Need for a biofidelic dummy to determine triggers for Event Data Recording

- in collisions against vulnerable road users (VRU) by measuring, evaluating and recording of acceleration -

Erforderlichkeit eines biofidelen Dummy zur Bestimmung der Trigger für die Ereignisdatenaufzeichnung im DER auch bei Kollisionen mit vulnerablen Verkehrsteilnehmern

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Member of the Board of the European Association for Accident Research and Analysis, EVU

Increase of killed vulnerable road users – especially Pedestrians and Pecedels

Zunahme der getöteten vulnerablen Verkehrsteilnehmer – insbesondere Fußgänger & Pedelec

Getötete bei Verkehrsunfällen nach Art der Verkehrsbeteiligung

Getötete[1]	2024[2]	2023	2022	2021
Benutzer von ...				
Krafträder mit Versicherungskennzeichen	41	53	57	56
Elektrokleinstfahrzeuge (E-Scooter)	26	21	10	5
Krafträder mit amtlichen Kennzeichen	511	497	492	473
Personenkraftwagen	1 165	1 191	1 192	1 118
Bussen	8	16	8	5
Güterkraftfahrzeugen	104	116	127	140
Fahrrad ohne Hilfsmotor	249	256	266	241
Pedelec	192	190	208	131
Fußgängerinnen und Fußgänger	397	437	368	343

1: Einschließlich innerhalb von 30 Tagen Gestorbene.
2: Vorläufiges Ergebnis.

Stand 27. März 2025

[DESTATIS Statistisches Bundesamt: Getötete bei Verkehrsunfällen nach Art der Verkehrsbeteiligung - Statistisches Bundesamt, Stand: 27.03.2025]

Based on the positive experience in the US in 2019 the EU Parliament adopted a new general safety regulation in which Event Data Recorder (EDR) in all M1 and N1 vehicles are mandatory for new type approval after July 2022:

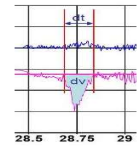
The introduction of event data recorders storing a range of crucial anonymised vehicle data, accompanied by requirements for data range, accuracy, resolution and for its collection, storage and retrievability over a short timeframe before, during and immediately after road accident (for example, triggered by the deployment of an airbag) is a valuable step in obtaining more accurate, in-depth accident data. All motor vehicles should therefore be required to be equipped with such recorders …

Specifications of what cars in the US have to save as an minimum data set, if either an airbag deployed or delta-v exceeded 8 kph within 0.15 s[1]

Parameter Relevant for accident reconstruction	Duration / Start-time (relativ to start of algorithm and/or deployment time [t0])	sample rate/ frequency in Hz (values per second)
Delta-V longitudinal (cumulative change in speed over time)	0 – 250 ms	100 Hz
Maximum speed-change within 300 ms	0 – 300 ms	n. n.
Time until reaching the maximum Delta-V	0 – 300 ms	n. n.
Vehicle indicated Speed (average wheel speed in a period of 0,5 s)	-5 – 0 s	2 Hz
Position of Throttle and/or Driving-Pedal (%-value of its maximum)	-5 – 0 s	2 Hz
Activation of service-brake (yes/no)	-5 – 0 s	2 Hz
Usage of the belt (contact on belt-buckle of Driver/ Passenger) [yes/no])	-1 s	n. n.
Airbag-warning-light (on/off)	-1 s	n. n.
relative time and duration of any Airbag-deployment	complete event-time	n. n.
Time between 2 deployments, if the Airbag is deployed in stages	as long as it take	n. n.

1) Part 563 Nat'l Highway Traffic Safety Admin. - Event Data Recorders according www.gpo.gov/fdsys/pkg/CFR-2011-title49-vol6/pdf/CFR-2011-title49-vol6-part563.pdf

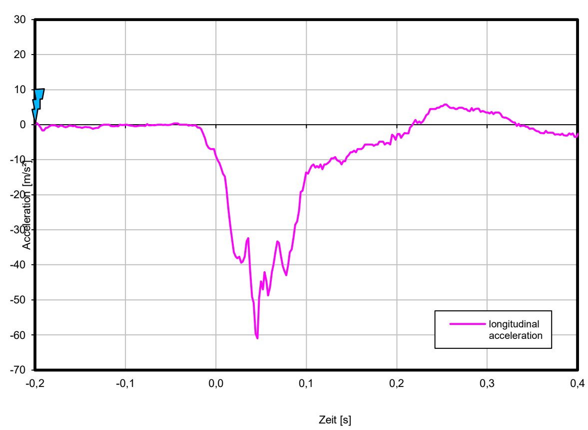
What triggers storage in the EDR?



1.) Deployment-Event „Airbag, Pretensioner, Pop-Up Hood“
When a non-reversible restraint system is deployed, time t = 0 is the "wake-up moment" of the algorithm for the respective trigger (front, rear, side). The change in acceleration, i.e., the jerk, is the decisive factor here, in conjunction with the delta-V; the airbag must be deployed very early to prevent airbag injuries, i.e., within less than 30 ms.

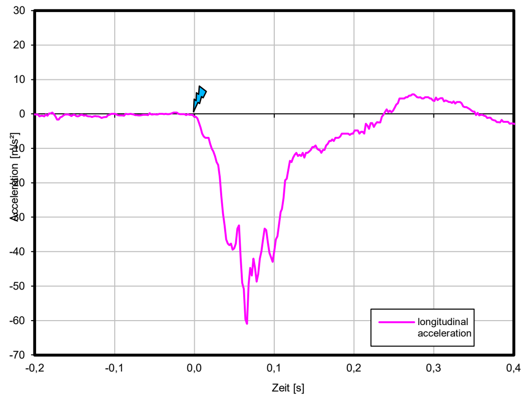
2.) Non-Deployment „without activation of any restraint system“
Without activation of a restraint system, t = 0 is the moment at which there was a change in speed dV of more than 0.8 km/h, namely within: t = 20 ms in longitudinal direction (dt_longitudinal := 0.02 s) ***[corresponds to 40 km/h per sec. = 11 m/s²]*** **or 5 ms in lateral direction (dt_lateral := 0.005 s)** ***[corresponds to 160 km/h per sec. ~ 44 m/s² - thus practically never occurs because the side airbags have already been deployed].***
In case of no deployment Data is only stored, if **in the further course** ***after t0*** **over a time period of dt = 150 ms a dV of 8 km/h is reached** ***[corresponding to 53 km/h per sec. = 15 m/s² as an average over 150 ms]***

