UNIVERSITÀ DEGLI STUDI FIRENZE

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DICEA
DIPARTIMENTO DI INGEGNERIA CIVILE E AMBIENTALE

Road safety through FEM simulations: concepts and criteria towards a 0-deaths strategy

The finite element methods in the road accident reconstruction

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Accident reconstruction

Objectives:

Reconstruct, after the event, the dynamics of the accident in order to determine the pre-collision parametres:

1) Velocity of the vehicles involved in the occurrence;
2) Trajectors of the vehicles involved in the occurrence;
3) Injury level;
4) Responsability in the causation of the event.

ROAD HOMICIDE

Main methods

Semi-empirical methods

allows the determination of the speed pre-collision by means of equations obtained from experimental data

i.e. full scale crash test, real events with camera, laboratory analysis

Vehicle-pedestrian collision

Vehicle-pedestrian collision

km/h $\boxed{V = k\sqrt{d}}$ m

Appel

Adulto

$V_{imp} = 13{,}607 \cdot \sqrt{d_t}$

Bambino

$V_{imp} = 12{,}136 \cdot \sqrt{d_t}$

Frontale alto

$V_{imp} = 12{,}421 \cdot \sqrt{d_t}$

Frontale basso

$V_{imp} = 14{,}120 \cdot \sqrt{d_t}$

Happer

Forward projection	$V_{imp} = 11{,}3 \cdot \sqrt{d_t} - 0{,}3$
Wrap	$V_{imp} = 13{,}3 \cdot \sqrt{d_t} - 4{,}5$
Forward projection & Wrap	$V_{imp} = 12{,}8 \cdot \sqrt{d_t} - 3{,}6$

Wood

Forward projection

$V_{imp\,\min} = 9{,}62 \cdot \sqrt{d_t}$ $\quad$ $V_{imp\,\max} = 13{,}7 \cdot \sqrt{d_t}$

Wrap

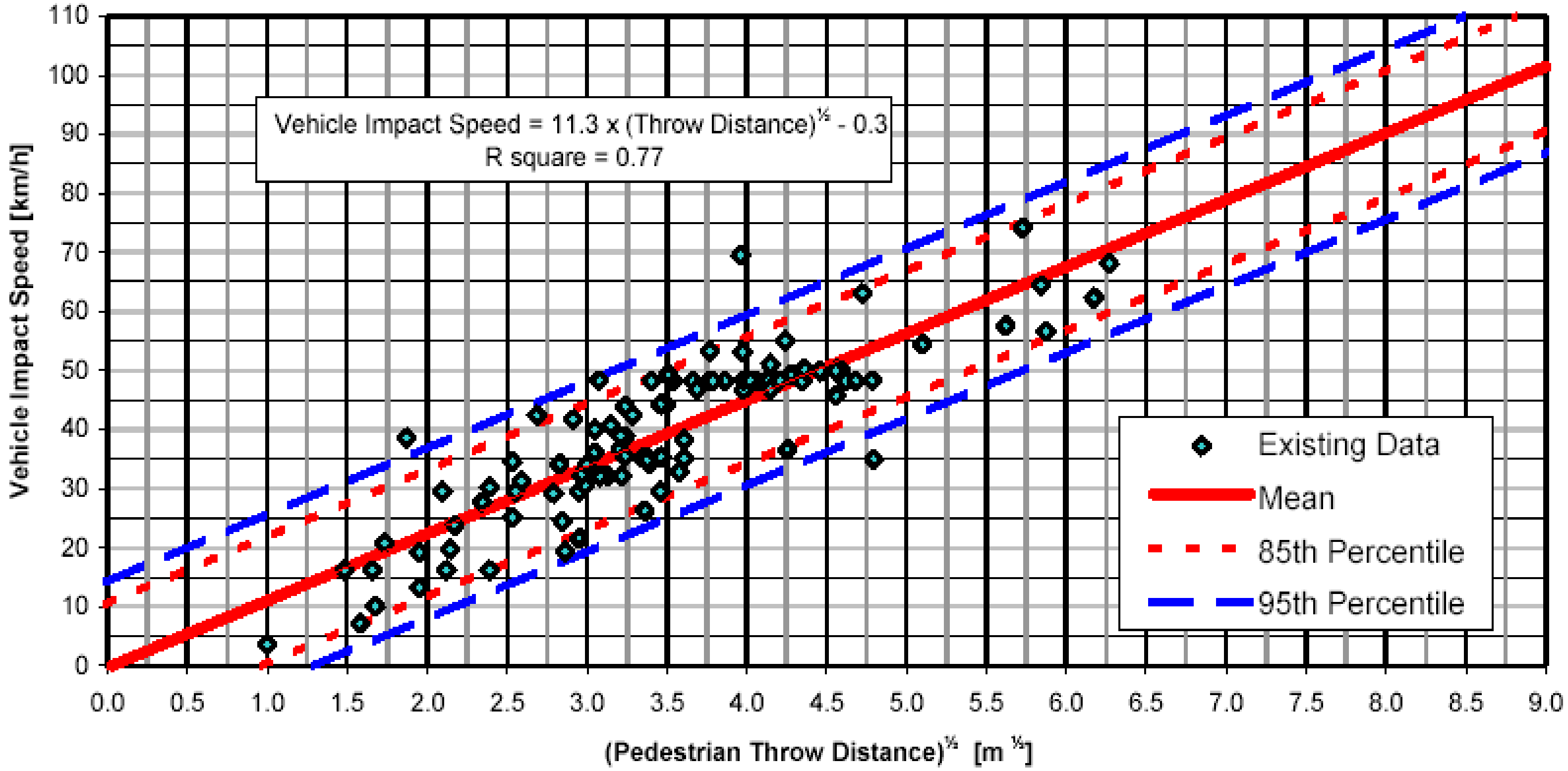
$V_{imp\,\min} = 8{,}77 \cdot \sqrt{d_t}$ $\quad$ $V_{imp\,\max} = 13{,}76 \cdot \sqrt{d_t}$

