



FI**X** 2026

Future Innovation tech eXpo Conference

Injury Analysis Study for Motorcycle Passenger Protection

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1. Research background
2. Crash accidents & literature reviews
3. Research methods
4. Injury investigation
5. Research approaches
6. Computer simulations
7. Conclusions



(1) Education

- Doctor of Philosophy, Department of Mechanical and Aerospace Engineering, University of Virginia, Charlottesville, December 2011
- Master of Science, Department of Mechanical Engineering, Hongik University, Seoul, Korea, February 1997
- Bachelor of Science, Department of Mechanical Engineering, Hongik University, Seoul, Korea, February 1995

(2) Work Experiences

- Kyungil University – School of Mechanical and Automotive Engineering, Professor, Associate/Assistant Professor, 2013-2026
- University of Virginia – Center for Applied Biomechanics, Visiting Professor, Research Associate, Research Assistant, Graduate Research Assistant, 2003-2014
- Ssangyong and Daewoo Motors – Technical Center, Assistant Manager, Research Engineer, 1997-2003

(3) Research Interests

- Human Body Modeling and Computational Biomechanics
- Impact and Injury Biomechanics
(Human Response under Impact Loadings)
- Applied Biomechanics using Finite Element Method
- Constitutive Modeling of Advanced Bio-materials
- Automobile Safety and Crashworthiness Research
- Optimal Structural Design and Analysis

1. Research Background

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THE RATINGS EXPLAINED

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The Ratings Explained

Euro NCAP introduced the overall safety rating in 2009, based on assessment in four important areas:

- Adult Occupant Protection (for the driver and passenger);
- Child Occupant Protection;
- Pedestrian Protection which has been expanded to include cyclists and is now known as Vulnerable Road User (VRU) protection; and
- Safety Assist, which evaluated driver-assistance and crash-avoidance technologies.

The overall star rating was introduced to add more flexibility to the previous ratings' scheme which had been in use since 1997.

**Adult Occupant**

**Child Occupant**

**Vulnerable Road Users**

**Safety Assist**

HOW SAFE IS YOUR CAR ?

Select one or more vehicles among the following possibilities.

Make

Model

OR

Class

Make

Model

OR

Class

[ALL RESULTS & REWARDS](#)

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VULNERABLE ROAD USER (VRU) PROTECTION

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[Head Impact](#)

[Upper Leg Impact](#)

[Lower Leg Impact](#)

[AEB Pedestrian](#)

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Vulnerable Road User (VRU) Protection

As well as assessing how well cars protect their occupants, Euro NCAP tests how well they protect those vulnerable road users – pedestrians and cyclists – with whom they might collide.

In these tests, the potential risks of injuries to a pedestrian's head, pelvis, upper and lower leg are assessed. Cars which perform well can gain additional points if they have an autonomous emergency braking (AEB) system which recognises pedestrians and cyclists.

Click below to learn more about the tests.

**Head impact**

**Upper Leg Impact**

**Lower Leg Impact**

**AEB Pedestrian**

**AEB Cyclist**

2. Domestic Motorcycle Crash Trends

Year	Crash Count	Fatalities	Injuries
2020	21,258	525	27,348
2021	20,598	459	26,617
2022	18,295	484	23,469
2023	16,567	392	21,318
2024	15,290	361	19,847
2025	14,129	388	18,047

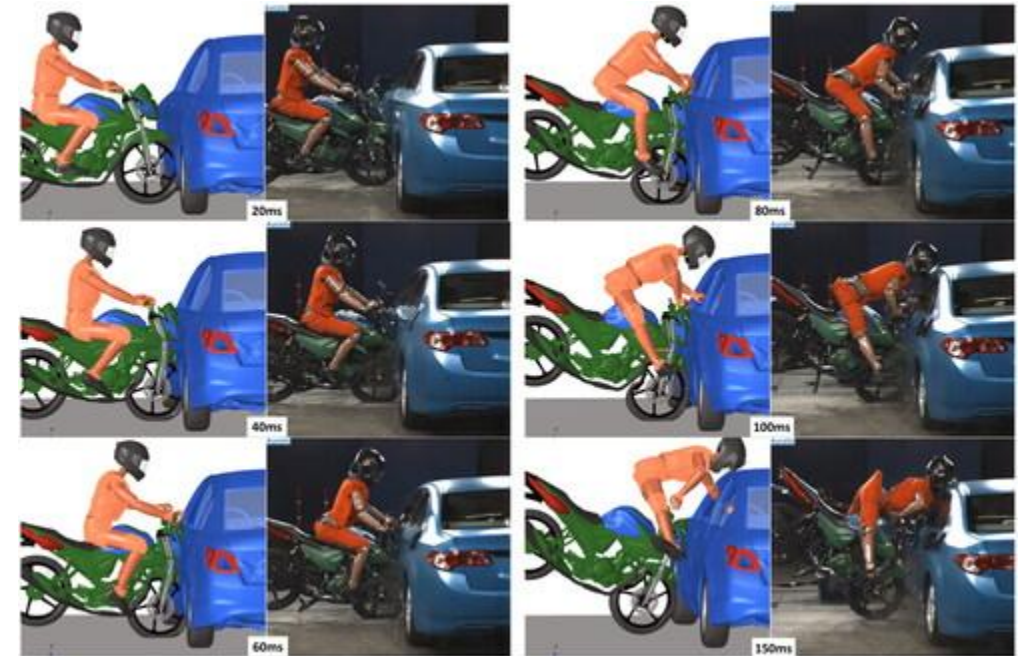
Key Observations

- **Crash Reduction:** Total crashes steadily decreased by ~33.5% from 2020 to 2025.(TASS Database)
- **Fatality Rebound Warning:** While overall numbers are down, fatalities increased year-over-year in 2025.
- **Crucial Conclusion:** Independent of declining macro crash metrics, advanced protective tech is highly necessary to minimize severe and fatal tissue-level injuries.

2. Real-World Crash Configurations

Primary Crash Configurations

- **Motorcycle-Car:** Direct impact followed by 2nd contact with hood, windshield, or A-pillar.
- **Motorcycle-Motorcycle:** Frontal/side collisions with extreme potential for occupant ejection.
- **Motorcycle-Fixed Object:** Severe impact with infrastructure like guardrails, medians, or poles.
- **Single-Vehicle Crash:** Sequential kinematics, Rollover → Sliding/Tumbling → Ground Impact.



2. Kinematic Variations & Research Gaps

Kinematic Path Disconnect

- Rider Kinematics:
High probability of severe localized impact with handlebars and forward internal structural clusters.
- Pillion Passenger:
Exhibits highly complex secondary trajectories. Includes mechanical loading against the front rider, secondary vehicle/ground impact zones, and vastly higher raw ejection ratios.

US FARS 2023 Fatality Insight

- Out of 6,335 total fatalities: 6,025 were drivers vs. 310 passengers.
- Notably, ~91% of all passenger fatalities are female.
- **Critical Research Gap:**
Passenger-focused biomechanics papers are massively limited compared to baseline rider research. FE human body modeling setups must cleanly isolate initial positions, distinct boundary constraint environments, and customized multi-body contact sequences.