Acceleration in a typical front vs. rear end crash



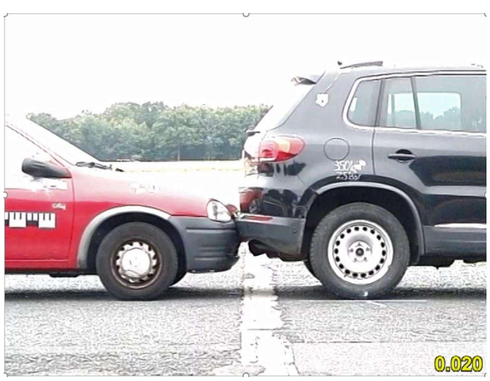
longitudinal acceleration-values over time in the bumping car
Opel Corsa vs. VW Tiguan - collision speed = 15 kph

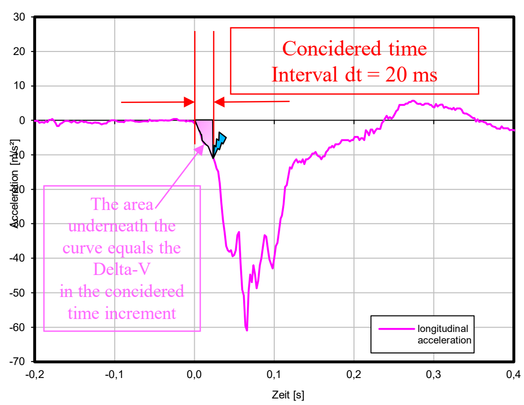
Example: Typical front vs. rear end crash



t_{crash} = 0,00 s : $V_{Opel\ t\_0\text{-}crash}$ = 15 kph
Opel Corsa vs. VW Tiguan; $V_{Volkswagen\ t\_0\text{-}crash}$ = 0 kph

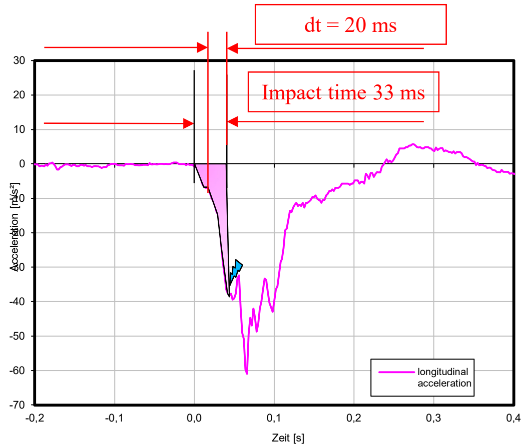
Example: Typical front vs. rear end crash





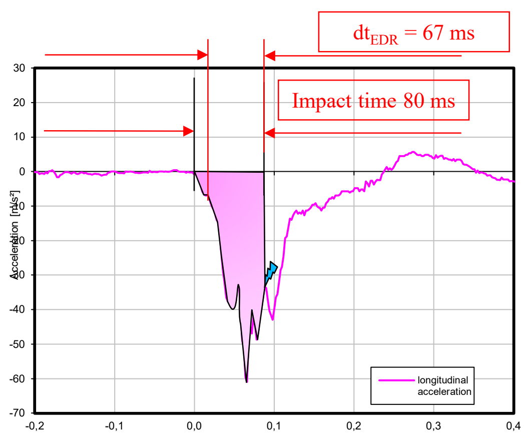
t_{crash} = 0,020 s : $dV_{Opel\ dt\_20ms}$ = 0,4 kph
Therefore: no Algo-Start in an EDR, yet

Example: Typical front vs. rear end crash



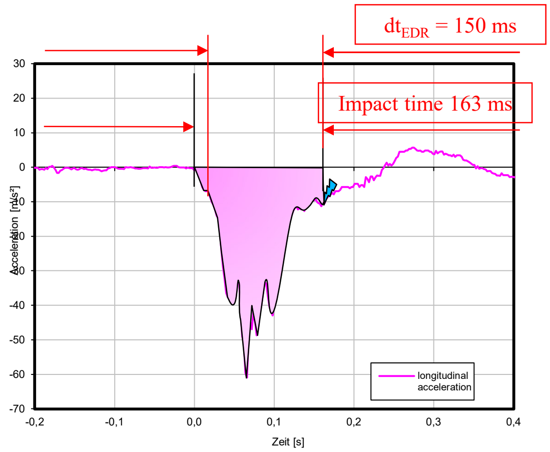
t_{crash} = 0,033 s : $dV_{Opel\ dt\_33ms}$ = 1,1 kph
Over the last 20 ms Delta-V exceeded 0,8 kph: $dV_{Opel\ dt\_20ms}$ = 0,8 kph
Therefore: Algo-Start in an EDR
and t_0 = +13 ms (time zero is 0,013 s after first impact)

Example: Typical front vs. rear end crash



t_{crash} = 0,08 s : $dV_{Opel\ dt\_80ms}$ = 8 kph
over the last 80 ms Delta-V exceeded 8 kph
But, still no recording in an EDR, because Algo started 13 ms later
and $dV_{Opel\ dt\_67ms}$ = 7,2 kph

Example: Typical front vs. rear end crash



t_{crash} = 0,163 s : $dV_{Opel\ dt\_150ms}$ = 14,5 kph
over the last 150 ms Delta-V exceeded trigger (8 kph)

Ergo, a recording will be in an EDR

Data elements and recording details According delegated Act of the EU Commission:

EUROPEAN COMMISSION

3. LEGAL ELEMENTS OF THE DELEGATED ACT

The Act establishes technical requirements and testing procedures for vehicle type-approval with regard to EDR …. the Act refers to the provisions of a 01 Series of Amendments to UN Regulation No 160, making its requirements applicable under the General Vehicle Safety Regulation (GSR)… These requirements concern data elements that EDR must record, the format of these data, requirements for data capture (including those on recording and overwriting of data, on-board storing and the locking of certain data records) and requirements for crash test performance...

The catalogue of data elements that EDR must record is included in Annex 5 to the 01 Series of Amendments to UN Regulation 160 …

In addition to the requirements of the 01 Series of Amendments to UN Regulation 160, the Act lays down additional requirements concerning data retrieval, privacy and security of data.

