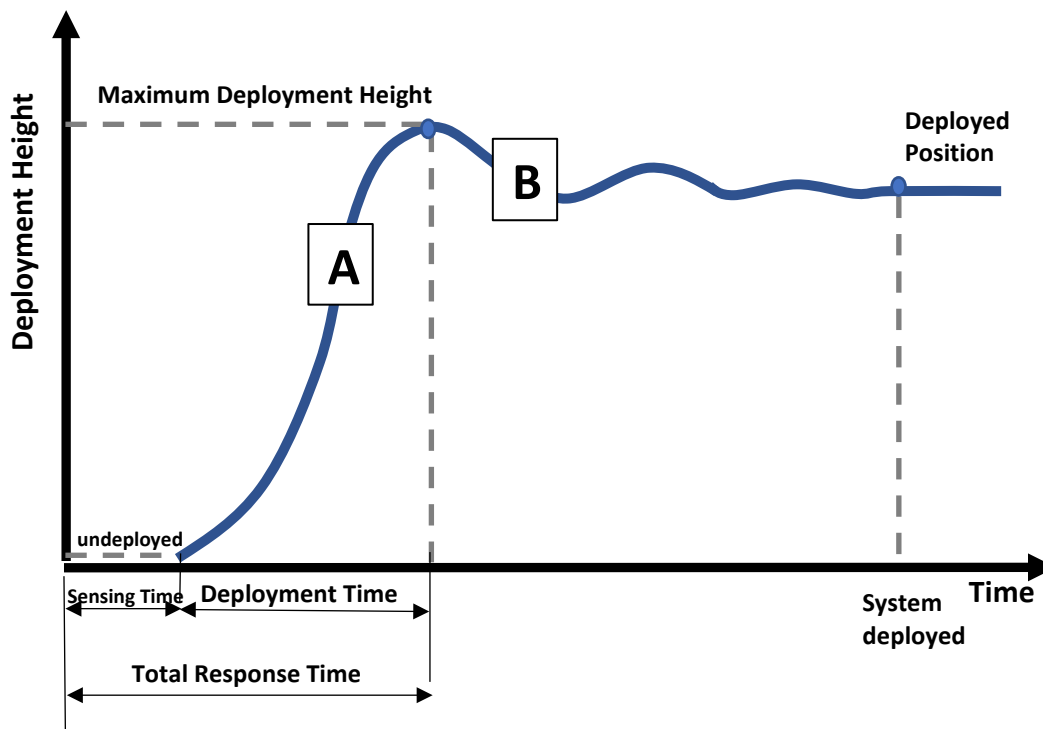
**If all the following preliminaries and prerequisites are met, the vehicle shall be tested with the Deployable Pedestrian Protection Systems (DPPS) activated as intended for the entire headform test area.**

**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.**

The principle of testing the DPPS is as follows:

Figure 1-1  
Deployment Time History Curve



- (a) In case of  $HIT_d < TRT$ , the test shall be performed dynamically at the timing of the head impact;
- (b) In case of  $HIT_d \geq TRT$ , the test may be performed either statically at a height no more than the deployed position or dynamically at the timing of the head impact.

1.1. If any of the prerequisites from paragraphs. 1.2 to 1.7. are not met, the vehicle shall be tested in the undeployed 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 the 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 information (not required for dynamic testing);
- (e) TRT (ST and DT separately) information (not required for dynamic testing, where only ST is requested);



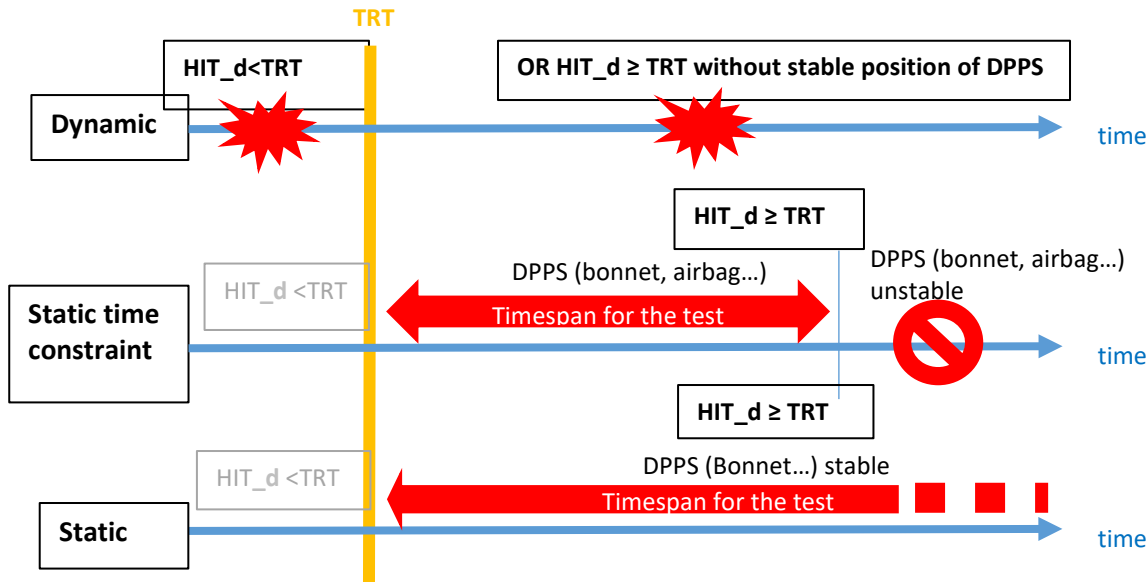
- (f) Evolution of system stability (e.g. pressure or force versus time diagram) (not required for dynamic testing).
- 1.3. The marking of the headform test areas of the DPPS shall always be done in undeployed position, for static, dynamic or combined testing.
- 1.4. Headform test for protection below the lower deployment threshold speed of the DPPS.
- 1.4.1. The vehicle outer surface shall remain in undeployed position.
- 1.4.2. 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 HIC1700 and HIC1000 zones may differ from those at nominal velocity (9.7 m/s) headform impact tests according to paragraph 5.2.4 of this Regulation.
- 1.4.3. The HIC shall comply with paragraph 5.2.3 of the Regulation.
- 1.5. HBM qualification shall be provided according to Annex 2. HIT information shall be provided according to Annex 3.<sup>2</sup>
- 1.6. Verification of the prerequisites for deployed static tests: Deployed Position, Maximum Deployment Height and Deployment Time as illustrated in the deployment time history curve (see Figure 1-1 of this Annex).
- The values specified by the manufacturer shall be verified by using appropriate tracking means, such as high-speed videos, accelerometer, or laser at the reference points as indicated by the manufacturer (on the lifting devices). The tolerances are  $\pm 20$  per cent for the specified values. If the measured values are within the defined tolerances, the values specified by the manufacturer shall be used. Otherwise, the measured values shall be used for the test.
- 1.7. Sensing System Verification
- 1.7.1. The vehicle manufacturer shall specify the lowest speed of activation (lower deployment velocity threshold) of the DPPS.
- 1.7.1.1. 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 [within the detection test area] at the DPPS lower deployment velocity threshold.
- 1.7.2. [A] test with the flexible lower legform impactor shall be performed at nominal speed at vehicle centreline (Y0).
- 1.7.3. 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.
- 1.7.4. If the system is not activated during any of the verification tests, all headform tests shall be conducted in undeployed position according to paragraphs 7.2. to 7.4. of this Regulation.
- 1.7.5. For tests with stationary vehicle: the vehicle shall be set to the normal running condition as specified by the manufacturer for a vehicle speed corresponding to the particular use case.