2. Crash Environment Analysis (US & Europe)

United States (FARS Data)

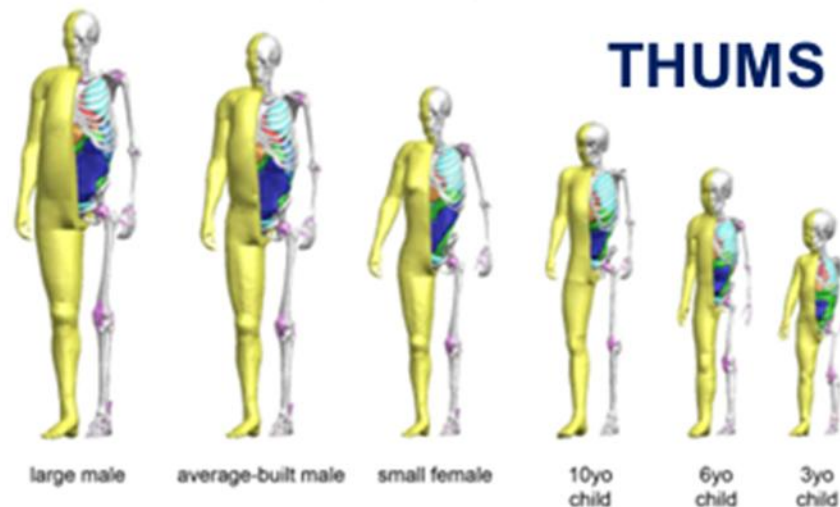
- Fatality Surge: 6,335 fatalities in 2023, tracking an elevated historical baseline (~26% macro increase vs. 2019).
- Proportional Impact: Motorcycle fatalities represent roughly 15% of all motor vehicle crash deaths.
- Granular Benefits: High data availability for parameterizing exact person types, crash environments, and helmet deployment parameters.

Europe (CARE Data)

- Fatality Scale: ~3,361 total motorcycle deaths recorded in 2022.
- Configuration Split: ~1,442 vehicle-to-motorcycle multi-body collisions vs. ~1,280 isolated single-vehicle events.
- Road Typography: High rural skew (~55% rural, ~39% urban, ~6% motorway structural environments).

2. Cross-Regional Matrix

Attribute	South Korea (TAAS)	United States (FARS)	Europe (CARE)
Trend Lines	Declining total crash frequencies	Sustained high baseline fatalities	Long-term progressive reduction
Critical Injuries	Head/Neck, Lower Extremity	Head/Neck, Thorax, Lower Extremity	Head/Neck, Lower Extremity
FE/HBM Maturity	Limited localized research integration	Highly diversified HBM platforms	Highly diversified HBM platforms



2. Prior Literature Trends

Authors	Methods	Key Scientific Literature Milestones
Carmai et al. (2019)	MBD + THUMS	Integration mapping full-body injury mechanics across child pillion models.
Liu et al. (2024)	THUMS	Deployment quantifying E2W side impact vectors over velocity transitions.
Jia et al. (2020)	Accident reconstruction + THUMS	Isolating structural helmet vs secondary contact brain strains.
Miralbes (2014)	Hybrid-III	Hardware-virtual validation optimizing localized guardrail shielding criteria.

■ Computational Implication:

Since urban vs. rural crash layouts vary wildly by specific geographic nations, computational FE scenarios must actively utilize condition-specific velocity presets rather than over-relying on a single country's flat average speed standard.

3. Data-to-FE Extraction Framework

6-Step Real-to-Virtual Translation

Step 1: Extract representative crash profiles from macro historical databases.

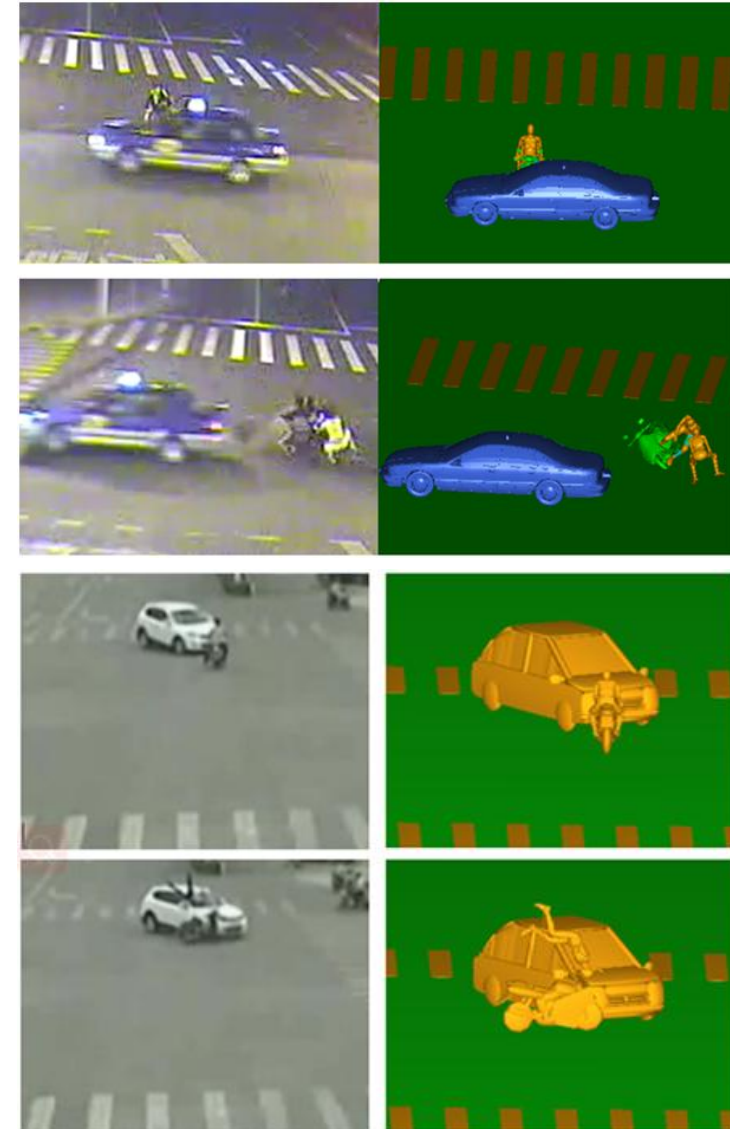
Step 2: Statistically resolve velocity, impact angles, and structural geometries.

Step 3: Discretize boundary setups (Rider vs Pillion, helmet deployment, ejections).

Step 4: Replicate macro occupant trajectories using Multi-Body Dynamics (MBD).

Step 5: Run high-fidelity non-linear solvers (ex: LS-DYNA) utilizing HBMs (ex: THUMS model).