Input data: throw distance

Distance between the collision point and the final position of pedestrian hit

Vehicle-pedestrian collision

$$\boxed{V = 13{,}3\sqrt{d} - 4{,}5}$$



Main methods

Matemathical models

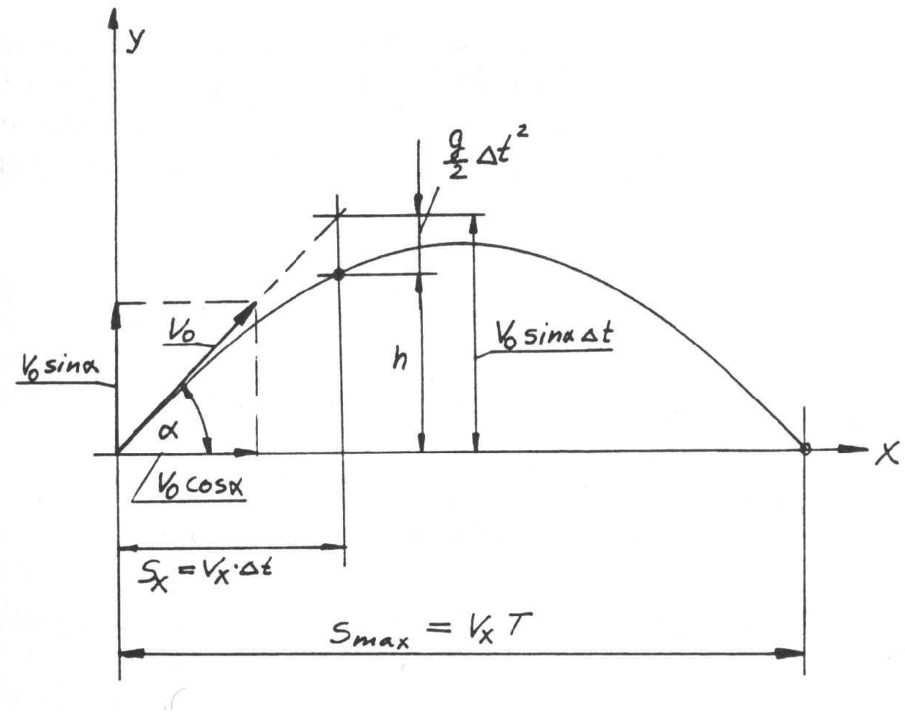
Results obtained consequently the evaluation of the physical model representing the real phenomenon

i.e. physical formulations

Vehicle-pedestrian collision

Main methods

Ballistic motion



$$V_0 = \frac{S_x \sqrt{g/2}}{\cos\alpha \sqrt{S_x \tan\alpha \pm h}}$$

h = height difference between launch and landing point
S_x= horizontal distance
α = starting angle

Reconstruction by FEM

Allow to:

Evaluate all parametres but…It is necessary to know:

→**Boundary condition …** both velocities and directions (or hypothesis)