According to the amendment of 2022 recording of acceleration also prior to the impact

E/ECE/TRANS/505/Rev.3/Add.159/Rev.1

3 February 2023

Agreement

Concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations*

(Revision 3, including the amendments which entered into force on 14 September 2017)

Addendum 159 – UN Regulation No. 160

Revision 1

01 series of amendments — Date of entry into force: 8 October 2022

Occupant size classification, driver	If recorded	-1.0 sec	N/A	5th percentile female or larger.	N/A	Yes or No.	Planar Rollover
Occupant size classification, front passenger	If recorded	-1.0 sec	N/A	6yr old HIII US ATD or Q6 ATD or smaller	N/A	Yes or No.	Planar Rollover
Safety belt status, rear passengers	Mandatory	-1.0 sec	N/A	Fastened, not fastened	N/A	Fastened, not fastened	Planar Rollover
Tyre Pressure Monitoring System (TPMS) Warning Lamp Status	Mandatory	-1.0 second relative to time zero	N/A	N/A	N/A	On, Off	Planar Rollover
Longitudinal acceleration (pre – crash)	Mandatory	-5.0 to 0 second relative to time zero	2 Hz	-1.5g to +1.5g	+/- 10%	0.1g	Planar VRU
Lateral acceleration (pre – crash)	Mandatory	-5.0 to 0 second relative to time zero	2 Hz	-1.0g to +1.0g	+/- 10%	0.1g	Planar
Yaw Rate	Mandatory	-5 to 0 seconds relative to time zero	2	-75 to +75 degrees / second	± 10% of the full range of the sensor	0.1	Planar Rollover

But, only in a rate of 2 Hz, i.e. only every 0,5 Second and therefore in an insufficient frequency and no Lateral Accleration and Yaw-Rate in VRU Accidents

No post crash acceleration…

… in case of an impact against a VRU according to the UN-ECE Regulation R160

- **Except for rollover, acceleration data may only be available <u>after</u> time-ZERO**
- **Otherwise, only for a quarter of a second (250 ms) after t0**
- **And only, if a non-reversible restraint-system deployed or if Delta-V exceeded 8 kph**

E/ECE/TRANS/505/Rev.3/Add.159
Annex 4

Annex 4

Data elements and format[1]

Table 1

Data element	*Condition for requirement*[2]	*Recording interval/time*[3] *(relative to time zero)*	*Data sample rate (samples per second)*	*Minimum range*	*Accuracy*[4]	*Resolution*	*Event(s) recorded for*[5]
Lateral acceleration (post-crash)	If Recorded	0–250 ms or 0 to End of Event Time plus 30 ms, whichever is shorter.	500	-50 to +50g	+/- 10%	1 g	Planar Rollover
Longitudinal acceleration (post-crash)	If Recorded	0–250 ms or 0 to End of Event Time plus 30 ms, whichever is shorter.	500	-50 to +50g	+/- 10%	1 g	Planar
Normal acceleration (post-crash)	If recorded	-1.0 to 5.0 sec[9]	10 Hz	-5 g to +5 g	±10%	0.5 g	Rollover
Delta-V, lateral	Mandatory - not required if lateral acceleration recorded at ≥500 Hz and with sufficient range and resolution to calculate delta-v with required accuracy	0–250 ms or 0 to End of Event Time plus 30 ms, whichever is shorter.	100	-100 km/h to + 100 km/h.	±10%	1 km/h.	Planar

Disadvantage of present EDR-Regulations:

- According to UN-ECE Regulation R160 we have at least information on acceleration, steering-angle, yaw-rate in present EDR (but only 5 seconds prior to impact at 2 Hz in M1 vehicles)

- Nevertheless, collisions against VRU will not be detected by present EDR, unless there is an active bonnet, because according to US and UN-ECE-Regulation a speed change of more than 8 kph within 0,15 s is needed to trigger the recording of data

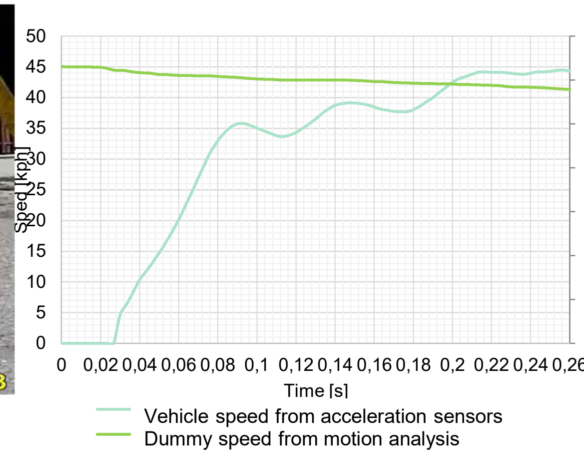
- Not only crash tests, also real cases show that speed change of M1 cars seldomly exceeds 6 kph due to impacts against VRU

Analysis of biofidelic dummy movement

Crash Test [52.6 kph]

$$\bar{v} = \frac{\Delta s_{mesured}}{\Delta t_{Frame}}$$

Quelle: Priester & Weyde



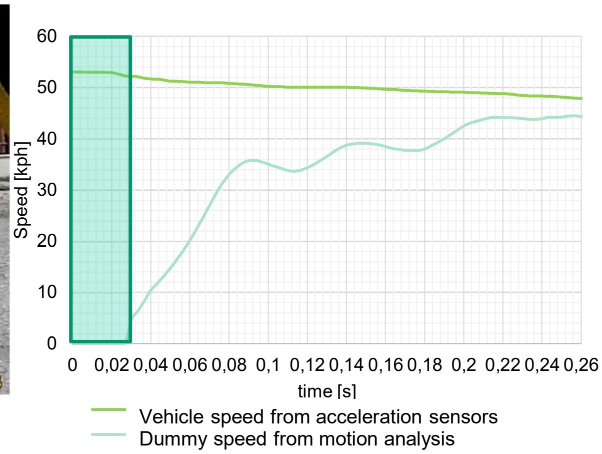
Need for a biofidelic dummy to determine triggers for Event Data Recording

Analysis of biofidelic dummy movement

Crash Test [52.6 kph]