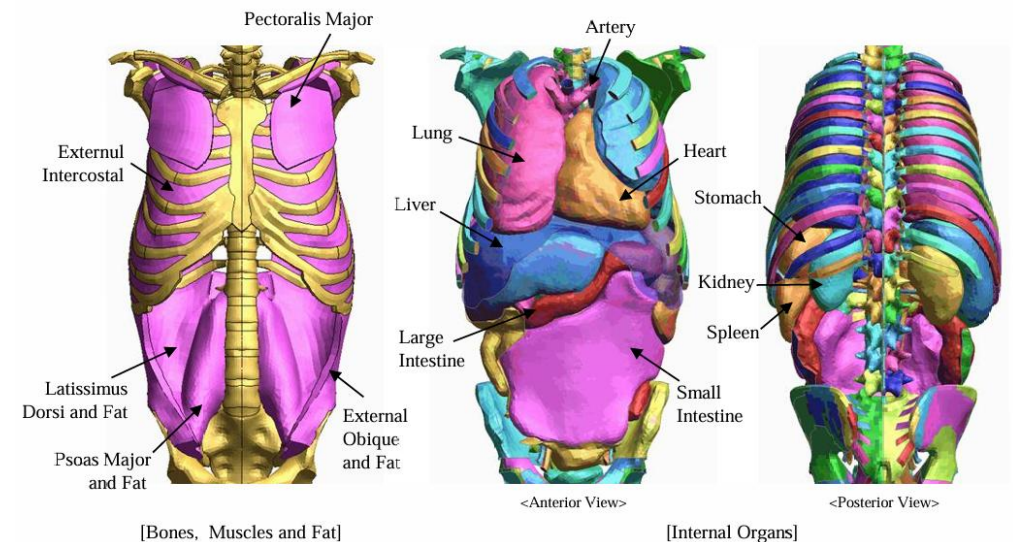
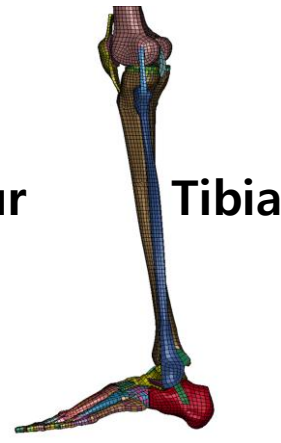
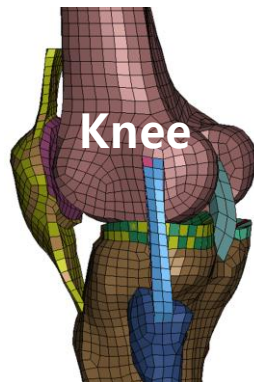
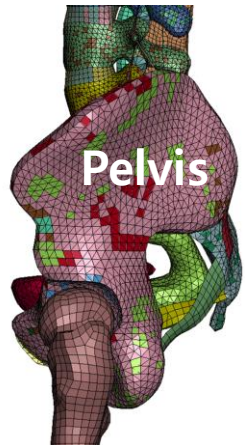
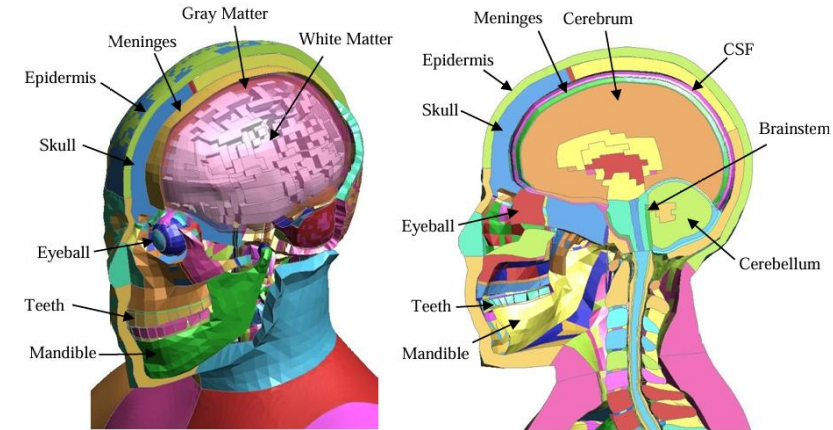
Step 6: Map micro tissue-level criteria directly to real-world AIS/ISS medical databases.



4. Injury Regions

Anatomical Injury Characteristics

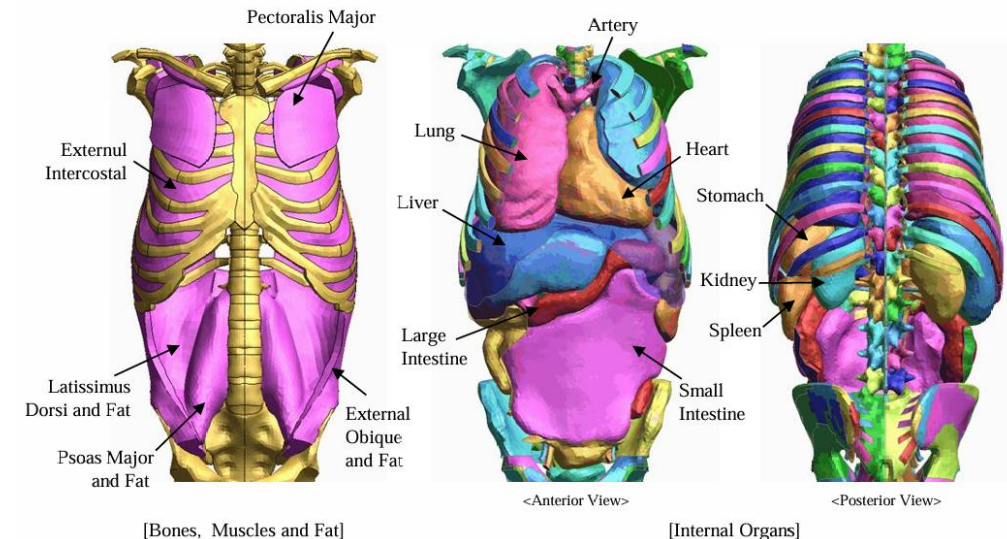
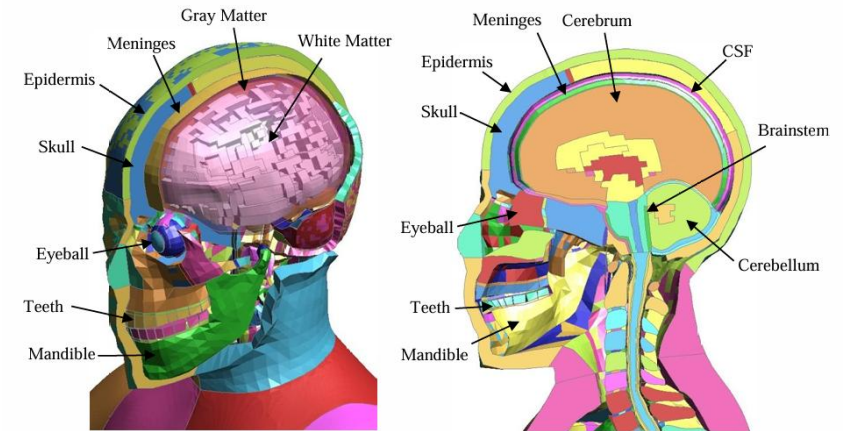
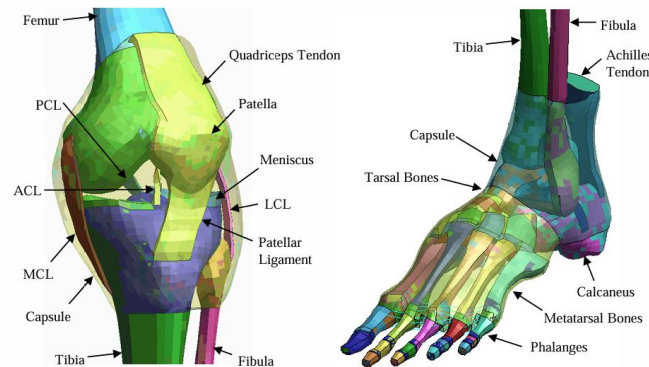
- **Head/Neck:** Trauma directly responsible for major fatalities and critical spinal damage.
- **Lower Extremity:** Femur, tibia, knee, and ankle are vulnerable to direct structure impacts.
- **Thorax/Abdomen:** Contact causes severe rib fractures, lung contusions, and internal organ lacerations.



