Risk Scenario Designs for Driving Simulator Experiments

Roja Ezzati Amini[1], Eva Michelaraki[2], Christos Katrakazas[2], Christelle Al Haddad[1], Bart De Vos[3], Ariane Cuenen[4], George Yannis[2], Tom Brijs[4], Constantinos Antoniou[1]

[2]Department of Transportation Planning and Engineering, National Technical University of Athens, Athens, Greece
[3]DriveSimSolutions, Diepenbeek, Belgium
[4]School for Transportation Sciences Transportation Research Institute UHasselt Diepenbeek, Belgium

[1]Department of Civil, Geo and Environmental Engineering

Chair of Transportation System Engineering

Technical University Munich

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Driving Simulator Experiments

iDREAMS

- Driving simulators have become widely used tools for examining the impact of driver behaviour with respect to individual driver differences or road layout by offering a **safe, realistic, and controlled** environment.

- Driving simulators along with the corresponding equipment and technologies (e.g. dash cameras, wearables, steering wheel and heart rate monitoring systems, mobile phone applications) have the potential to identify **physiological driver state** indicators and **driving performance characteristics**.

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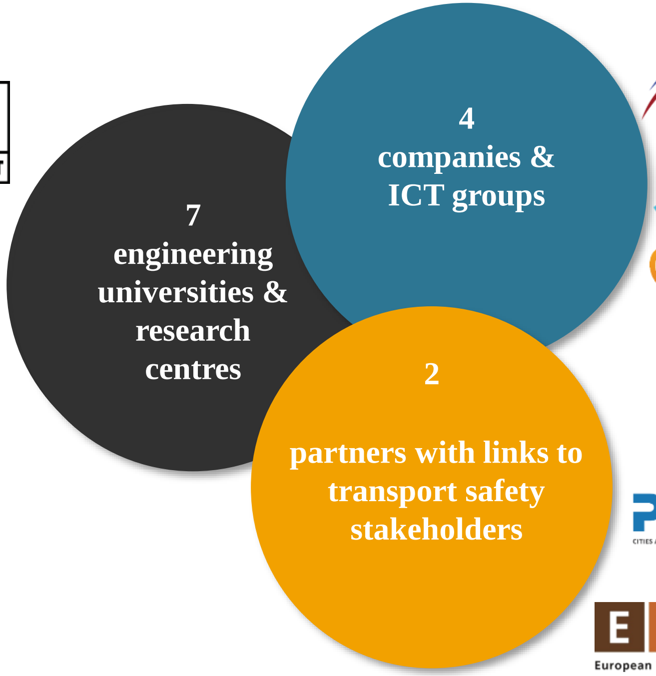
i-DREAMS Project

- Within this context, the i-DREAMS project aims to optimally exploit these opportunities in order to define, develop, test and validate a context-aware safety envelope for driving in a **‘Safety Tolerance Zone’ (STZ)**.



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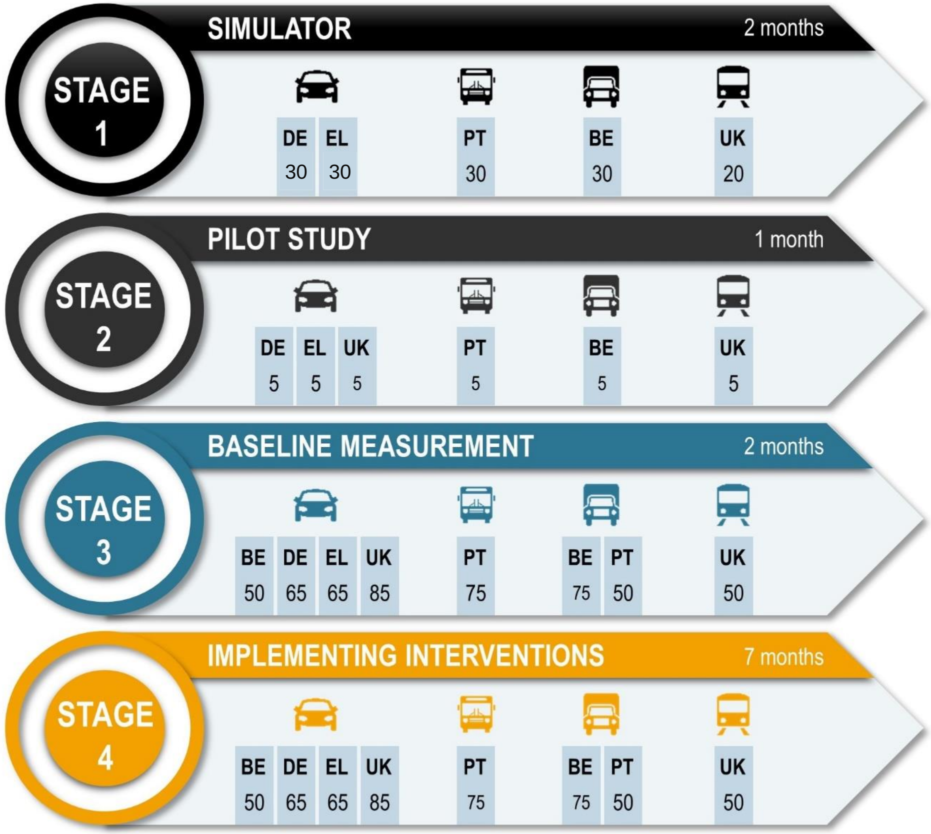
i-DREAMS Project: 5-Country 4-Stage study