<sup>2</sup> Will be updated with DPPS Phase 2 (HIT determination by a generic approach option).

- 2. Verification of the Total Response Time and /or Sensing Time at Nominal Velocity**
- 2.1. TRT shall be confirmed by using the flexible lower legform impactor at the vehicle speed at 11.1 m/s and at the centre line of the vehicle.
- 2.2. ST is measured either independently, or during a TRT measurement test, at the vehicle speed as specified in this Regulation and at the vertical longitudinal centre plane of the vehicle (Y0).
- 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 manufacturer shall be used. Otherwise, the measured value shall be used for the test.
- 2.2.2. For tests with stationary vehicle: the vehicle shall be set to the normal running condition as specified by the manufacturer.
- 3. Tolerances**
- 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:  $\pm 0.6$  m/s; impact accuracy:  $\pm 50$  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 Procedure at Nominal Velocity (9.7m/s)**
- The impact points and the allocation of the HIC1700 and HIC1000 zones shall always be based on and related to the test area with undeployed DPPS.
- 4.1. Static test option:  
If the vehicle manufacturer opts for the static test procedure, the following conditions shall be fulfilled. If so, the head impact tests on the headform test area shall be performed statically.  
If any of the following conditions are not met, the head impact tests on the headform test area shall be performed dynamically.
- 4.1.1. Where the vehicle manufacturer has demonstrated by numerical simulations on the deployed DPPS, that  $HIT_d \geq TRT$  for the smallest selected stature pedestrian, as defined in Annex 3, then all tests may be performed statically.
- 4.1.2. The vehicle outer surface shall represent the deployed position (see Figure 1-1, B section) within the specified tolerances, while the resisting force is considered:
- 4.1.2.1. Static time constraint condition, linked to the resisting force:  
When there is a constraint on time for the stability of the system and  $HIT_d \geq TRT$ , the launching time of the headform test shall ensure that the system remains stable (tolerance  $\pm 10$  per cent of corresponding resisting force), as identified by the manufacturer (prerequisite in paragraph 1.2. of Annex 1).  
Based on the evolution of system stability (see Figure 1-2), 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 1-2  
Testing Time Aim = LAB Tests Represent Real Life



- 4.1.2.2. Appropriate means (e.g. actuator surrogates) may be used to ensure that the corresponding resisting force of the DPPS is reached.
- 4.1.3. The test procedures specified in paragraphs 7.2. to 7.4. of this Regulation shall apply.
- 4.1.4. Test accuracy at impact location
- 4.1.4.1. 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.
- 4.1.4.2. 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.
- 4.1.4.3. Alternative methods to demonstrate the test accuracy may also be accepted.
- 4.2. Dynamic test option
- 4.2.1. 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 synchronised to achieve the correct HIT\_s.
- The following steps are conducted:
- 4.2.1.1. 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 DPPS to confirm that impact velocity and impact location are within tolerances.

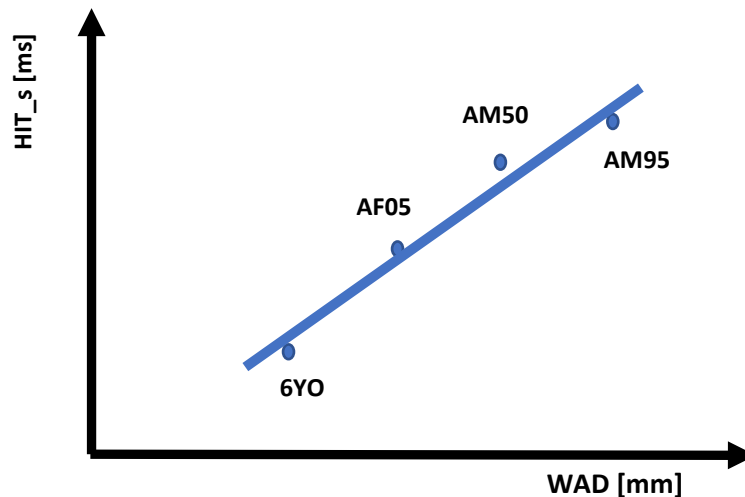
If the tolerances for impact speed and location are met during the undeployed test, there is no requirement to meet these tolerances during dynamic tests, provided test inputs remain the same.

4.2.1.2. To enable dynamic testing to be conducted, HIT<sub>s</sub> and sensing time (ST) are required inputs, which shall be established by the following:

- (a) HIT<sub>s</sub> (see Figure 1-3 hereafter, obtained from Annex 3, Figure 3-3).

Figure 1-3

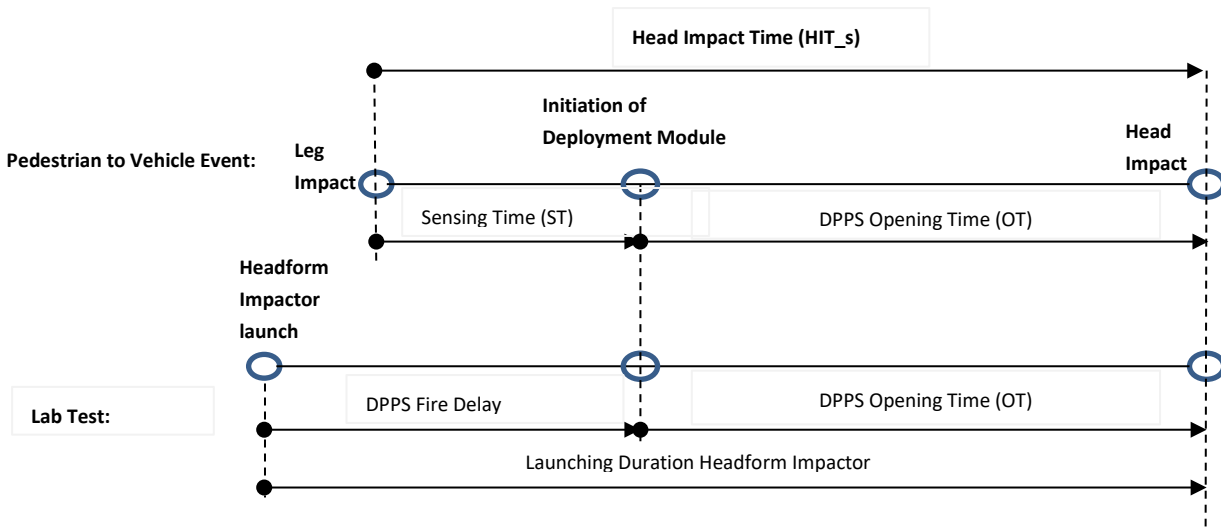
Head Impact Time(s for synchronisation) versus Wrap Around Distance (HIT<sub>s</sub> vs WAD)



- (b) ST is determined from the manufacturer prerequisite or sensor verification test, carried out at the vertical longitudinal centre plane of the vehicle (Y0).