4. Injury Metrics

Recommended Computational Injury Metrics

- **Head/Brain:** HIC15/36, linear/rotational acceleration, principal tissue strain, CSDM.
- **Cervical Spine:** Axial/shear forces, flexion/extension moments, ligament tensile strain limiters.
- **Thorax/Abdomen:** Chest deflection mapping, rib stress/strain tensors, organ compression criteria.
- **Pelvis/Lower Ext:** Pelvic ring load distribution, femur/tibia forces, cortical bone fracture risk.



5. Target Testing Scenarios

Proposed FE Evaluation Scenarios

- **Scenario 1: Motorcycle-to-Car Frontal Impact**

Tracks aggressive forward-displacing occupant kinematics and forward cluster structures contact profiles.

- **Scenario 2: Car-to-Motorcycle Lateral Impact**

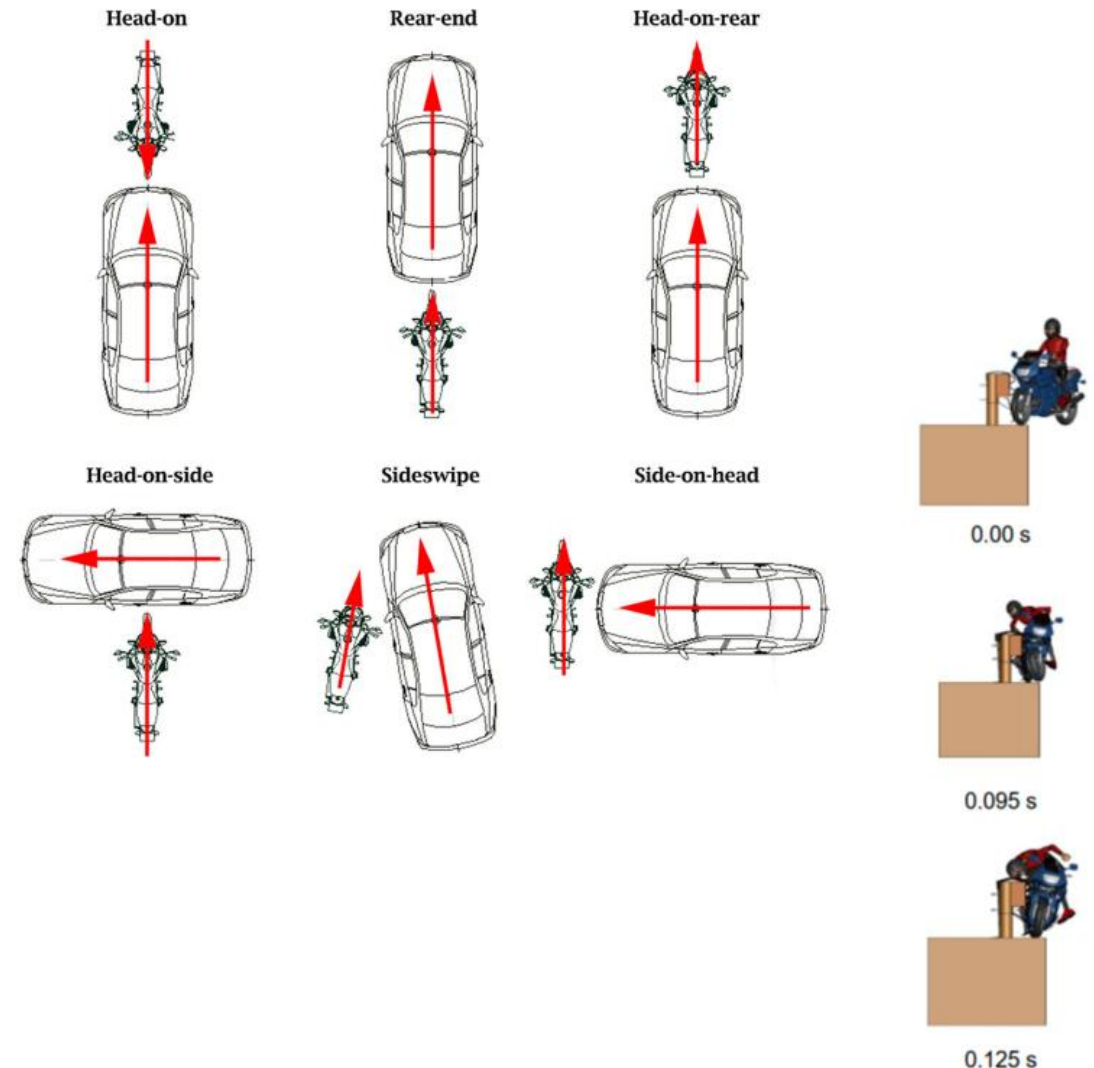
Quantifies sudden side-loading torso excursions and lower extremity crushed fractures.

- **Scenario 3: Single-Motorcycle Rollover/Tumble**

Replicates high-speed sliding mechanics and sequential secondary ground impact brain strains.

- **Scenario 4: Motorcycle-to-Guardrail/Fixed Object**

Models direct localized high-energy impacts against hostile structural terrain landmarks.