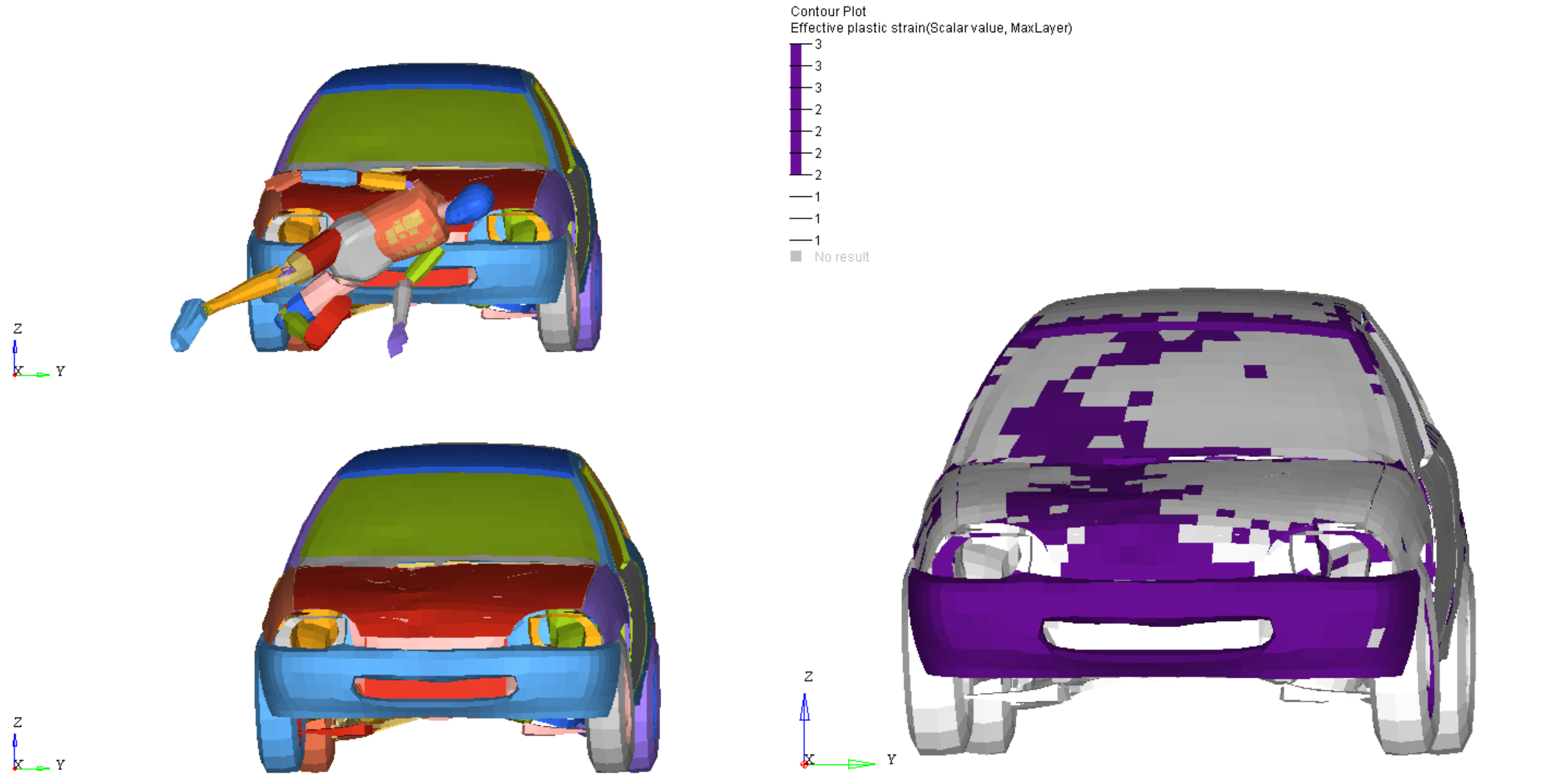
→For example

Reconstruction by FEM

Results:

Damages

Throw distance



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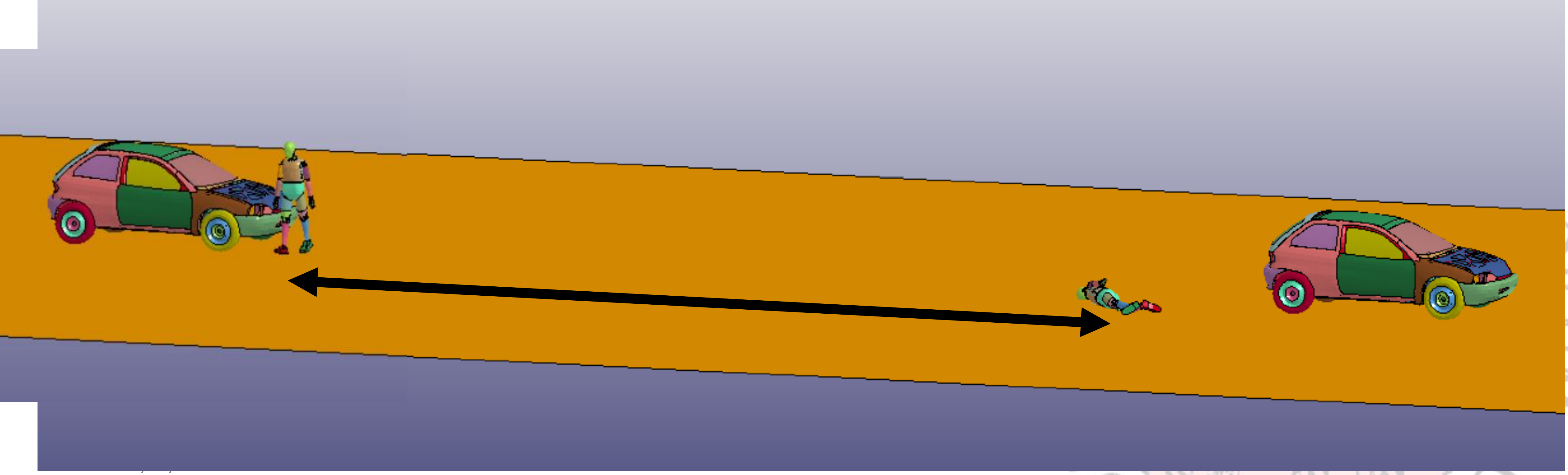
Reconstruction by FEM

Results:

Damages

Throw distance



Main methods

Between two (or more vehicle)

Conservation of momentum – 2 DoF

X and Y coordinates allow to define the position of the vehicle

$$m_1\bar{V}_1\cos(\bar{\theta}_1)+m_2\bar{V}_2\cos(\bar{\theta}_2)=m_1V_1\cos(\theta_1)+m_2V_2\cos(\theta_2)$$

$$m_1\bar{V}_1 sen(\bar{\theta}_1)+m_2\bar{V}_2 sen(\bar{\theta}_2)=m_1V_1 sen(\theta_1)+m_2V_2 sen(\theta_2)$$

Input: known parametres

$$\bar{V}_1,\ \bar{V}_2,\theta_1,\theta_2,\bar{\theta}_1,\bar{\theta}_2$$

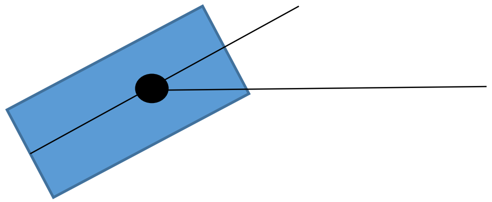
Results of the system

$$V_1 \text{ e } V_2$$

Main methods

Between two (or more vehicle)

Conservation of momentum – 3 DoF



X, Y and angle allow to define the position of the vehicle

8 different equations

Input: known parametres

Results of the system

$$V_1, V_2, \omega_1, \omega_2$$

When???

…when the problem can't be represented in 2 dimension

The main examples can be summarized follow:

- Vehicle rollover;
- Definition the position of the occupants;
- Collision with road restraint systems (definition of the energy dissipation)

- ..in the other cases the methodology can be applayed with an improve of computational cost if compared ofthe traditional methods.

When???