4.2.1.3. 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<sub>s</sub> and ST, as shown in Figure 1-4 below.

**Figure 1-4**  
An Example of Test Rig Synchronisation



"DPPS Opening Time" is calculated by deducting the ST from the HIT\_s at that particular test point.

$$\text{"DPPS Fire Delay"} = \text{Launching Duration Headform Impactor} - \text{HIT}_s + \text{ST}$$

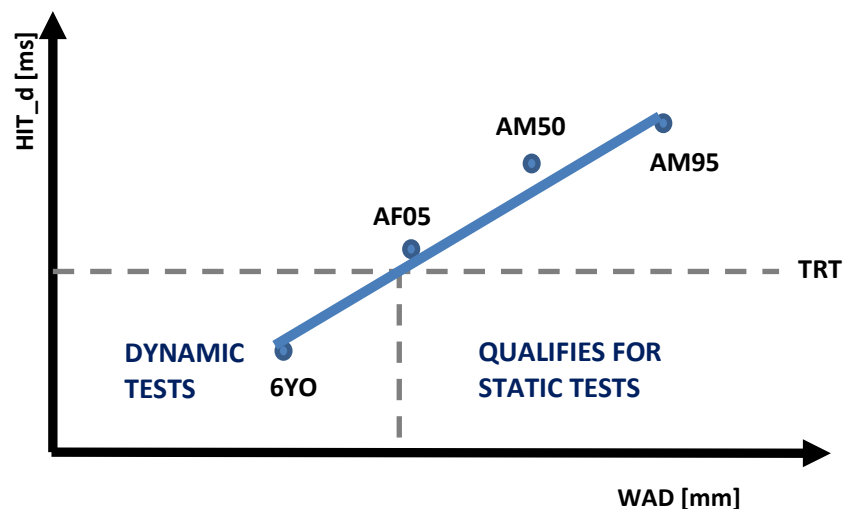
Launching Duration Headform Impactor is rig-specific and is the time period between launching of the headform impactor and the time of head impact to the undeployed DPPS.

4.3. "Combined" test option:

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

If the headform test area consists of sections where the HIT\_d at the corresponding impact point is less than TRT ( $\text{HIT}_d < \text{TRT}$ ), as in A) in Figure 1-1, and sections where the HIT\_d at the corresponding impact point is greater than or equal to TRT ( $\text{HIT}_d \geq \text{TRT}$ ), as in B) in Figure 1-1, then all test points forward of the corresponding WAD ( $\text{HIT}_d < \text{TRT}$ ) shall be tested dynamically. The remaining section of the headform test area may be tested statically. (see Figure 1-5 below, obtained from Annex 3, Figure 3-2).

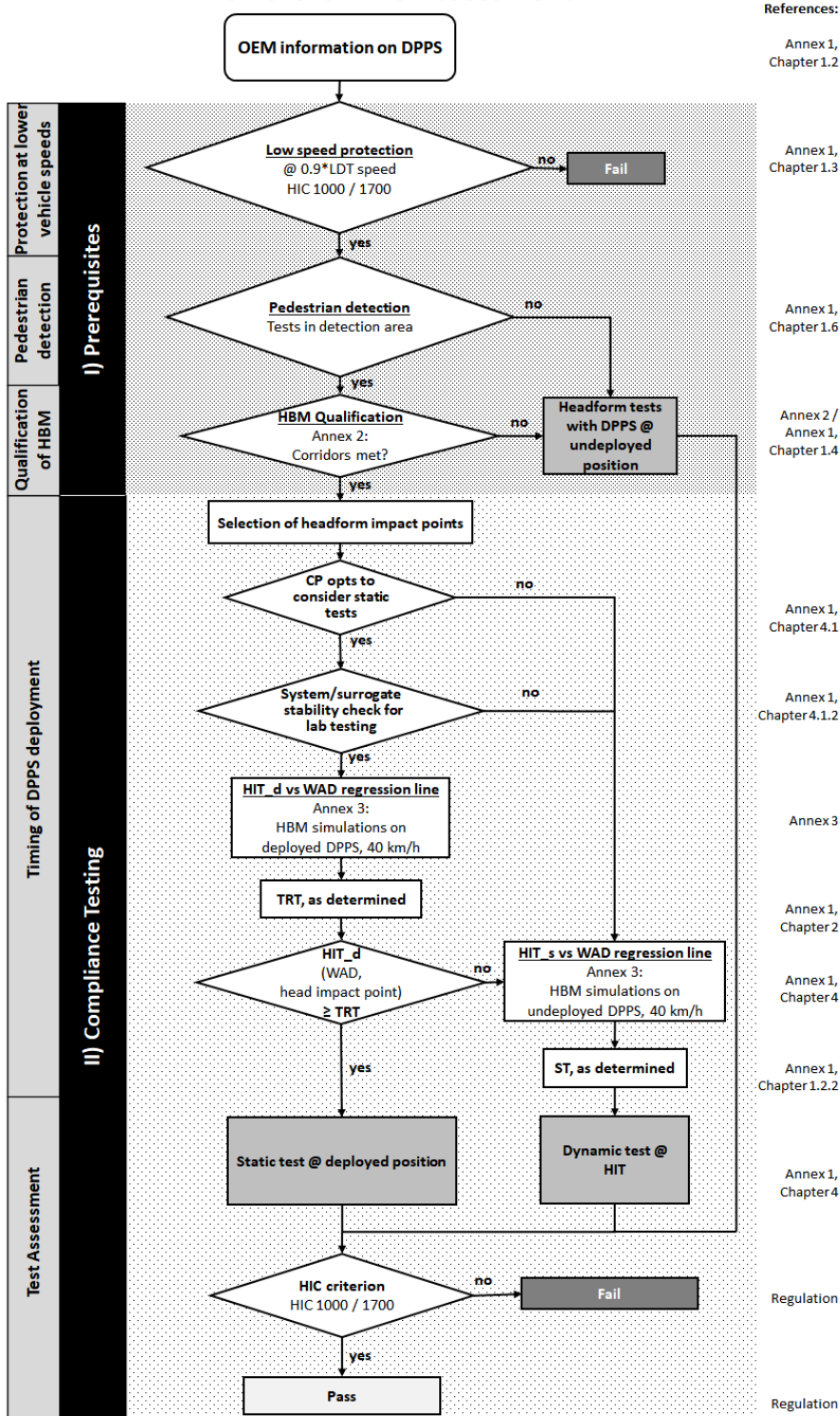
**Figure 1-5**  
Scheme of HIT\_d vs WAD for Combined Testing