Analysis of Dummy movement

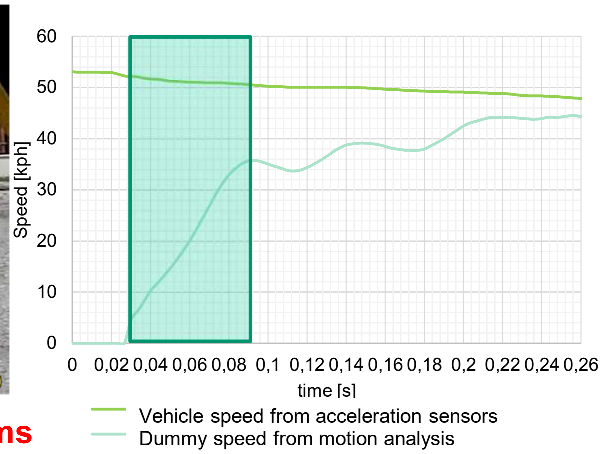
Quelle: Priester & Weyde



Analysis of biofidelic dummy movement

Crash Test [52.6 kph]

Quelle: Priester & Weyde



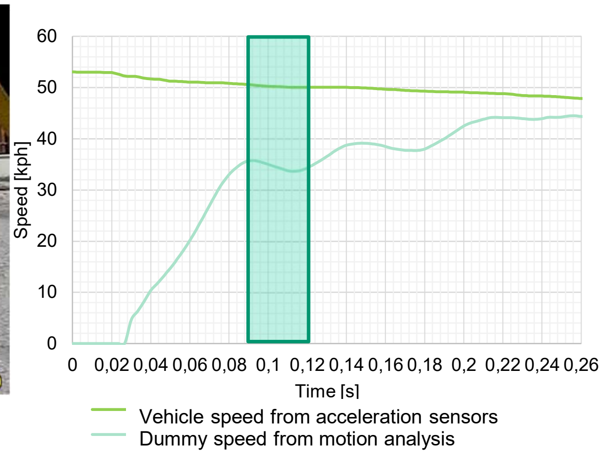
Delta-V of the car over 20 ms
Delta-$V_{t0.02-0.04}$: ≈ 1.2 kph
Acceleration: a = 16,67 m/s² ≈ 1.7 g

Analysis of biofidelic dummy movement

Crash Test [52.6 kph]

Analysis of Dummy movement

Quelle: Priester & Weyde

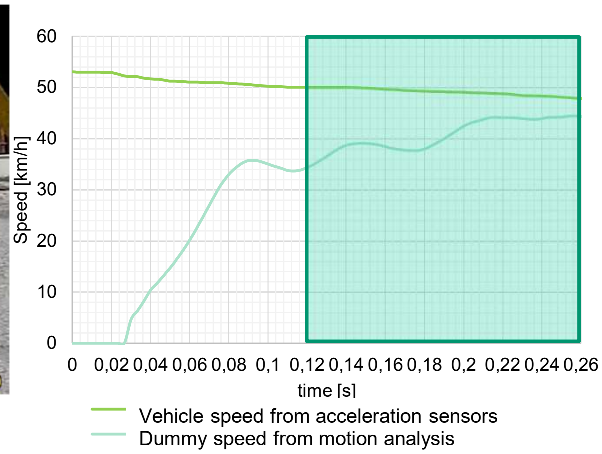


Analysis of biofidelic dummy movement

Crash Test [52.6 kph]

Analysis of Dummy movement

Quelle: Priester & Weyde



Delta-V over 250 ms
Car: ≈ 5 kph
Pedestrian-Dummy: 45 kph

Findings from previous tests with Bioficelic-Dummies:

- During a time of 150 ms, impacts of a passenger car against a biofidelic dummy weighing 80 kg never lead to a change in speed (Delta-V) of the vehicle of more than 8 km/h
- However, a Delta-V of 0.8 km/h is often achieved within 20 ms
- Maybe this or any different Delta-V (i.e. 0.5 kph within 10 ms) could be an appropriate Trigger-Value for data storage

Case Study: Car vs. Pedestrian

No EDR Data even after a severe impact at a speed of 100 km/h against a Pedestrian

BOSCH CDR CRASH DATA RETRIEVAL

IMPORTANT NOTICE: Robert Bosch LLC and the manufacturers whose vehicles are accessible using the CDR System urge end users to use the latest production release of the Crash Data Retrieval system software when viewing, printing or exporting any retrieved data from within the CDR program. Using the latest version of the CDR software is the best way to ensure that retrieved data has been translated using the most current information provided by the manufacturers of the vehicles supported by this product.

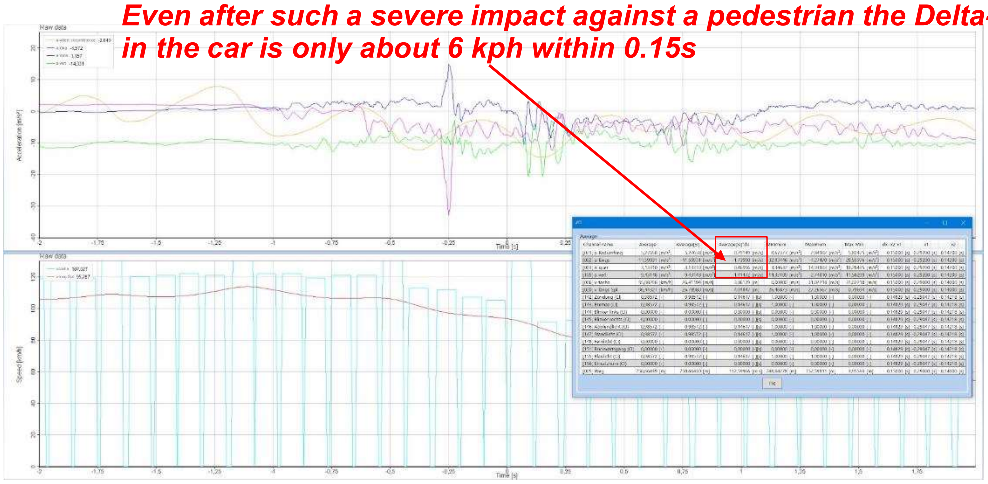
CDR File Information

User Entered VIN	WVGZZZ1TZJ
User	Dr. Michael Weyde
Case Number	VU 2244
EDR Data Imaging Date	.20
Crash Date	.20
Filename	WVGZZZ1TZJ ACM B- VU CDRX
Saved on	, Februar at : :
Imaged with CDR version	Crash Data Retrieval Tool 19.3
Imaged with Software Licensed to (Company Name)	Ingenieurbuero Priester und Weyde
Reported with CDR version	Crash Data Retrieval Tool 19.3
Reported with Software Licensed to (Company Name)	Ingenieurbuero Priester und Weyde
EDR Device Type	Airbag Control Module
Event(s) recovered	None