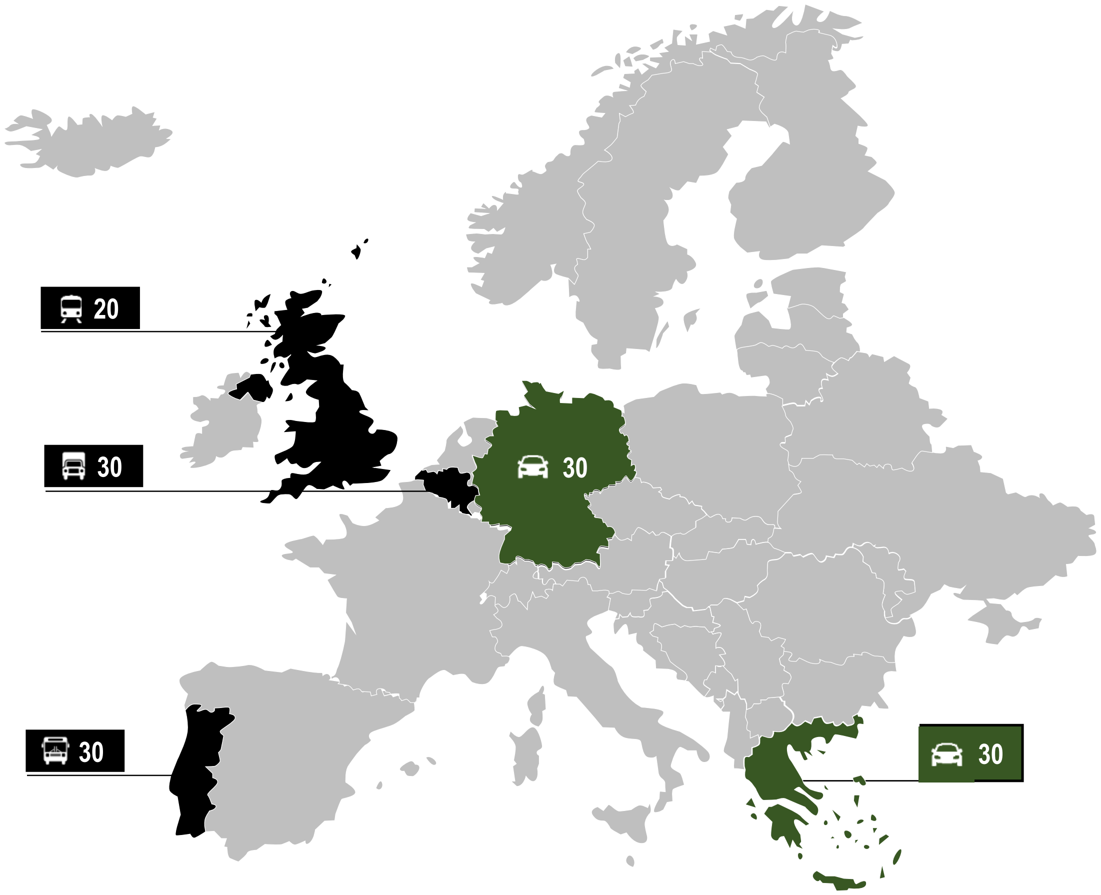


Number of vehicles per country to be tested
Total duration: 12 months

i-DREAMS Project: Driving Simulator Experiments

STAGE 1

SIMULATOR
2 months



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i-DREAMS Project: Key Output

- The key output of the i-DREAMS project is an integrated set of **monitoring and communication tools** for intervention and support, including in-vehicle assistance, feedback, and notification tools, as well as a gamified platform for self-determined goal setting.

Risk Scenarios Examination

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The content of the simulator scenarios will focus on specific target risks. To reach the scope of the i-DREAMS project, several risk factors will be measured for cars, including:

- **Tailgating,**
- **Illegal overtaking,**
- **VRU collision,**

And as additional driving conditions:

- **Driver distraction,**
- **Adverse weather conditions.**

Driving Simulator Experiment - Sessions

The selected risk factors were used for designing the scenarios for the simulator trials. The risk factors will be examined through three sessions:

- **The first session (drive-1: ~15min):** monitoring drive without interventions,
- **The second session (drive-2: ~15min):** an intervention drive with fixed timing warnings,
- **The third session (drive-3: ~15min):** an intervention drive with interventions based on task completion capability including the risky conditions.

Each risk factor is captured by several separate events.