# Annex 1 - Appendix

## Flowchart DPPS Assessment Guideline

Flowchart DPPS Assessment<sup>1</sup>



<sup>1</sup>: Will be updated with DPPS Phase 2 (Generic approach)

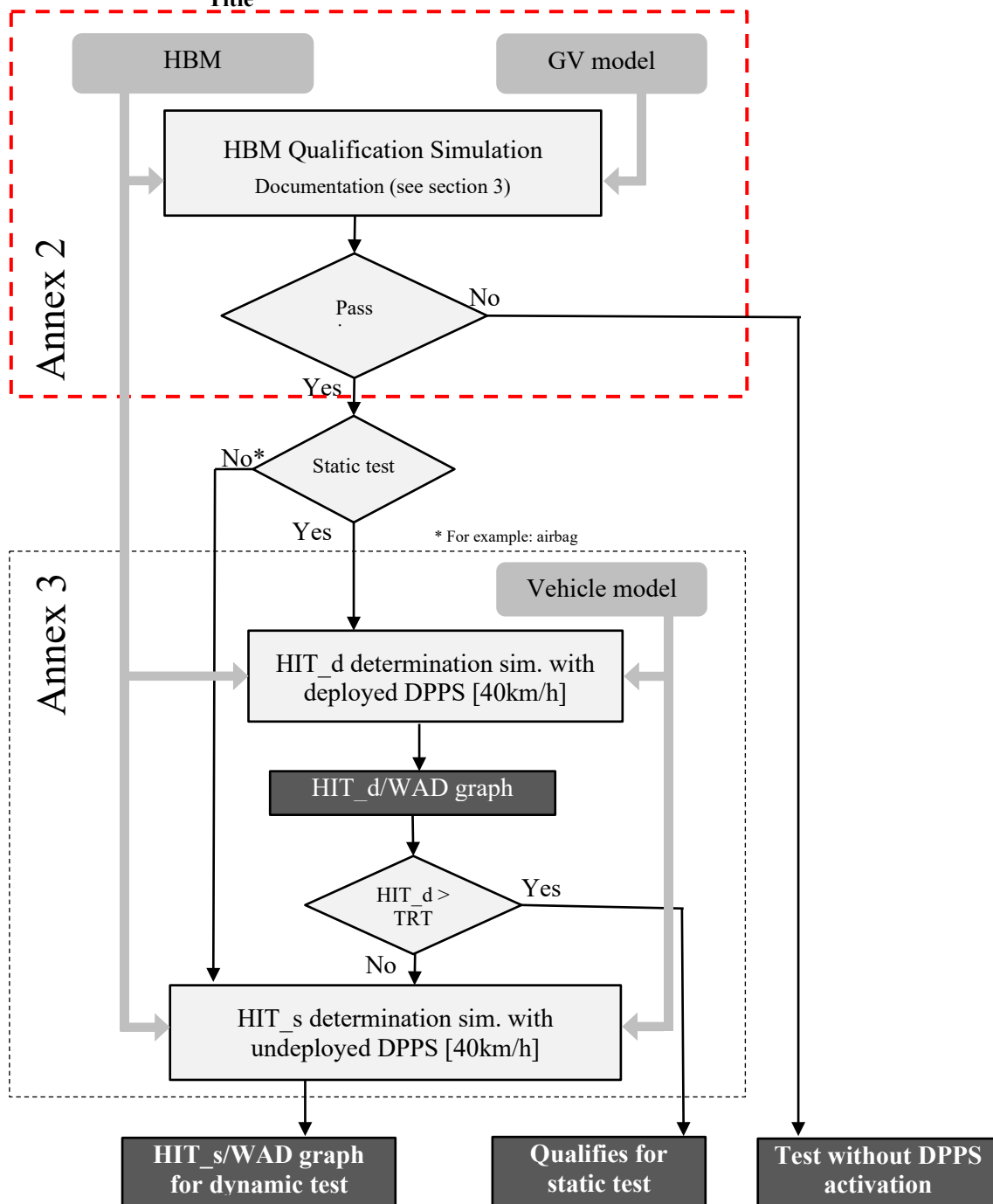
## Annex 2

### Qualification Process of Human Body Models for Pedestrian HIT Determination

#### 1. Introduction

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

Figure xxx  
Title



## 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, and have been determined within sensitivity studies and round robin simulations.

## 1.2. Definitions

Throughout Annexes 2 and 3, the following definitions are used:

1.2.1. 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 Annex 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).

1.2.2. "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 [as Addendum 4 of Mutual Resolution No. 1 (M.R.1) of the 1958 and the 1998 Agreements ECE/TRANS/WP.29/1101]. 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.

1.2.3. "HBM versus 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.

## 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:

- (a) Version of the Human Body Model;
- (b) Node-Position of every single node of the Human Body Model;
- (c) If available:
  - (i) identical initial element stresses/strains;
  - (ii) identical initial contact penetrations/contact forces.



- (d) **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:**

- (a) **Solver-Version;**
- (b) **Solver-Platform ([Shared Memory Parallel processing (SMP), Massively Parallel Processing (MPP)]);**
- (c) **Solver-Precision (Single, Double Precision);**
- (d) **The time-step used for simulations;**
- (e) **Time-step settings (relating to initial and dynamic mass scaling);**
- (f) **Contact settings (between Human Body Model and Vehicle);**
- (g) **Control settings which are affecting the pedestrian model.**