Pedestrian was killed by a Volkswagen Touran which was equipped with an U.S. EDR and an additional mounted Accident Data Storage System (UDS)

Case Study: Car vs. Pedestrian

Even after such a severe impact against a pedestrian the Delta-V in the car is only about 6 kph within 0.15s



No Data in present EDR because Delta-V over 0.15 s is too low to trigger a recording

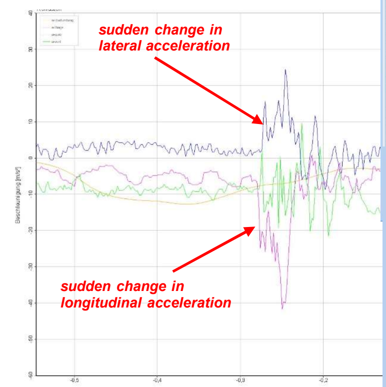
Data from UDS: Acceleration (top graphic) and wheel speed (graphic below) of the car about 2 s before and after the impact against the pedestrian, as well as average values over 0.15 s during impact

Case Study: Car vs. Pedestrian

Although the car was braked prior to the impact, it is clearly possible to differentiate normal driving from an impact against a pedestrian by evaluation of the change in acceleration, the so called Jerk, even if the Delta-V during impact is rather small

Data from UDS: Acceleration (top graphic), wheel speed (graphic in the middle) and status data (lowest graphic) about 0.6 s before and after the impact against the pedestrian, as well as average values over 0.25 s before impact

Case Study: Car vs. Pedestrian



Mitteln

Kanalname	Mittelwert	Mittelwert[SI]	Mittelwert[SI]*dx	Minimum	Maximum	Max-Min	dx=x2-x1	x1	x2
[023] a-Radumfang	-7,52946 [m/s²]	-7,52946 [m/s²]	-0,03012 [m/s]	-7,71931 [m/s²]	-7,33960 [m/s²]	0,37971 [m/s²]	0,00400 [s]	-0,28000 [s]	-0,27600 [s]
[002] a-längs	-14,16601 [m/s²]	-14,16601 [m/s²]	-0,05666 [m/s]	-24,97807 [m/s²]	-6,44311 [m/s²]	18,53497 [m/s²]	0,00400 [s]	-0,28000 [s]	-0,27600 [s]
[003] a-quer	2,11828 [m/s²]	2,11828 [m/s²]	0,00847 [m/s]	1,57890 [m/s²]	2,46152 [m/s²]	0,88262 [m/s²]	0,00400 [s]	-0,28000 [s]	-0,27600 [s]
[109] a-vert	-8,19363 [m/s²]	-8,19363 [m/s²]	-0,03277 [m/s]	-8,70849 [m/s²]	-7,04133 [m/s²]	1,66717 [m/s²]	0,00400 [s]	-0,28000 [s]	-0,27600 [s]
[006] v-tacho	0,00000 [km/h]	0,00000 [m/s]	0,00000 [m]	0,00000 [m/s]	0,00000 [m/s]	0,00000 [m/s]	0,01000 [s]	-0,28000 [s]	-0,27000 [s]
[020] v-längs-Spl	97,66362 [km/h]	27,12878 [m/s]	0,27129 [m]	27,09122 [m/s]	27,16634 [m/s]	0,07512 [m/s]	0,01000 [s]	-0,28000 [s]	-0,27000 [s]
[142] Zündung (CI)	1,00000 [-]	1,00000 [-]	0,00532 [-][s]	1,00000 [-]	1,00000 [-]	0,00000 [-]	0,00532 [s]	-1,13076 [s]	-1,12545 [s]
[143] Bremse (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,00532 [s]	-1,13076 [s]	-1,12545 [s]
[144] Blinker links (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,00532 [s]	-1,13076 [s]	-1,12545 [s]
[145] Blinker rechts (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,00532 [s]	-1,13076 [s]	-1,12545 [s]
[146] Abblendlicht (CI)	1,00000 [-]	1,00000 [-]	0,00532 [-][s]	1,00000 [-]	1,00000 [-]	0,00000 [-]	0,00532 [s]	-1,13076 [s]	-1,12545 [s]
[147] Standlicht (CI)	1,00000 [-]	1,00000 [-]	0,00532 [-][s]	1,00000 [-]	1,00000 [-]	0,00000 [-]	0,00532 [s]	-1,13076 [s]	-1,12545 [s]
[148] Fernlicht (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,00532 [s]	-1,13076 [s]	-1,12545 [s]

Mitteln

Kanalname	Mittelwert	Mittelwert[SI]	Mittelwert[SI]*dx	Minimum	Maximum	Max-Min	dx=x2-x1	x1	x2
[023] a-Radumfang	-7,30892 [m/s²]	-7,30892 [m/s²]	-0,21927 [m/s]	-7,71931 [m/s²]	-7,06317 [m/s²]	0,65615 [m/s²]	0,03000 [s]	-0,28000 [s]	-0,25000 [s]
[002] a-längs	-22,70288 [m/s²]	-22,70288 [m/s²]	-0,68109 [m/s]	-41,74780 [m/s²]	-6,44311 [m/s²]	35,30470 [m/s²]	0,03000 [s]	-0,28000 [s]	-0,25000 [s]
[003] a-quer	8,29007 [m/s²]	8,29007 [m/s²]	0,24870 [m/s]	1,57890 [m/s²]	16,09306 [m/s²]	14,51415 [m/s²]	0,03000 [s]	-0,28000 [s]	-0,25000 [s]
[109] a-vert	-8,78368 [m/s²]	-8,78368 [m/s²]	-0,26351 [m/s]	-19,29990 [m/s²]	2,27519 [m/s²]	21,57509 [m/s²]	0,03000 [s]	-0,28000 [s]	-0,25000 [s]
[006] v-tacho	335,03955 [km/h]	93,06654 [m/s]	2,79200 [m]	0,00000 [m/s]	279,19963 [m/s]	279,19963 [m/s]	0,03000 [s]	-0,28000 [s]	-0,25000 [s]
[020] v-längs-Spl	97,40015 [km/h]	27,05560 [m/s]	0,81167 [m]	26,94727 [m/s]	27,16634 [m/s]	0,21908 [m/s]	0,03000 [s]	-0,28000 [s]	-0,25000 [s]
[142] Zündung (CI)	1,00000 [-]	1,00000 [-]	0,03119 [-][s]	1,00000 [-]	1,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[143] Bremse (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[144] Blinker links (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[145] Blinker rechts (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[146] Abblendlicht (CI)	1,00000 [-]	1,00000 [-]	0,03119 [-][s]	1,00000 [-]	1,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[147] Standlicht (CI)	1,00000 [-]	1,00000 [-]	0,03119 [-][s]	1,00000 [-]	1,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[148] Fernlicht (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[151] Rückwärtsgang (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[155] Blaulicht (CI)	1,00000 [-]	1,00000 [-]	0,03119 [-][s]	1,00000 [-]	1,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[156] Einsatzhorn (CI)	0,00000 [-]	0,00000 [-]	0,00000 [-][s]	0,00000 [-]	0,00000 [-]	0,00000 [-]	0,03119 [s]	-1,12935 [s]	-1,09816 [s]
[005] Weg	749,41833 [m]	749,41833 [m]	22,48255 [m s]	748,02234 [m]	750,81433 [m]	2,79200 [m]	0,03000 [s]	-0,28000 [s]	-0,25000 [s]