5. Integrative Architecture

Core Differentiator & Architecture

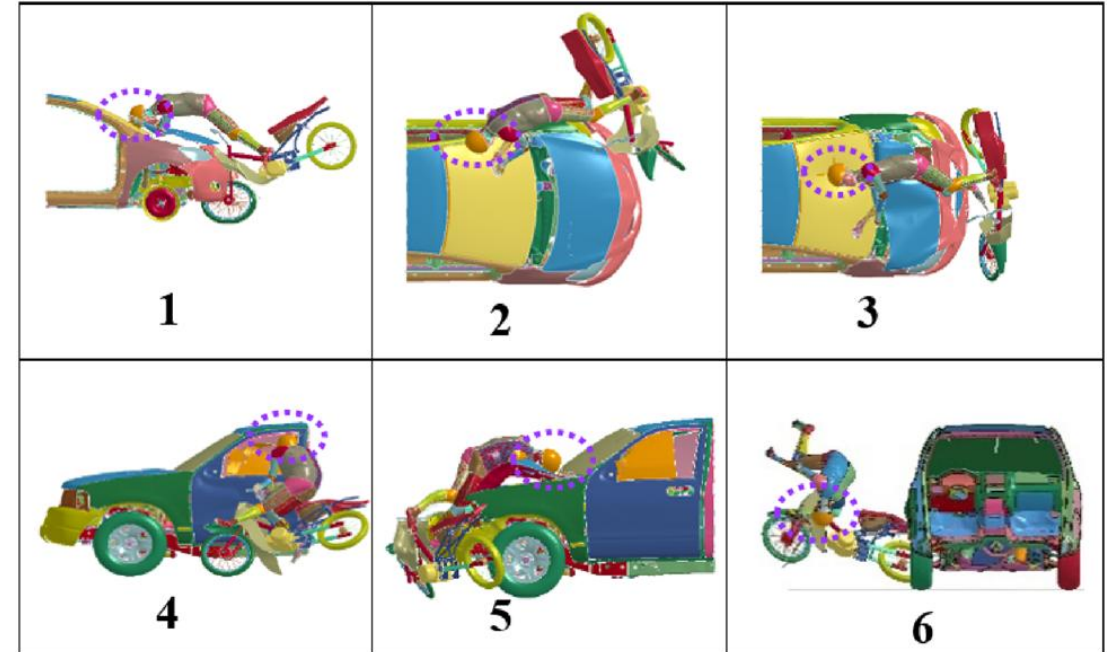
■ The Gap:

Traditional statistical data lacks engineering depth, while conventional isolated FE models lack real-world validation data. Adult pillion passenger tracking represents a severe blindspot in current global vehicle regulatory baselines.

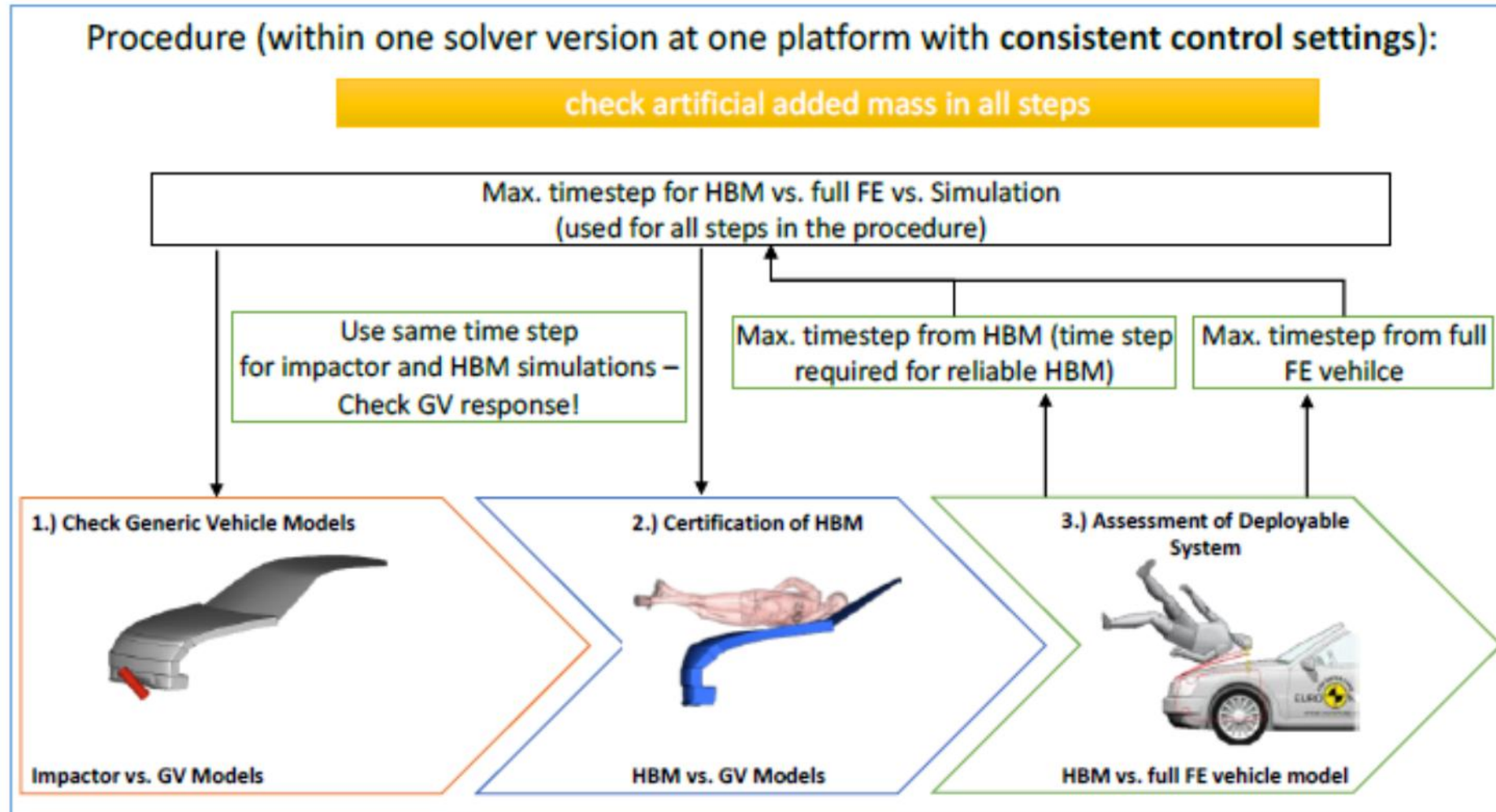
■ Integrated Methodological Loop:

Real-World Crash Data Matrix (TAAS/FARS/CARE)

- Global Kinematic Trajectory Resolvers (MBD)
- Non-Linear High-Fidelity Solvers (THUMS/GHBMC)
- Localized Biomaterial Damage Evaluation Criteria
- Industrial Safety System Engineering (Design specifications for helmets, advanced PPE, and structural energy-absorbing motorcycle platforms).



5. Computational Procedure



6. Computer Simulations

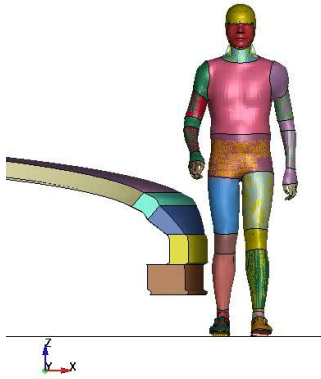
Sedan

Coupe

SUV

AM50

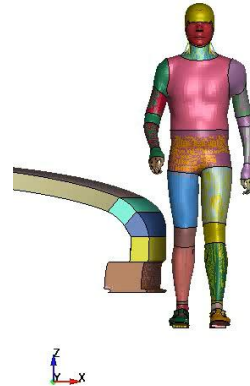
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GHBMC 6YO-PS v2.8.2
Time = 0