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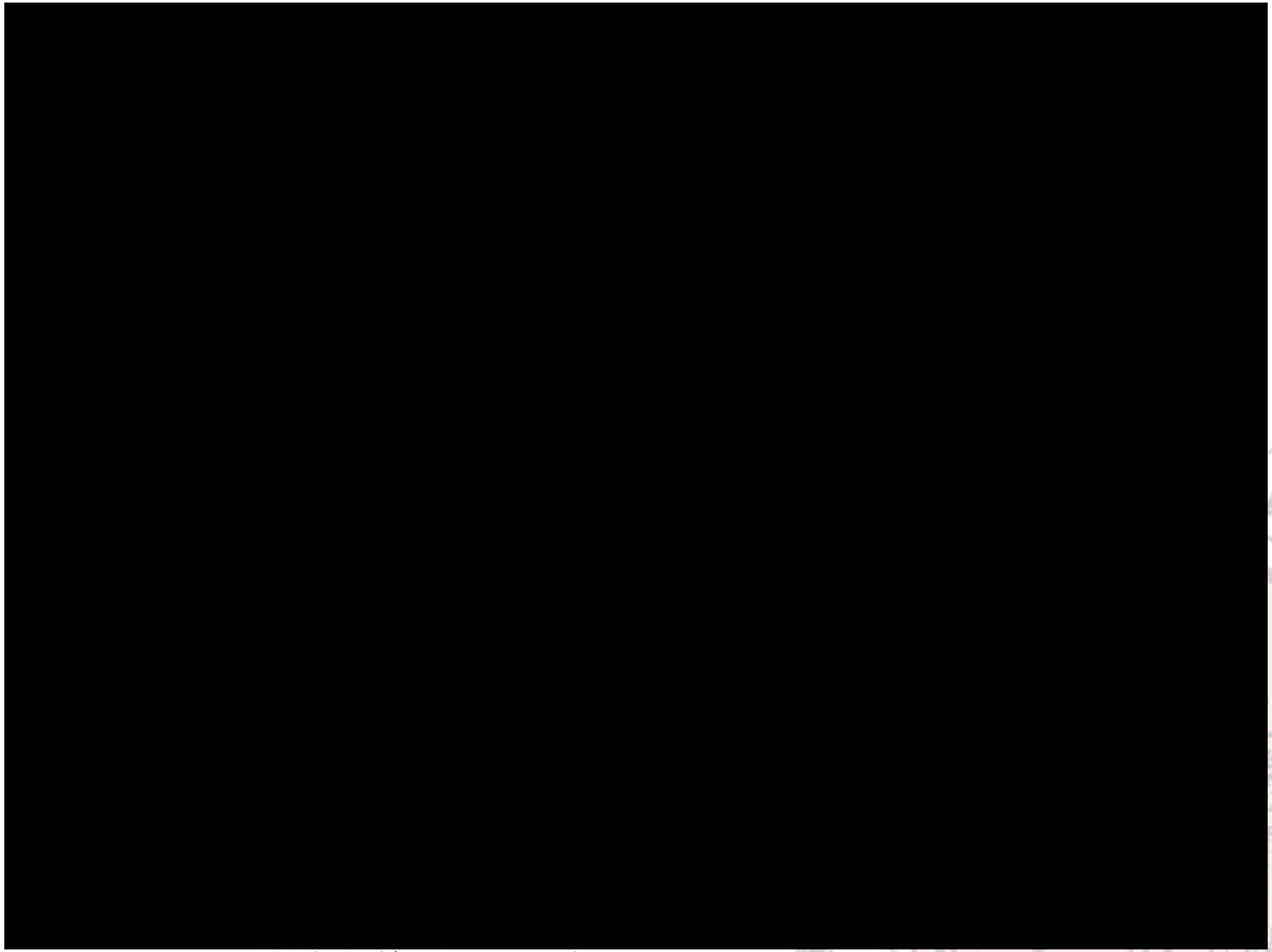
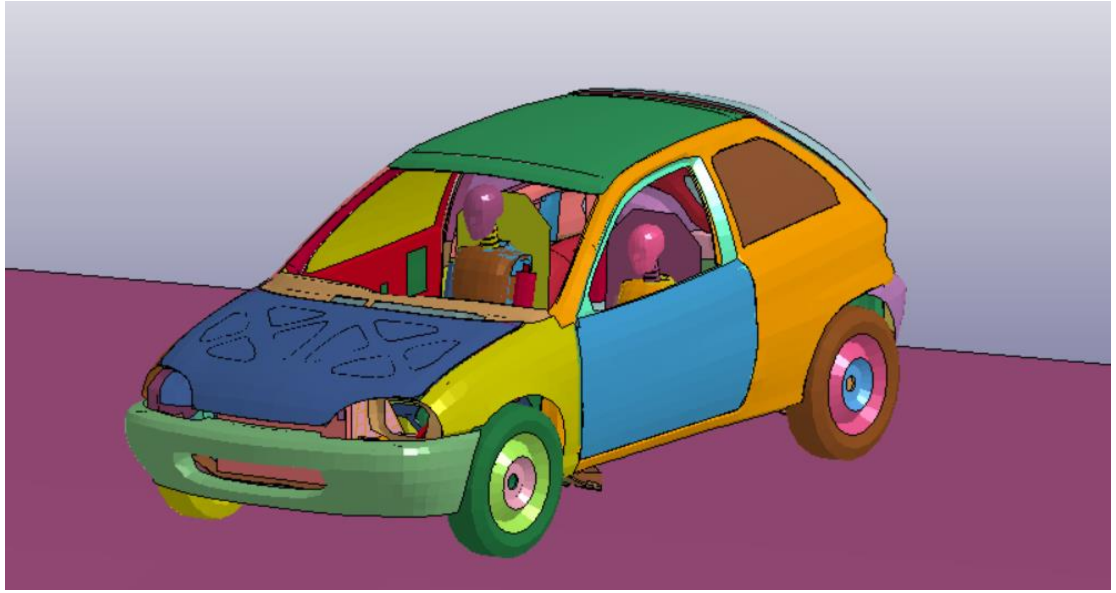
When???