## **2. Procedure**

### **2.1. Human Body Model Pre-Processing**

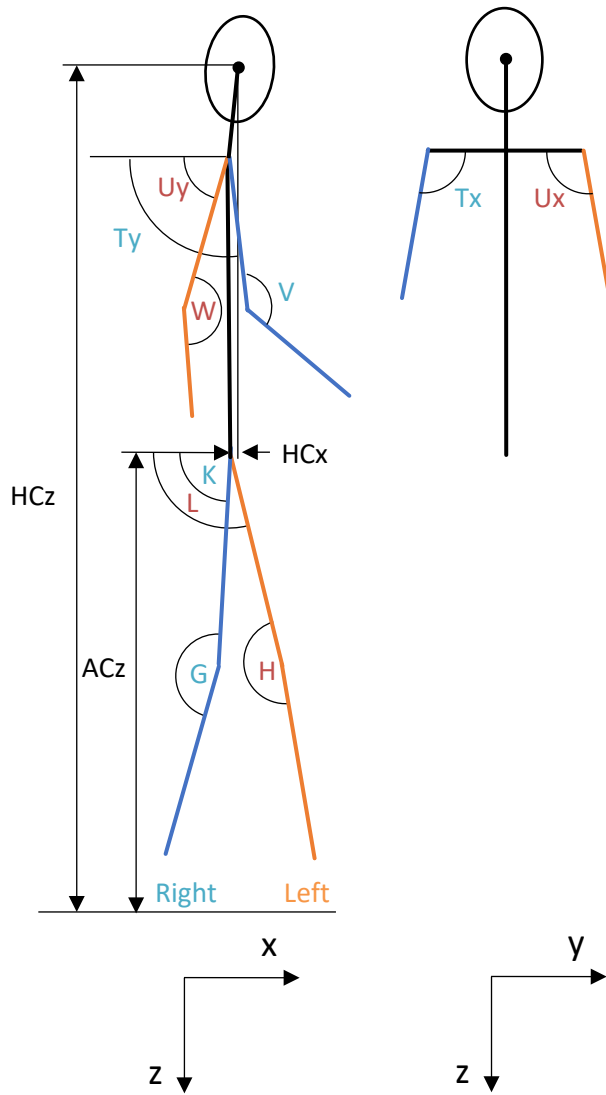
#### **2.1.1. Shoes**

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

#### **2.1.2. 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 2-1. All other model sizes have to meet the required initial posture defined in Table 2-2.**

Figure 2-1  
**Measurements to Describe the Initial Posture of the Human Body Model (HBM)**



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

Table 2-1  
Initial Posture 50th percentile male  
(AM 50)

<i>Abbrev.</i>	<i>Measure</i>	<i>Reference Value</i>	<i>Tolerance (+/-)</i>
Px	Heel to heel distance Longitudinal	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. horizontal)	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	1 686 mm	1.5%
M	Total mass	76.7kg	5%

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

Table 2-2  
Reference Posture of Other Pedestrian Sizes

<i>Abbrev.</i>	<i>Unit</i>	<i>Reference</i>			<i>Tolerance</i>
		<i>6YO</i>	<i>AF05</i>	<i>AM95</i>	
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	1 100	1 468	1 836	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 shall 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 shall be exposed to a vertical acceleration field constituting the gravitational loading for HBM qualification and HIT determination simulation.

### 2.1.3. Output Parameters

The HBM must be equipped with "sensors" and other output definitions, which allow tracking the trajectories of selected body parts.

Node histories must be output at the HC and AC. Outputs shall 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 2-3, 2-4 and 2-5, HBM must be impacted by the Generic Vehicle models defined in 1.2.2. 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 shall 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 shall be confirmed that the following outputs have been generated from each simulation:

Time history curves of:

- (a) x and z coordinate of HC and – only for AM50, also AC - in the global coordinate system;
- (b) x displacement of vehicle COG in the global coordinate system;
- (c) Resultant acceleration of HC;
- (d) Contact forces (between vehicle and HBM without upper extremities, vehicle and HBM head and total contact force);
- (e) Total hourglass and internal energies of the total setup;
- (f) Mass increase.

All are plotted every 0.1ms.

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

### 2.4. Quality Checks

The following Quality Checks shall be performed:

- (a) Contact force (between HBM and vehicle) is zero at simulation start;

- (b) Total energy remains constant within a 15 per cent tolerance;
- (c) Hourglass energy  $\leq 10$  per cent of the total energy;
- (d) Artificial mass increase is less than 3 per cent.

**2.5. 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 shall be applied and documented.

**2.6. Reference Results for Qualification Simulations**

From the qualification simulations with the generic vehicle models, HIT values and the location of HC and – only for AM50, also AC- at the time of head impact shall be compared with the references in Tables 2-3, 2-4 and 2-5.

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 2-3  
50th Percentile Male  
(AM 50)]

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 2-4  
Six-Year-Old  
(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 2-5  
5th Percentile Female  
(AF 05)**

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										

**95th Percentile Male  
(AM 95)**

AM 95 does not need to be specifically qualified. AM 95 models which can be used are all derived from AM 50 models and therefore the AM9 5 only has to meet the positioning requirements and no specific qualification simulations need to be performed.

### 3. Documentation of Results

#### 3.1. General

The following information shall be provided:

- (a) Date of report;
- (b) Name of the car manufacturer;
- (c) Type and release version of software (FE-software package name, revision and version);
- (d) Name and version of the Human Body Model;
- (e) 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 shall be added to the report.

### 3.2 Quality Checks

For all simulations, Table 2-6 shall be filled in.

**Table 2-6**  
**Quality Checks**

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

### 3.3. Initial Posture of Pedestrian Model

To qualify each HBM stature the following Table 2-7 has to be filled in using the references from Table 2-1 and 2-2.

**Table 2-7**  
**Initial Posture Check**

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

**3.4. Results of Qualification Simulations**

To qualify one HBM stature, the following Table 2-8 has to be filled in including all GV shapes and collisions speeds, where reference values are provided in the corresponding Tables 2-3, 2-4 or 2-5. To pass the requirements the values of the respective HBM have to be within the min/max values of Tables 2-3, 2-4 and 2-5.

**Table 2-8  
Results of Qualification Simulation**

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

**For each simulation, the following diagrams shall be provided:**

- (a) **ACx and HCx as a function of time;**
- (b) **ACz and HCz as a function of time;**
- (c) **HCz as a function of HCx and ACz as a function of ACx;**
- (d) **Total Contact Force between HBM and GV as a function of time;**
- (e) **Total, kinetic, internal and hourglass energy as a function of time.**



## Appendix A

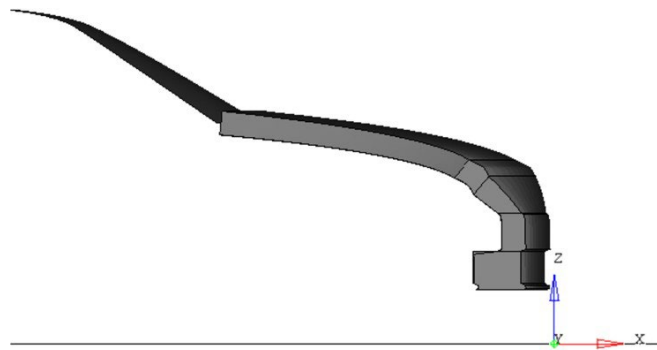
### Reference Systems

#### 1. Global Coordinate System

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

- (a) X direction is the driving direction of the vehicle (longitudinal axis) and  $X=0$  at the foremost point of the vehicle at  $t=0$ ;
- (b) Y direction is the vehicle lateral axis with  $Y=0$  at the vehicle centreline;
- (c) 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 available [as Addendum 4 of Mutual Resolution No. 1 (M.R.1) of the 1958 and the 1998 Agreements ECE/TRANS/WP.29/1101] are already positioned correctly – no transformation of the vehicle is required.