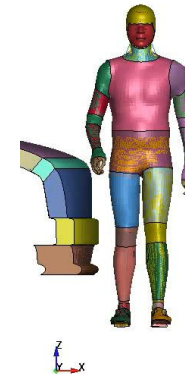
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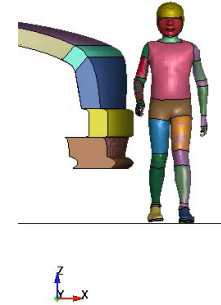
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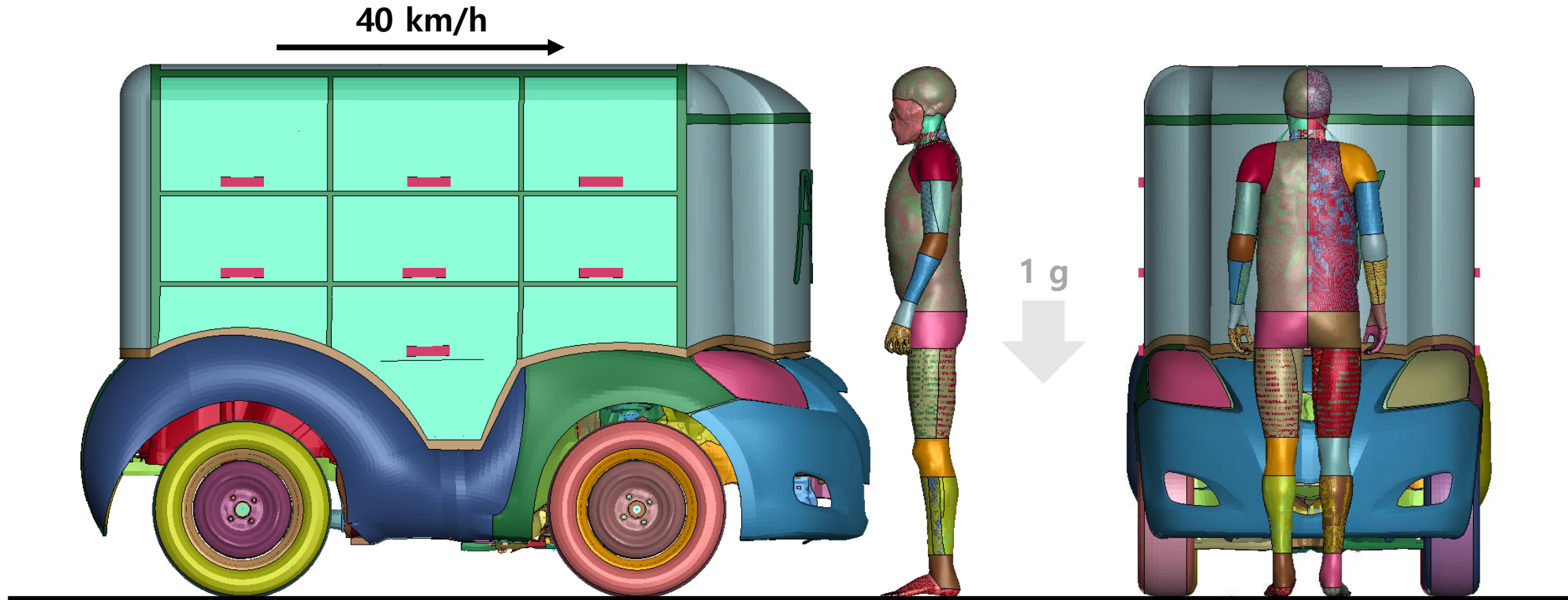
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6. Computer Simulations



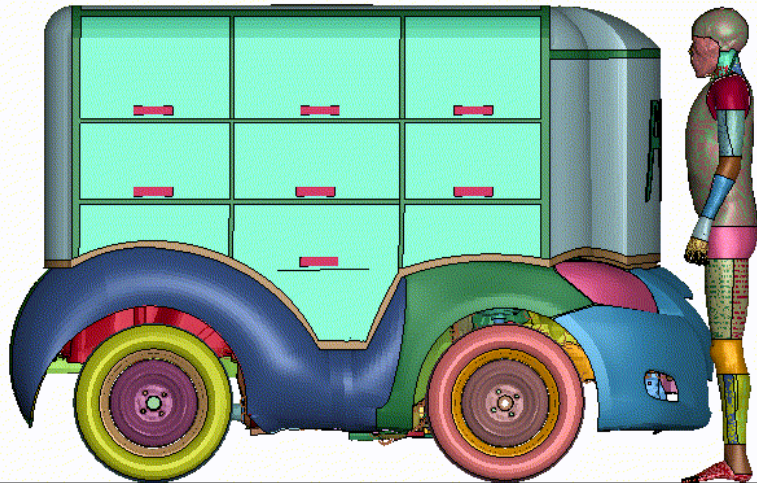
Autonomous vehicle model
(NHTSA)

AM50th%ile

6. Computer Simulations

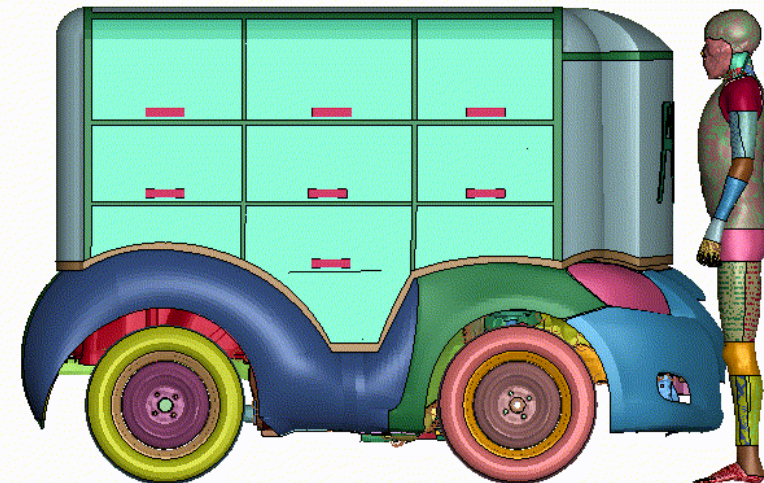
■ 40 km/h vehicle impact simulations

GMU-CCSA-GENERIC-SMALL-SIZE-ADS-VEHICLE
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With pre loading

GMU-CCSA-GENERIC-SMALL-SIZE-ADS-VEHICLE
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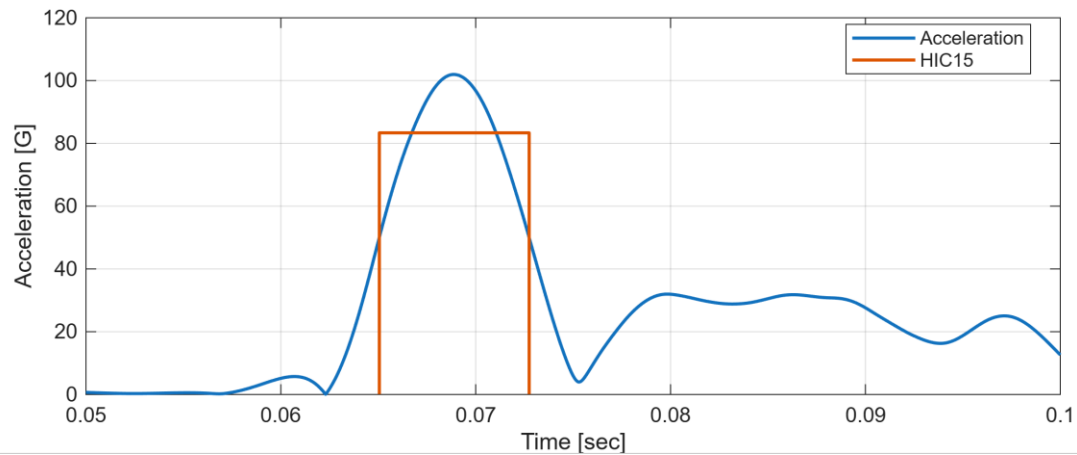