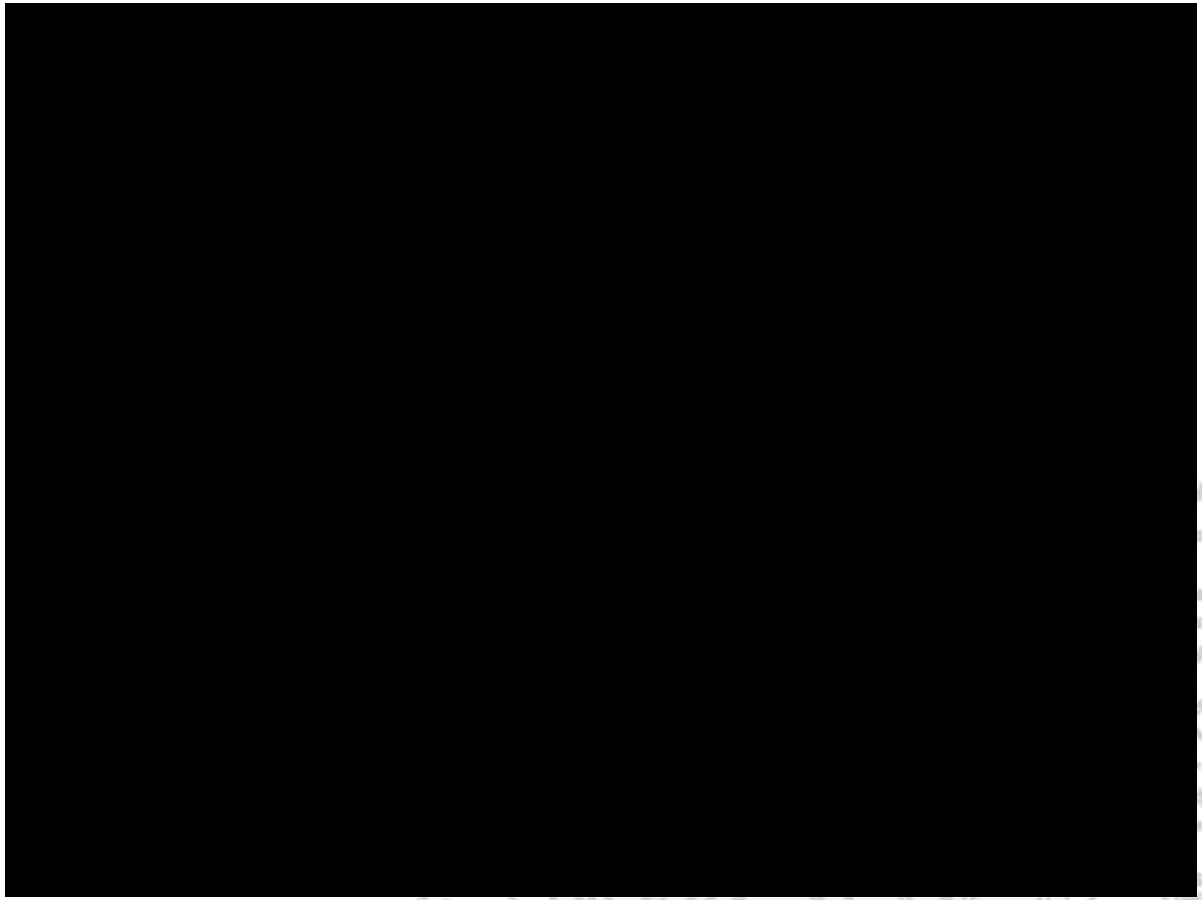
Rollover



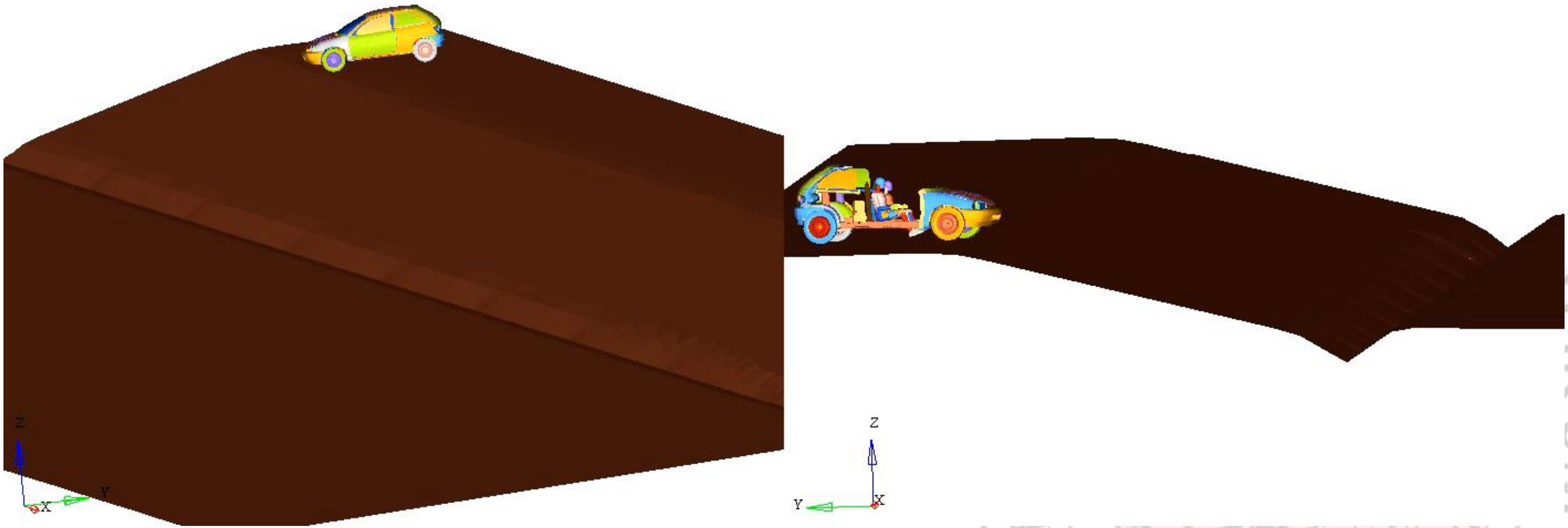