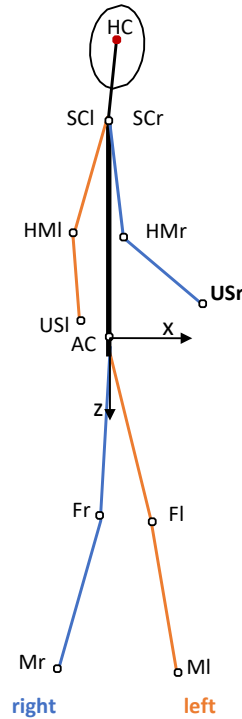
#### 2. Human Body Model Reference Axis

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).

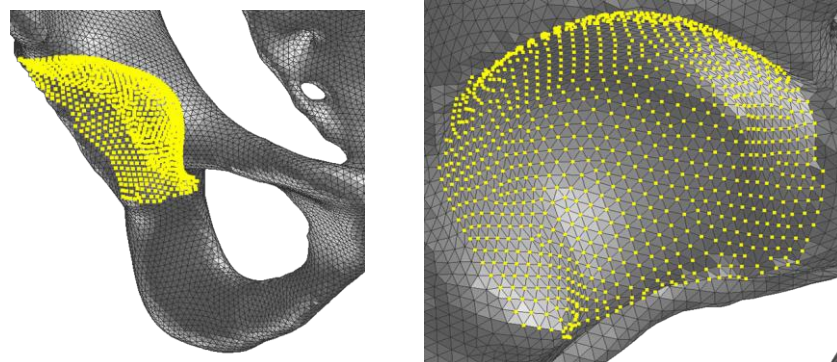
### 3. Human Body Model with Skeleton

**Figure A.2**  
Local Human Body Model Axes for Angle Definitions



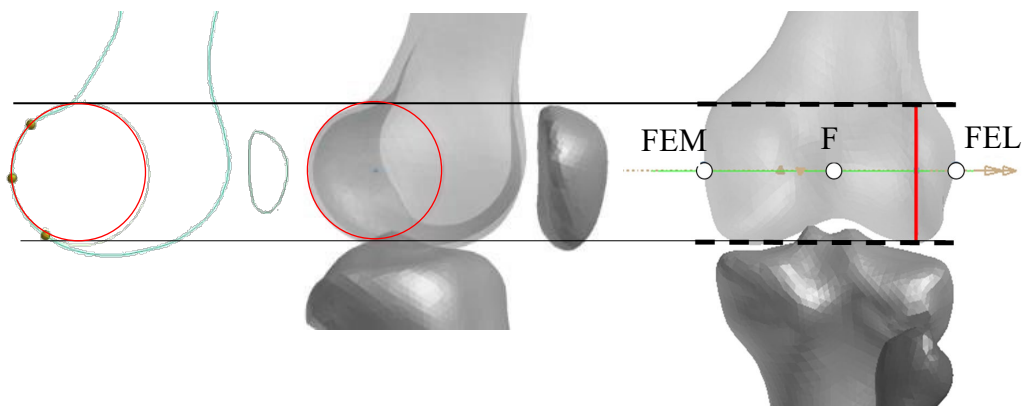
- (a) The centre of gravity of the head (hereafter called HC) is defined as the mass centre of all parts of skull, scalp, face, brain, intracranial space, scalp. It shall be connected to all nodes of inner cranium for the dynamic output.
- (b) AC is defined as the geometric centre of the right and left 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 shall 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)



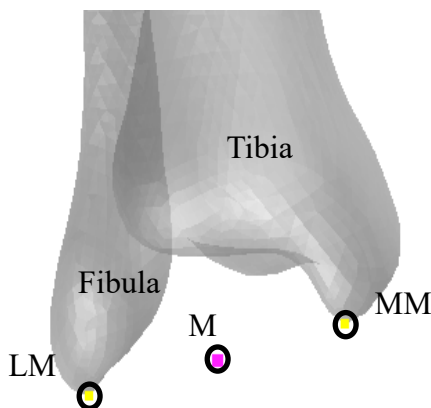
- (c) The Upper Leg Angle is defined as the angle about Y between the femur reference axis and the horizontal.
- (d) The femur reference axis is defined as the connection between the centre of the nodes of the acetabulum and the midpoint (F) between *Epicondylus femoralis medialis* (FEM) and *Epicondylus 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 the *femoral condyle*. The points of intersection of the axis of a longitudinal cylinder along the *femoral condyle* and the outer surface of the bone shall 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 the *Epicondylus Femoralis Lateralis* and the *Epicondylus Femoralis Medialis* (FEL and FEM)**



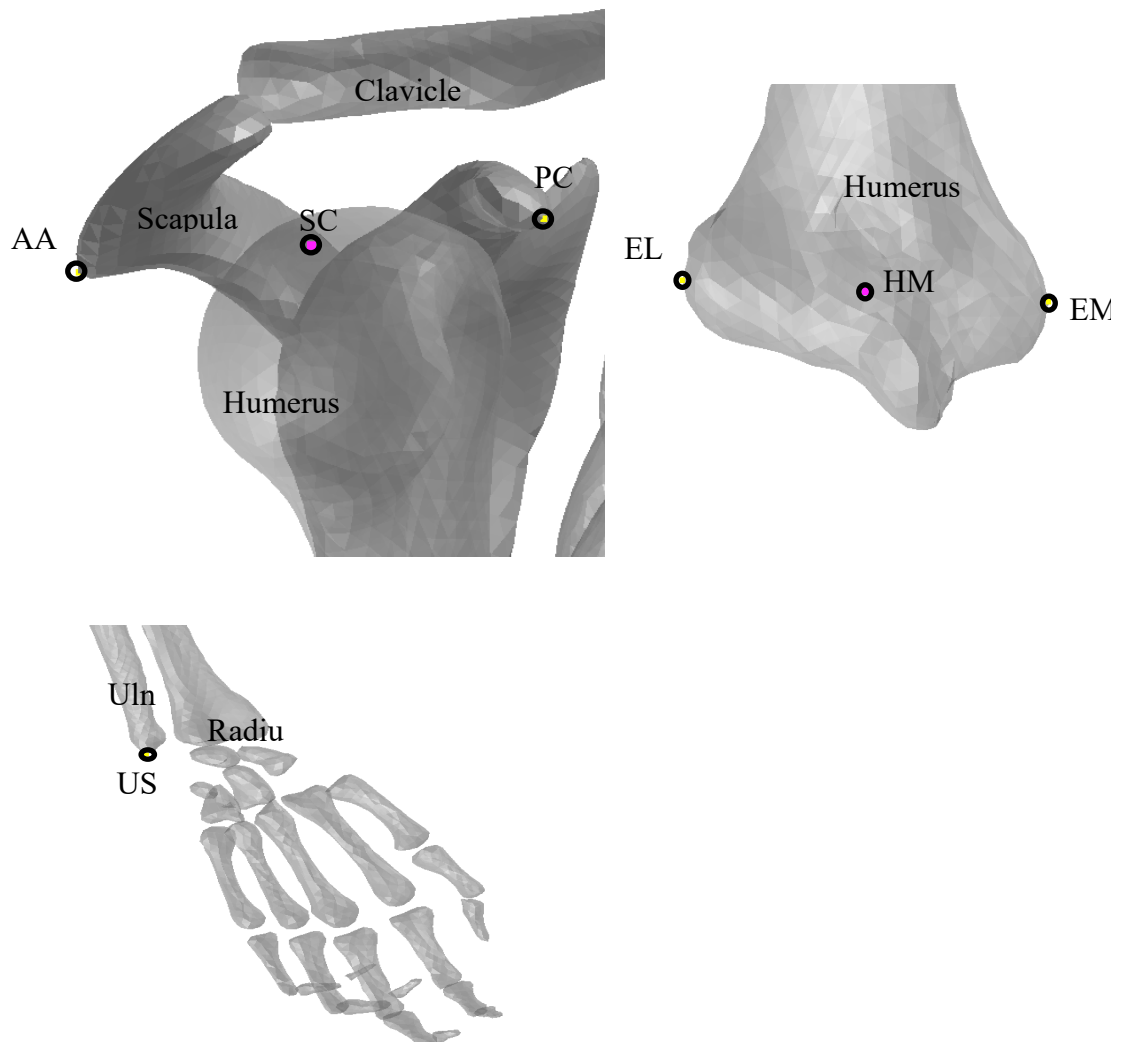
- (e) The Knee Flexion Angle is defined between the femur reference axis and the connection between the midpoint of the *femoral epicondyles* and the *inter-malleolar point* (M) located midway between the tip of the *medial malleolus* (MM) on the tibia bone and tip of the *lateral malleolus* (LM) on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