Without pre loading

6. Computer Simulations

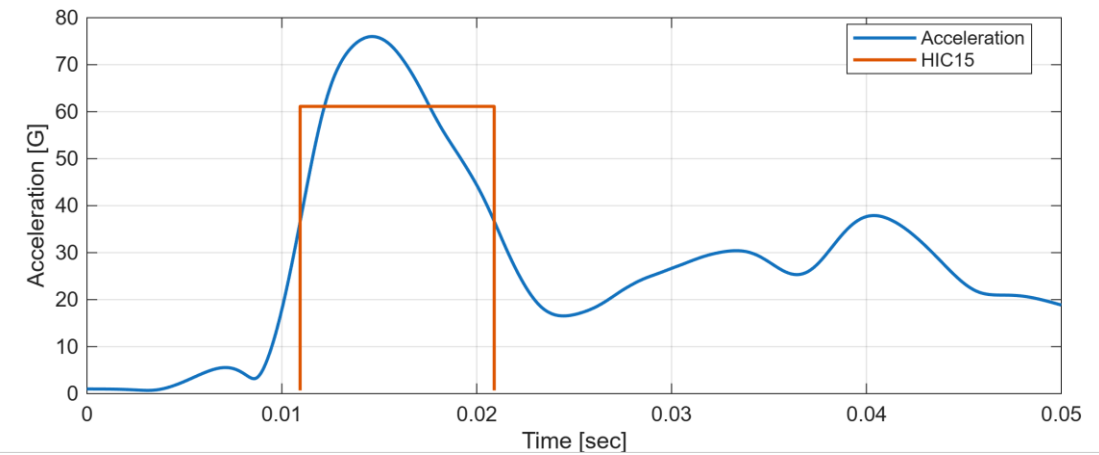
■ Head injury comparison

HIC15: 487.3



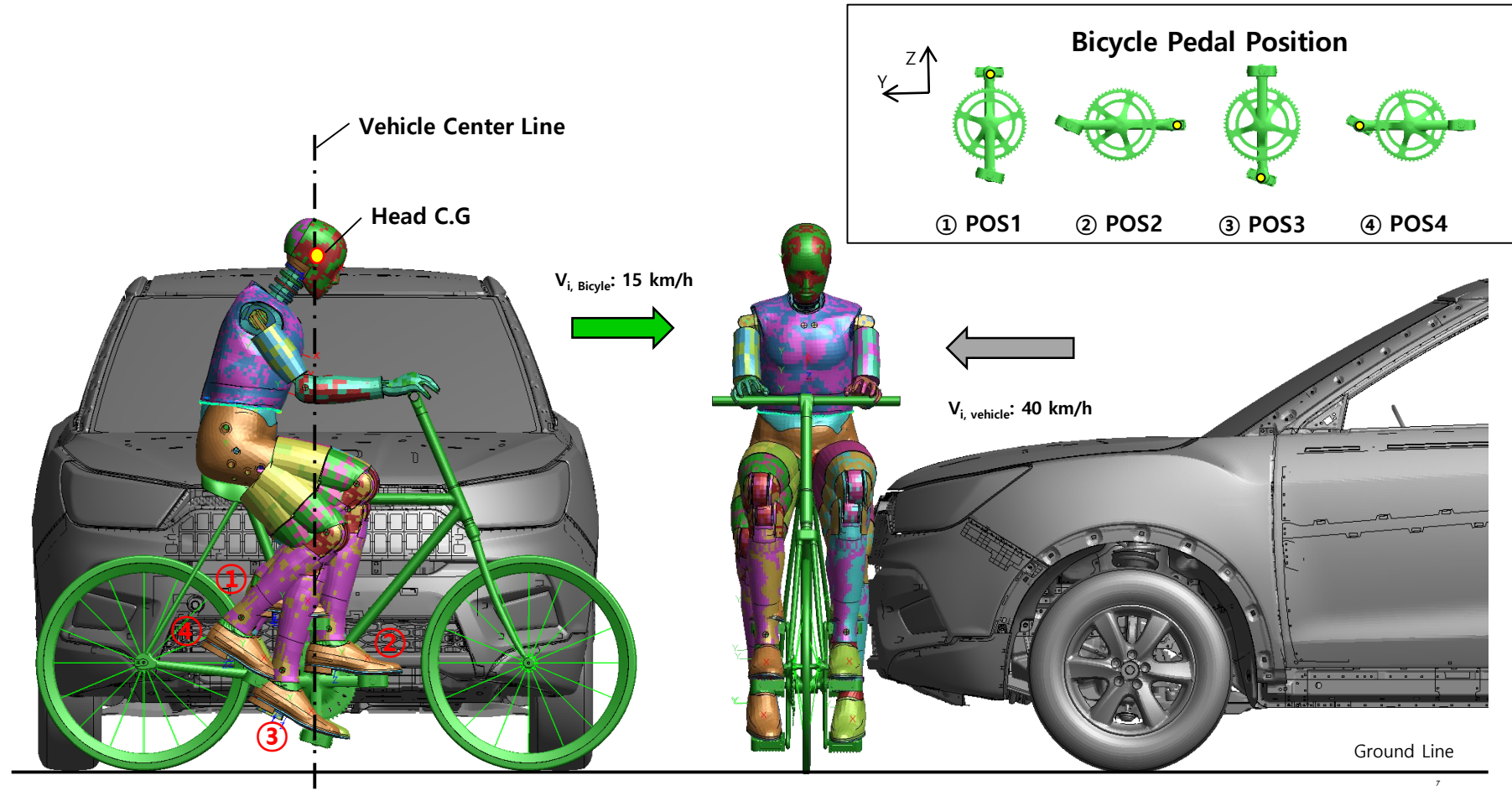
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HIC15: 280.1