When???

Occupant' position



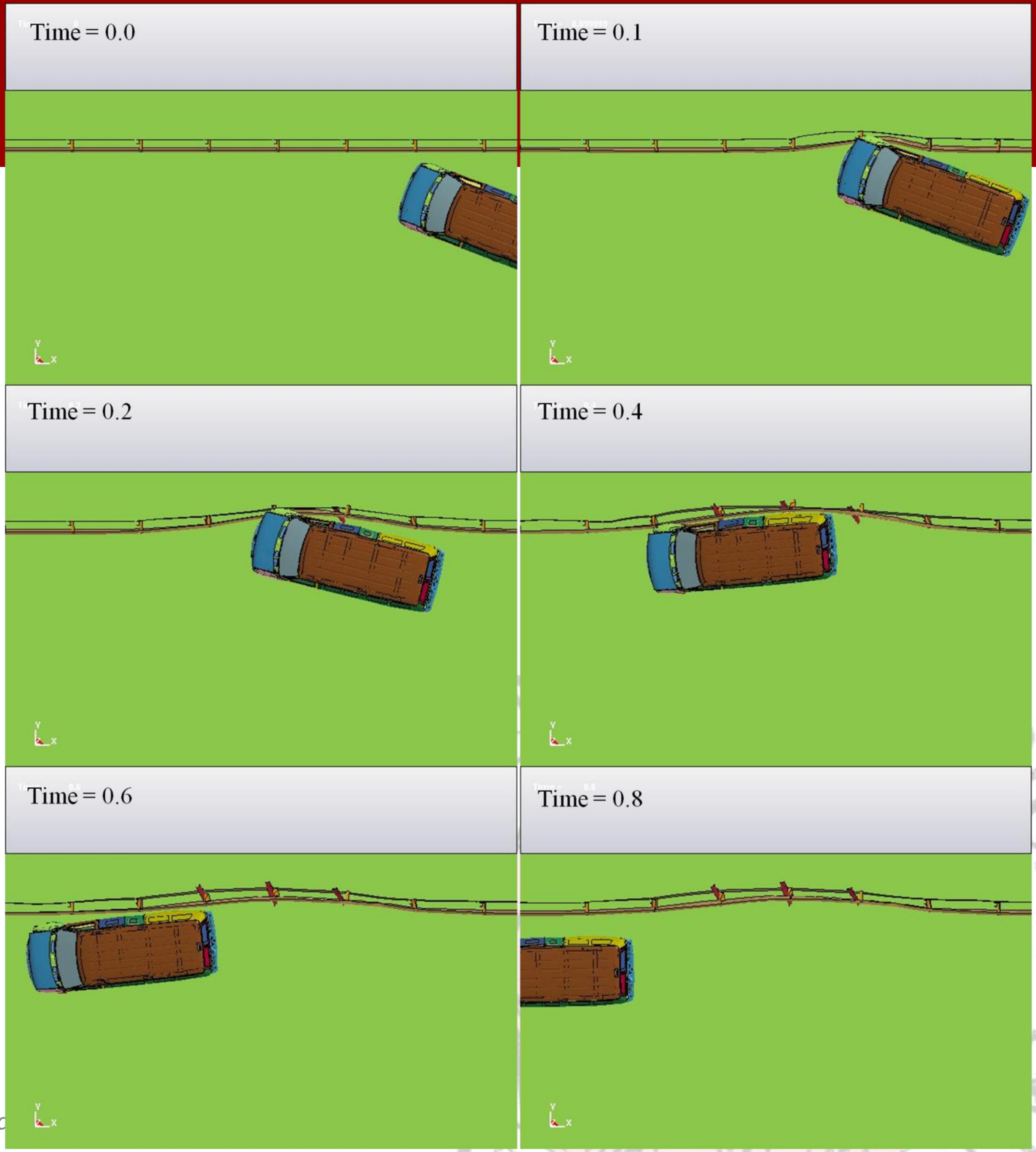


When???