By analysing acceleration data it is possible to differentiate driving from an impact by the sudden change in acceleration:
Whereby the Jerk in longitudianal direction is approximately 500 m/s³ within 4 ms and 1.200 m/s³ within 30 ms due to the VRU contact

Data from UDS: Acceleration over time - about 0,5 s before and after the impact against the pedestrian, and the calculated min-/max-values

Interim Conclusion:

- **Delta-V on its own is not suitable to differentiate an impact from normal driving**
- **Delta-V is generally below 8 kph in a normal car during an impact against a pedestrian or cyclist, thus we need a different trigger for crash detection**
- **Acceleration (longitudinal and lateral) is measured in a sufficient sampling rate (>>500 Hz) and resolution if car is equipped with ESC**
- **The Jerk - derived from acceleration – will not allows us to detect all impacts, but more than a Delta-V trigger of 8 kph within 150 ms**
- **To find a suitable Jerk-Trigger we need crash test with a suitable surrogate for vulnerable Road Users, thus a biofedelic dummy**

Need to conduct further crash tests using a biofidelic dummy

Not only for a correct jurisprudence, but also for research reasons it is important to understand, what the driver had actually done before the impact, therefore we need the Event Data not only in cases, where the Delta-V exceeded 8 kph

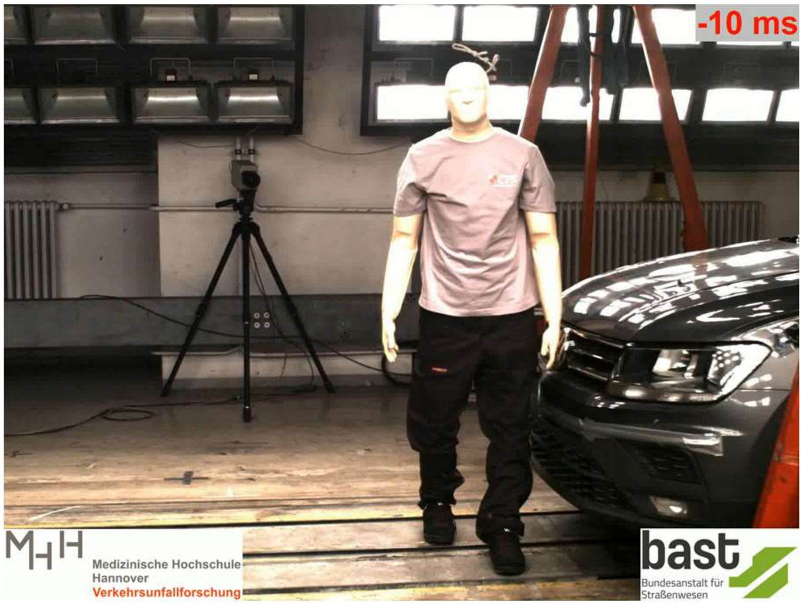
Test Programme by BASt[1] and MHH[2]

- Car and van impacts against pedestrians and cyclists
  - pedestrian impacts with stationary pedestrian
  - bicycle impacts with moving bicycle in perpendicular direction
- Impact locations and test speeds according to
  - accident data analysis
  - adjusted during testing in order to find critical accident severity for EDR triggering
  - for most of the configuration tests with and without wrapping up of pedestrians were planned

1) Bundesanstalt für Straßenwesen, Bergisch Gladbach

2) Medizinische Hochschule Hannover

Test example ($v_{collision} \approx 30$ kph)