Without pre loading

6. Computer Simulations



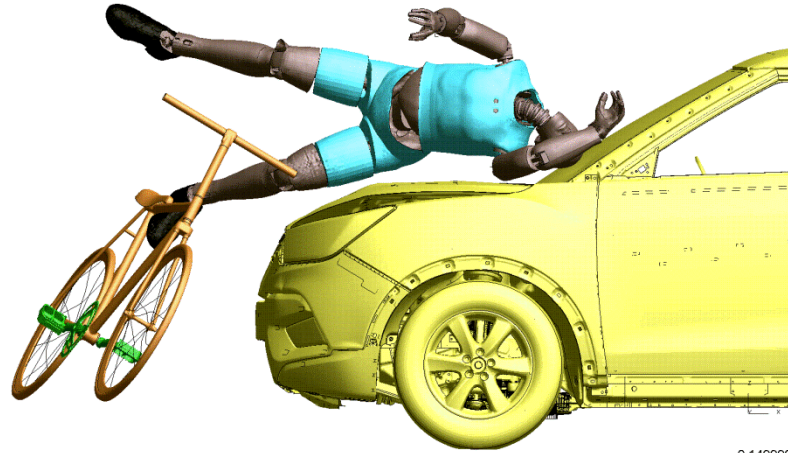
6. Computer Simulations

D3PLOT: X100_CYCLIST_IMPACT_40KPH_B19_Case07



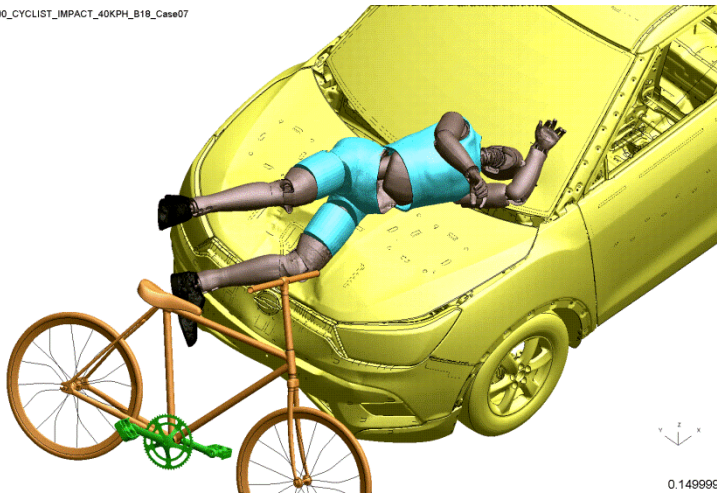
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D3PLOT: X100_CYCLIST_IMPACT_40KPH_B19_Case07



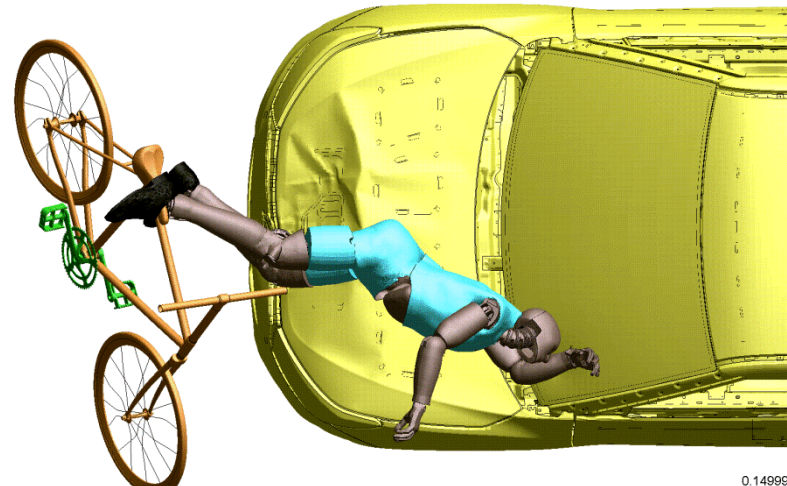
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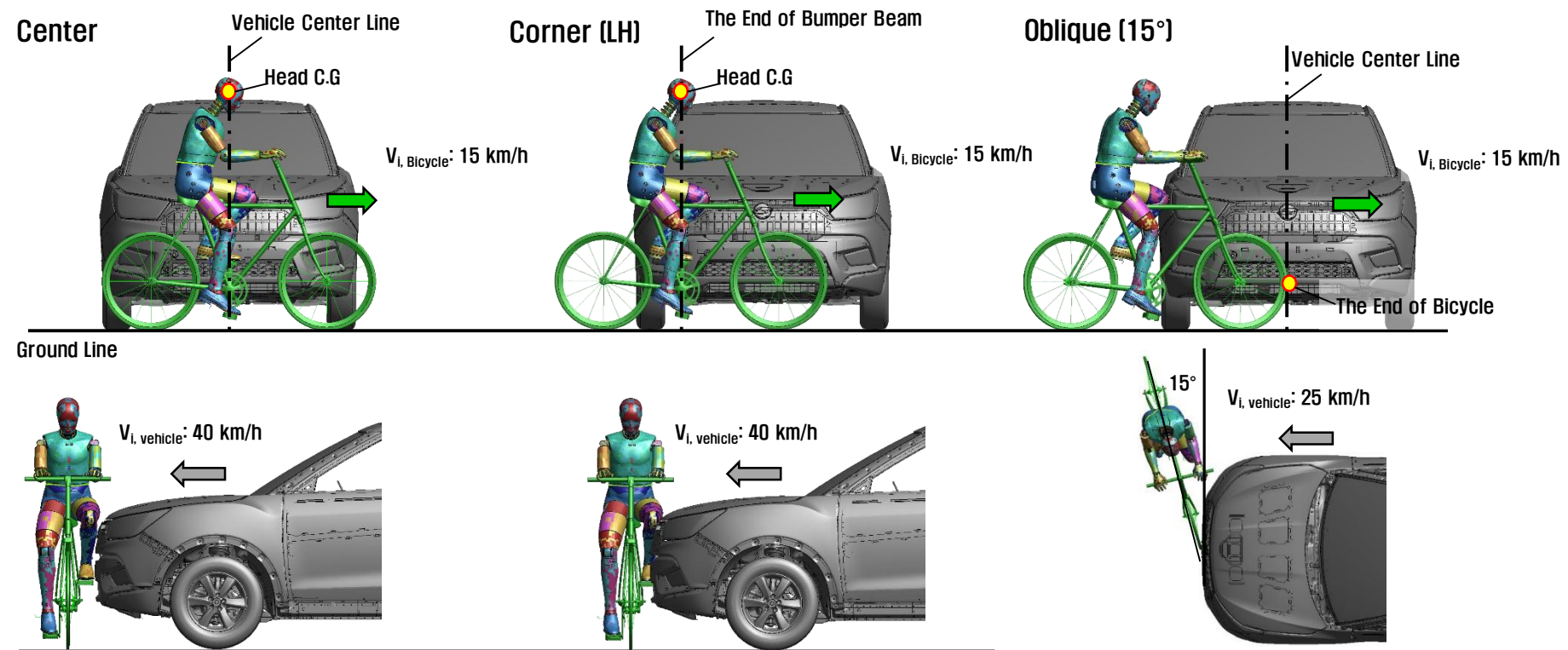
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D3PLOT: X100_CYCLIST_IMPACT_40KPH_B19_Case07



0.149999

6. Computer Simulations



7. Conclusions

Occupant protections

- Real-world crash accident analysis
- Experimental and computational approaches
- Head-neck protection & helmet design
- Restraint system design: belts and airbags
- Driver and passenger safety
- Secondary collisions

THUMS AM50 Version 41 Pedestrian Model 202506
Time = 0