**Figure A.5**  
**The Right Inter-Malleolar Point (MR) Located Midway Between the *Medial Malleolus* and the *Material Malleolus* (MM and LM)**



- (e) 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 the 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.
- (f) 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**



- (g) 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.

#### 4. A Human Body Model without a Skeleton

Wherever the landmarks described in the previous section cannot be identified in an HBM, points according to the definition in Table 2-10 shall be used.

**Table 2-10**  
**Reference Nodes Used for the Determination of the Initial Posture for**  
**the Human Body Model where Anatomic Landmarks Cannot Be Defined**

<i>HBM with full skeleton</i>	<i>HBM without skeleton</i>
<b>HC</b>	Centre of gravity of the body/bodies representing the full head moving with the head.
<b>ScI/SCr</b>	Geometric centre of shoulder joint connecting the thorax with the body representing the upper arm.
<b>HMI/HMr</b>	Geometric centre of elbow joint connecting the body representing the upper arm with the body representing the lower arm.
<b>USI/USr</b>	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).
<b>AC</b>	Geometric centre of hip joint connecting the body representing the pelvis with the body representing the upper leg.
<b>Fr/Fl</b>	Geometric centre of knee joint connecting the body representing the upper leg with the body representing the lower leg.
<b>Mr / Ml</b>	Geometric centre of ankle joint connecting the body representing the foot with the body representing the lower leg bones.

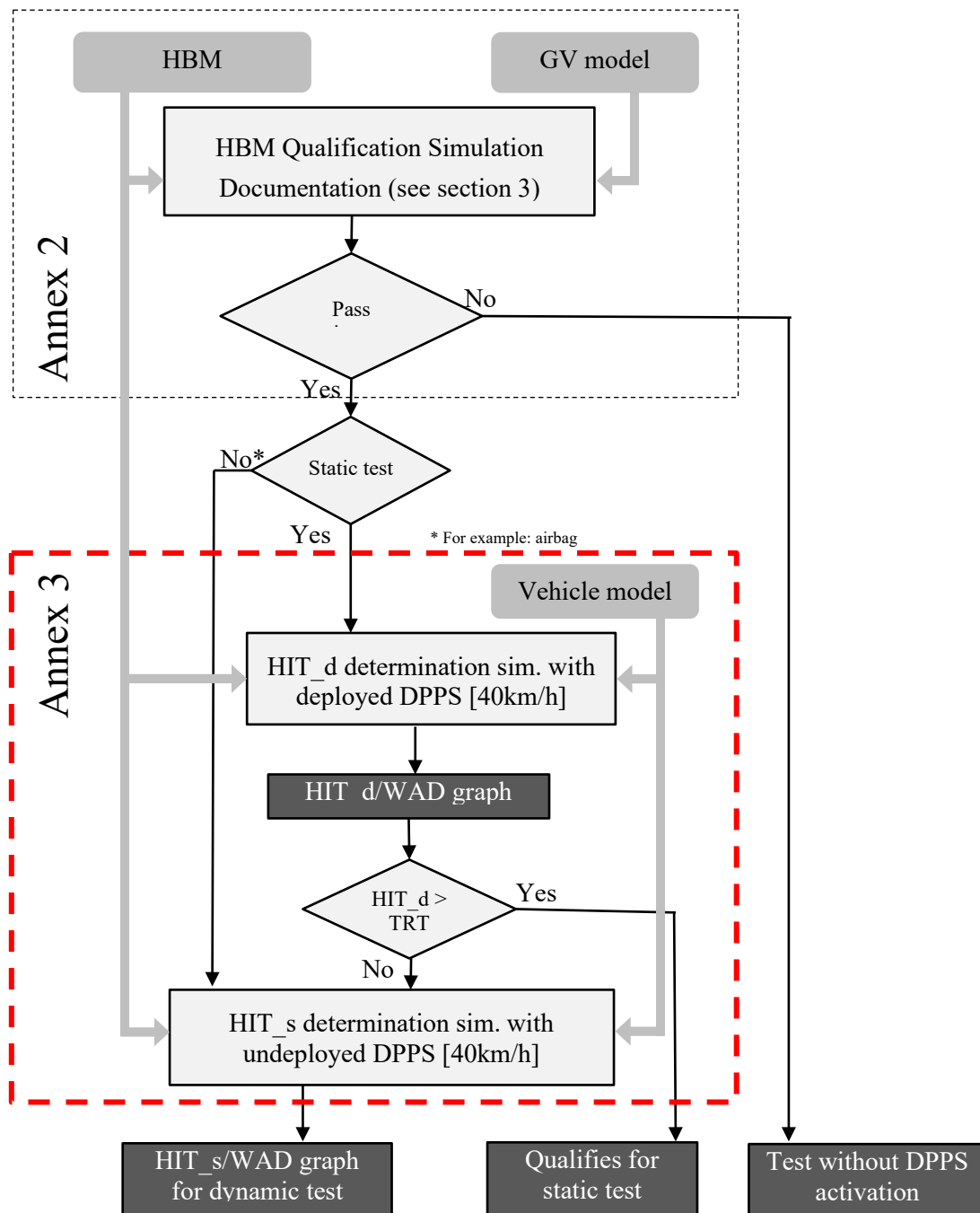
## Annex 3

### Head Impact Time - Determination Simulation

#### 1. Introduction

For all definitions specific to simulation, please refer to paragraph 1.2 of Annex 2.