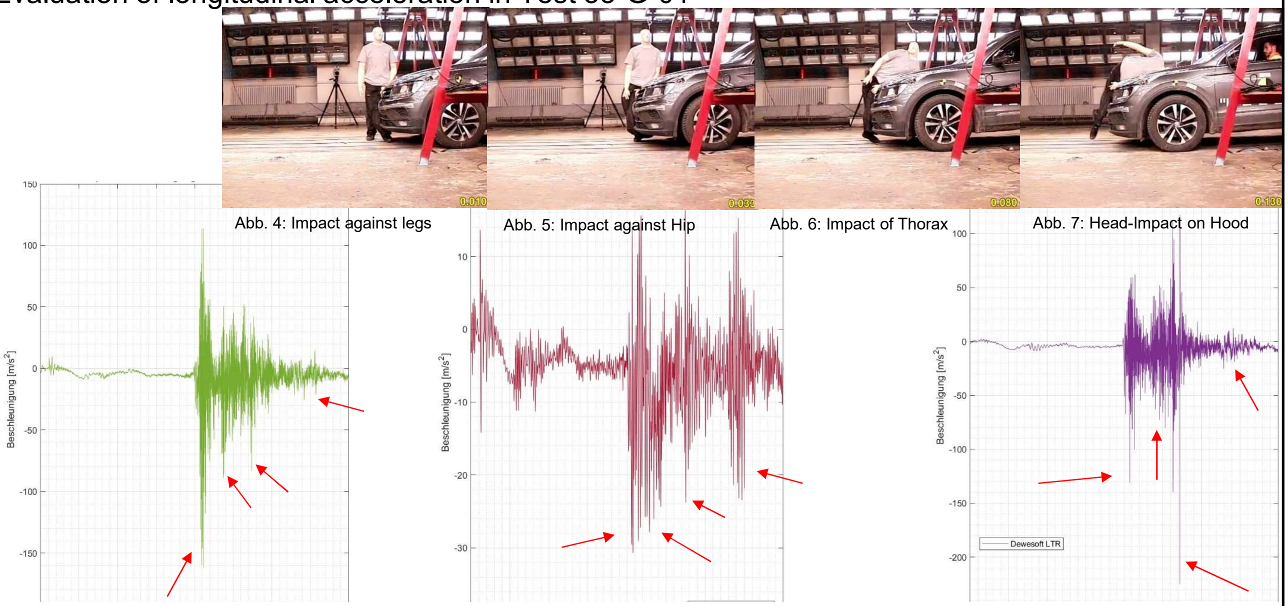
Presentation of Test 33-G-01

- Modus: braked
- Target Collision Speed v_{aim} = 33 km/h
- Measured Light-Barrier Speed v_{ref} = 31,98 ± 0,1 km/h
- Post collision distance s_x = 6,35 m ; s_y =0 m (-0,018 m)
- Throwing distance s_{FG}= 8,2 m (8,194 m)

Abb. 1: Collision-Position, Test 33-G-01

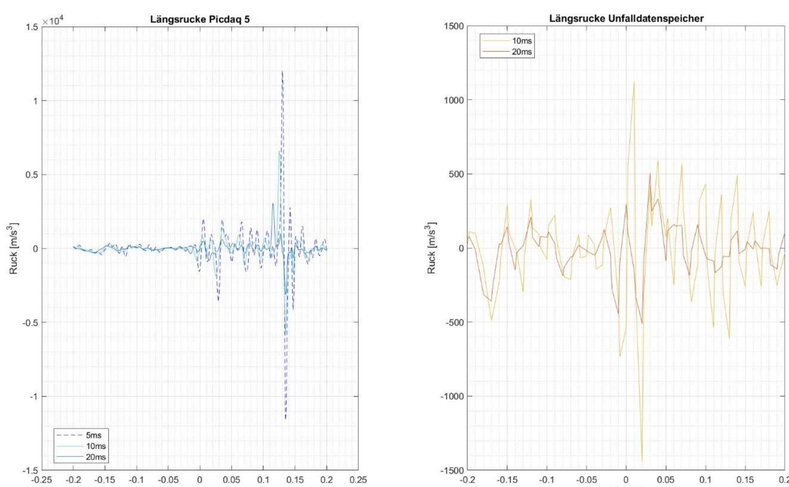
Abb. 2: Collision sketch, Test 33-G-01 (PC-Crash 15.0)

Evaluation of longitudinal acceleration in Test 33-G-01



Impact at 32 km/h against Dummy is detectable by up-front sensors on the beams as well as in the centre of gravity by peaks in acceleration, eventhough Delta-V is below 8 km/h

Evaluation of Test 33-G-01 - Longitudinal Jerk

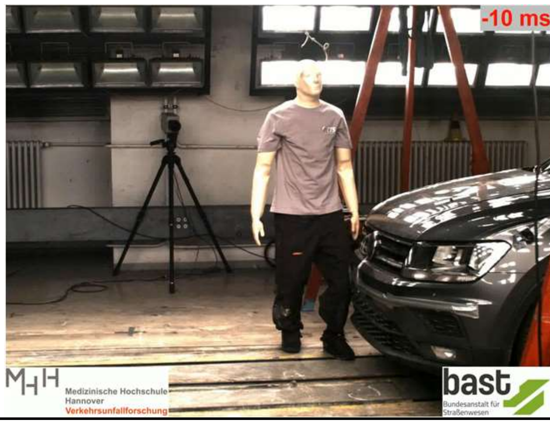


Delta-V in the car is far below 8 km/h within 150 ms at an impact speed of 32 km/h against the Biofidelic Dummy, but the Jerk exceeds 1000 m/s³ - Thus the impact is clearly detectable

Presentation of Test 10-G-01

- Modus: braked
- Target Collision Speed v_{aim} = 10 km/h
- Measured Light-Barrier Speed v_{ref} = 9,98 ±
- Post collision distance $s_{x\text{-}Car}$ = 0,87 m ; $s_{y\text{-}Car}$ =0 m (-0,015 m)
- Throwing distance s_{Dummy}= 1 m (0,925 m)

Abb. 1: Kollisionsstellung, Versuch 10-G-01



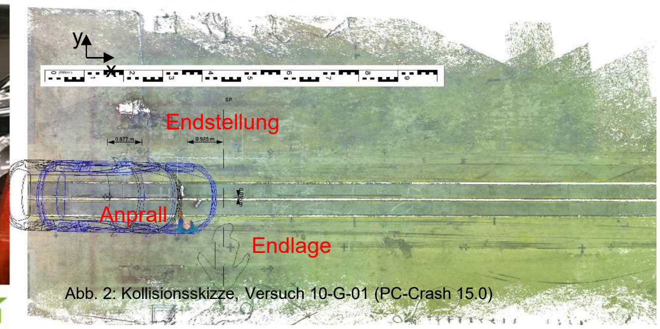
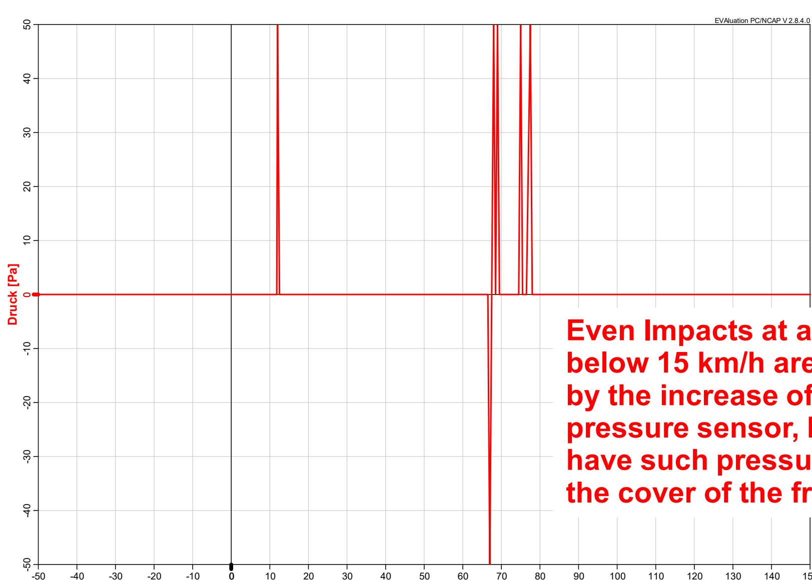