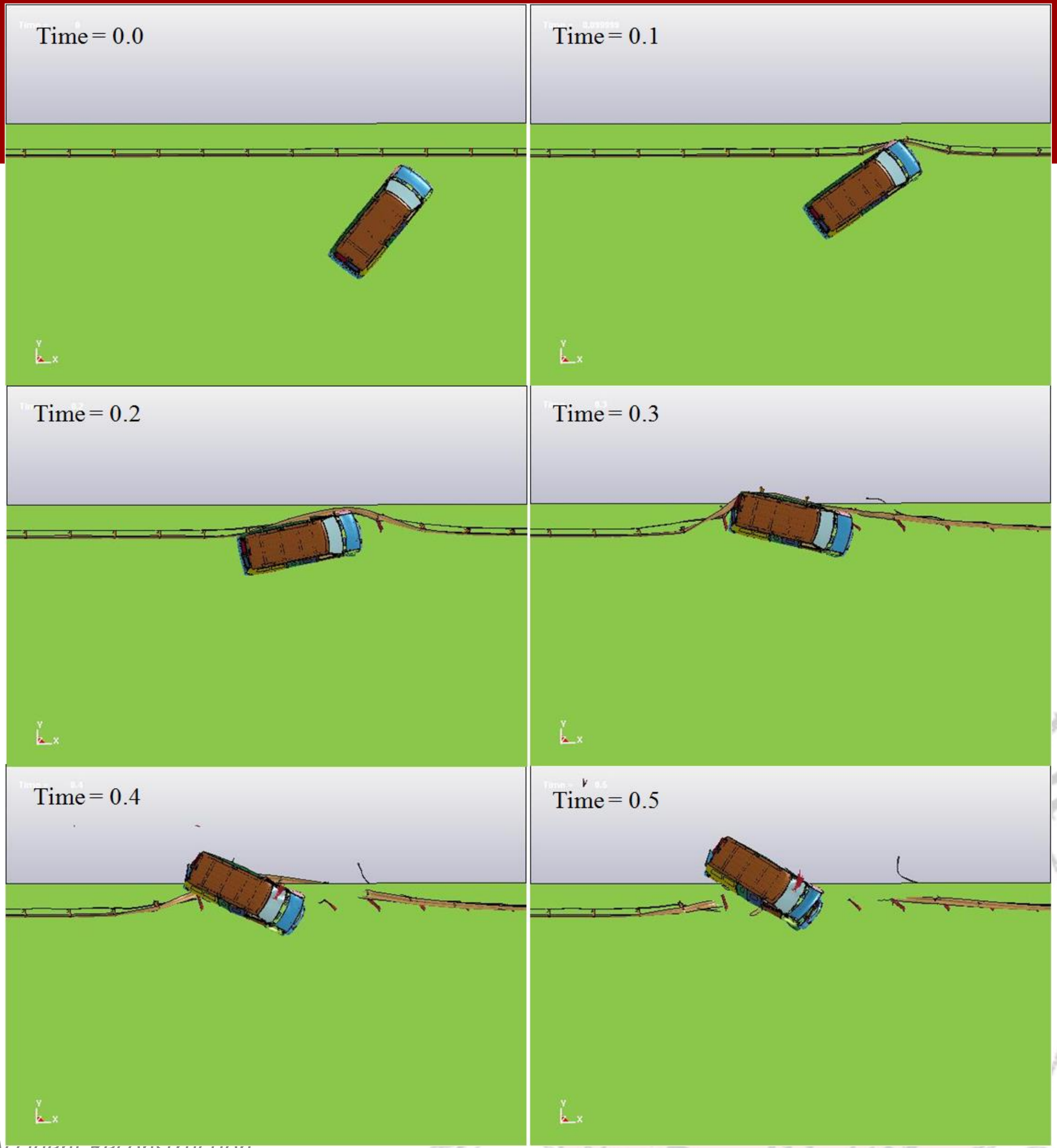
When???

Road restraint system collision



When???

Road restraint system collision



Severity of the collision