An 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**

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 shall 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 shall 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 Human Body Models**

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 the head and DPPS.

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

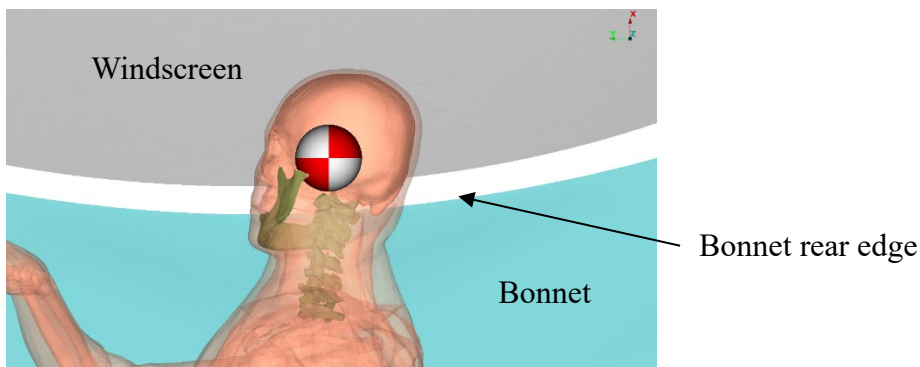
Simulations with the next tallest HBM shall also be performed, but only to prove that this HBM does not hit the DPPS properly.

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

Figure 3-1

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))





### 2.3. Output Requirements

It shall be confirmed that the following outputs have been generated from each simulation, time history curves of:

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

All are plotted every 0.1ms or less.

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

### 2.4. Quality Checks

The following Quality Checks shall be performed:

- (a) Contact force (between HBM and vehicle) is zero at simulation start;
- (b) Total energy remains constant within a 15 per cent tolerance;
- (c) Hourglass energy  $\leq 10$  per cent of the total energy;
- (d) Artificial mass increase is less than 3 per cent.

### 2.5. 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 may be applied and shall be reported.

### 2.6. 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. Documentation**

**3.1. General**

The following information shall be provided:

- (a) Date of report;
- (b) Name of car manufacturer;
- (c) Type and release version of software (FE-software package name, revision and version);
- (d) Name and version of the Human Body Model;
- (e) Specification of car.

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

**3.2. Consistency with Qualification Simulations**

For all simulations Table 3-1 shall be filled in.

**Table 3-1**  
xxx

<i>Checklist for simulation settings</i>	<i>Consistent between Qualification and HIT determination Simulation?</i>
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 3-2 shall be filled in.

**Table 3-2**  
xxx

<i>Verification evaluation criteria</i>	<i>Allowed</i>	<i>Observed</i>	<i>Pass?</i>
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. Results of Head Impact Time-Determination**

For those HBMs that are selected according to Table 2.2, the computed HIT-Values and corresponding WADs have to be filled into the following Tables 3-3 and 3-4.

If  $HIT_d \geq TRT$  for all HBMs, simulations on the undeployed DPPS are not required.

**Table 3-3**  
**HIT<sub>d</sub> Simulations on Deployable Pedestrian Protection Systems in Deployed Mode**

<i>HBM</i>	<i>WAD [mm]</i>	<i>HIT<sub>d</sub> [ms]</i>
6YO		
AF05		
AM50		
AM95		

**Table 3-4**  
**HIT<sub>s</sub> Simulations on Deployable Pedestrian Protection Systems in Undeployed Mode**

<i>HBM</i>	<i>WAD [mm]</i>	<i>HIT<sub>s</sub> [ms]</i>
6YO		
AF05		
AM50		
AM95		

For each simulation, the following diagrams shall be provided:

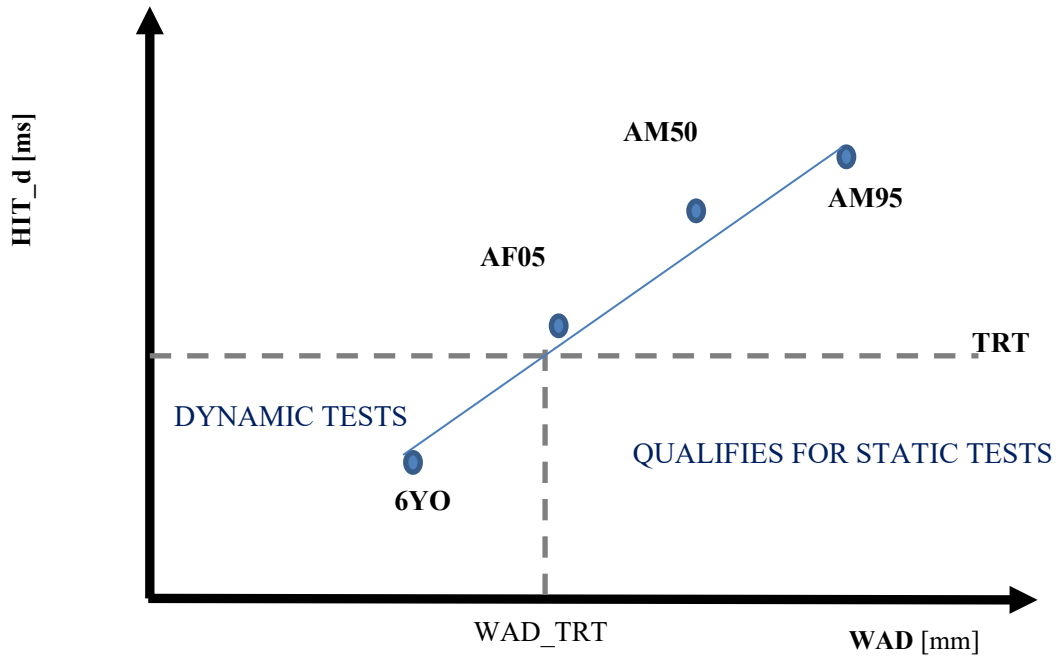
- (a) ACx and HCx as a function of time;
- (b) ACz and HCz as a function of time;
- (c) HCz as a function of HCx and ACz as a function of ACx;
- (d) Total Contact Force between HBM and vehicle as a function of time;
- (e) Total, kinetic, internal and hourglass energy as a function of time.

## 4. Evaluation

### 4.1. HIT<sub>d</sub> Simulations with Deployed DPPS

Based on the results of Table 3-3, a graph shall be plotted using a linear regression line for comparison with TRT in the diagram as shown in Figure 3-2.

Figure 3-2  
 Wrap Around Distance versus Head Impact Time\_for decision  
 (WAD vs HIT\_d)



4.2. HIT\_s Simulations with Undeployed DPPS

Based on the results of Table 3-4, a graph shall be plotted using a linear regression line as shown in Figure 3-3. The lines have to be extrapolated in both directions.

Figure 3-3  
 Wrap Around Distance versus Head Impact Time\_s (s for synchronisation)  
 (WAD vs HIT\_s)