Abb. 2: Kollisionsskizze, Versuch 10-G-01 (PC-Crash 15.0)

Pressure curve in the pressure hose sensor behind bumper cover after crash-test impact at v_k = 10 km/h against biofidelic Dummy



Bumper pressure sensor

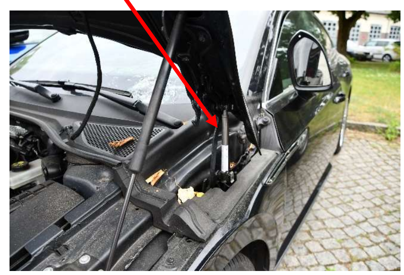
Even Impacts at a collision speed below 15 km/h are clearly identified by the increase of pressure in the pressure sensor, but only few cars have such pressure sensors behind the cover of the front bumper

Case Study: car vs. Pedestrian

EDR Data after an impact against a pedestrian, if the car is equipped with a Pop-Up Hood

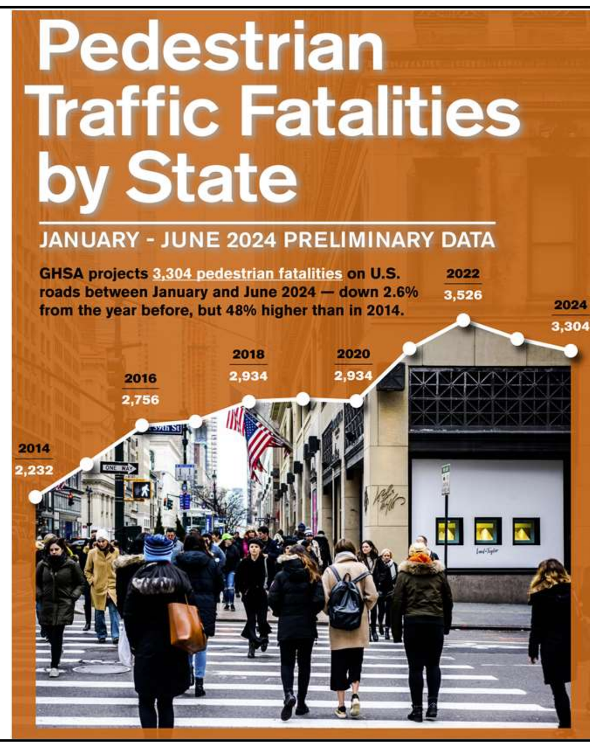
Pre-Crash Data -5 to 0 sec (Record 1, Most Recent)

Time (sec)	Anti-lock braking system activity	Stability Control	Speed, Vehicle Indicated (MPH [km/h])	Accelerator pedal, % full (%)	Service brake, on/off
-5.0	Non-Engaged	On	22 [36]	100	Off
-4.5	Non-Engaged	On	25 [41]	94	Off
-4.0	Non-Engaged	On	30 [48]	91	Off
-3.5	Non-Engaged	On	35 [56]	92	Off
-3.0	Non-Engaged	On	40 [64]	92	Off
-2.5	Non-Engaged	On	44 [71]	90	Off
-2.0	Non-Engaged	On	47 [76]	86	Off
-1.5	Non-Engaged	On	50 [80]	35	Off
-1.0	Non-Engaged	On	50 [80]	0	Off
-0.5	Non-Engaged	On	50 [80]	0	Off
0.0	Engaged	On	43 [70]	0	On



Pedestrian was servely injured by the impact.
Even the Delta-V within 150 ms was just 5 km/h,
EDR Data was stored, because the car was equipped with a secondary Pedestrian safety sytem (Pop-Up Hood)

Increase of pedestrian fatalities



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Federal Highway and Transport Research Institute

EDR - Update on VRU Triggers
27th IWG EDR/DSSAD

Federal Highway and Transport Research Institute
Marcus Wisch | BASt

Priester & Weyde, Berlin
Dr. Michael Weyde | Crash Reconstruction Expert, EVU

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Federal Highway and Transport Research Institute

Jerk-based trigger thresholds - Update

Three data sets were available for analyses

- New performed collision tests considering different pedestrian impact positions and ranging from lower to medium impact speeds between passenger car and ‘Biofidel’-dummy as part of the BASt project FE 82.0755 ‘EDR trigger for detecting motor vehicle collisions with vulnerable road users’
- 9535 data records from crash data recorders of official vehicles (including also recordings of non-crash events) and records from normal driving in parts of Berlin

Impact speed around 33 km/h

| Marcus Wisch: BASt | Michael Weyde: EVU 47

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Findings

- Collisions between a pedestrian and a car at collision speeds above 15 km/h are clearly recognizable by the acceleration peaks, but a delta-V of 8 km/h within 150 ms is not achieved.
- The analysis of vehicle's deceleration allows detecting even minor impacts with vulnerable road users (also differentiation from normal driving and hard brakings) especially if there is a noticeable jerk that occurs simultaneously in several spatial axes:
  - Significance found at > 500 m/s³ within 4 ms and > 1.200 m/s³ within 10 ms (e.g., at the time when the pedestrian's hip impacts the vehicle's hood)

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Driving data records

Investigation for alternative delta-v trigger thresholds

- Dedicated analyses for:
  - Δv ≥ 0.8 km/h within 20 ms (legal value for t0)
  - Δv ≥ 0.5 km/h within 10 ms
  - Δv ≥ 0.25 km/h within 5 ms
- Data analyses separated for impacts speeds:
  - < 15 km/h
  - 15 – 30 km/h
  - > 30 km/h

Photo provided by Michael Weyde

Conclusions

- Delta-V trigger threshold of 8 km/h within 150 ms (current standard trigger) is not appropriate for detecting collisions of a car with pedestrians.
- Alternative Delta-V trigger thresholds (e.g., 0.5 km/h within 10 ms) are promising for VRU detection
- Overall, jerk-based criterion remains preferred (future) trigger threshold to detect collisions of cars with vulnerable road users even at lower impact speeds
- Further robustness collision tests, data analyses and discussions with industry are required and will follow

| Marcus Wisch: BASt | Michael Weyde: EVU 50

Many Thanks for your Attention

- Vielen Dank für Ihre Aufmerksamkeit