Driving Simulator Experiment - NTUA

- In Greece, the driving simulator experiment will take place at the Department of Transportation Planning and Engineering of the National Technical University of Athens (NTUA) using the **FOERST Driving Simulator FPF**.

Driving Simulator Experiment - TUM

- The experiment in Germany will be held at the chair of Transportation Systems Engineering of the Technical University of Munich using a custom simulator developed by DriveSimSolutions (DSS). The simulator uses fully customizable **STISIM Drive 3 software**.

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Driving Simulator Experiment - Equipment

- For the experiment in Germany, the gaze data of participants during all three sessions will be collected using **Tobii Pro Glasses 2**.
- Tobii Pro Glasses 2 is equipped with two cameras for using Tobii's 3D eye model to ensure automatic slippage compensation and make it possible to **run eye tracking studies in dynamic environments**.

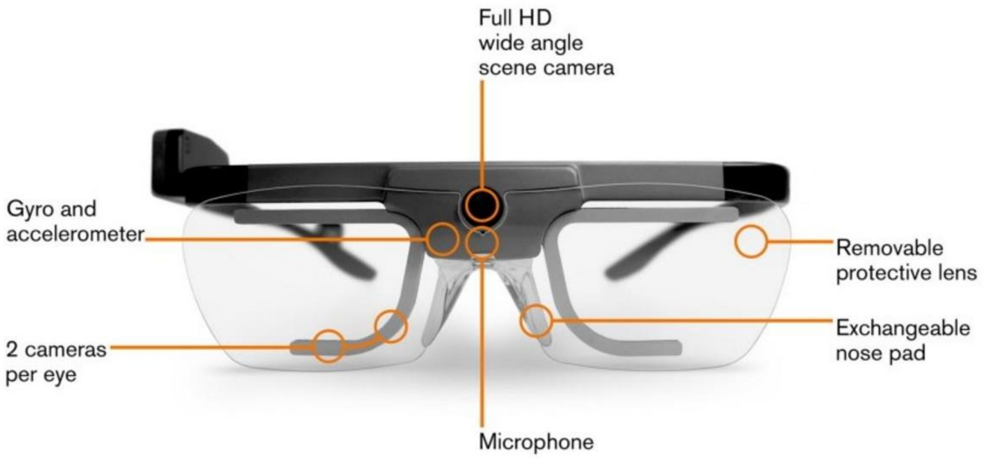

Fig.1. Tobii Pro Glasses 2 (Source: manufacturer’s website)

Driving Simulator Experiment - Equipment

- In both Greece and Germany, the biometric data of participants (e.g., heart rate) will be collected during all three sessions using **PulseOn Wearable Tracker**.
- Alternatively, **CardioWheel** will be used to transmit the biometric data acquiring the electrocardiogram (ECG) from the driver’s hands to detect biometric identity recognition.

Fig.2. Equipment for biometric data collection (Source: Carioid)

Application of Safety Interventions

During the intervention scenarios, based on the personalized identification of episodes of successful and degraded vehicle operation with respect to the STZ, customized interventions will be proposed. These include **real-time and in-vehicle warnings** (e.g., audio, visual, haptic) in safety-critical situations (i.e., close to the boundary of the STZ) and with respect to:

- Lane departure warning
- Headway warning
- Forward collision warning
- Speeding
- Pedestrian collision warning
- Weather forecast
- Mobile phone distraction warning

Application of Safety Interventions

The two intervention scenarios are designed:

- **First intervention scenario**: there will be a focus on fixed timing thresholds (audio and visual in-vehicle warnings),

- **Second intervention scenario**: to assess the impact of certain conditions on driving behaviour (i.e., distraction, adverse weather conditions) and by optimizing the intervention thresholds (by using dynamic or time-variable thresholds).

Development of Risky Scenarios

The experimental scenarios will focus on tailgating, illegal overtaking and VRU collision. The variables of interest for the different risk factors are:

- For **tailgating**: time headway, distance headway, forward collision avoidance.
- For **illegal overtaking**: average speed, standard deviation of lateral acceleration and position, steering variability, signal use.
- For **VRU collision**: detection time, reaction time, steering variability, and brake reaction.

Development of Risky Scenarios

For the additional conditions investigated in drive-3 scenario, following variables are of interest:

- For **distraction**: mobile phone use, attention.
- For **adverse weather condition**: time headway, distance headway, time-to-collision, reaction time.

Risk factors will be investigated through a series of risky events during the drive-1, drive-2, and drive-3 scenarios.

Development of Risky Scenarios

Risk factors investigated in **Germany**:

- **Tailgating**
- **VRU collision**
- **Distraction**

Risk factors investigated in **Greece**:

- **Tailgating**
- **Illegal overtaking**
- **Adverse weather conditions**

Development of Risky Scenarios - Tailgating (TUM-NTUA)

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To investigate **tailgating**, there will be a lead vehicle in front of the driver, to measure following behaviour (Fig. 3). car_1 refers to the driver and car_2 refers to the car driving in front of the driver within all risky events:

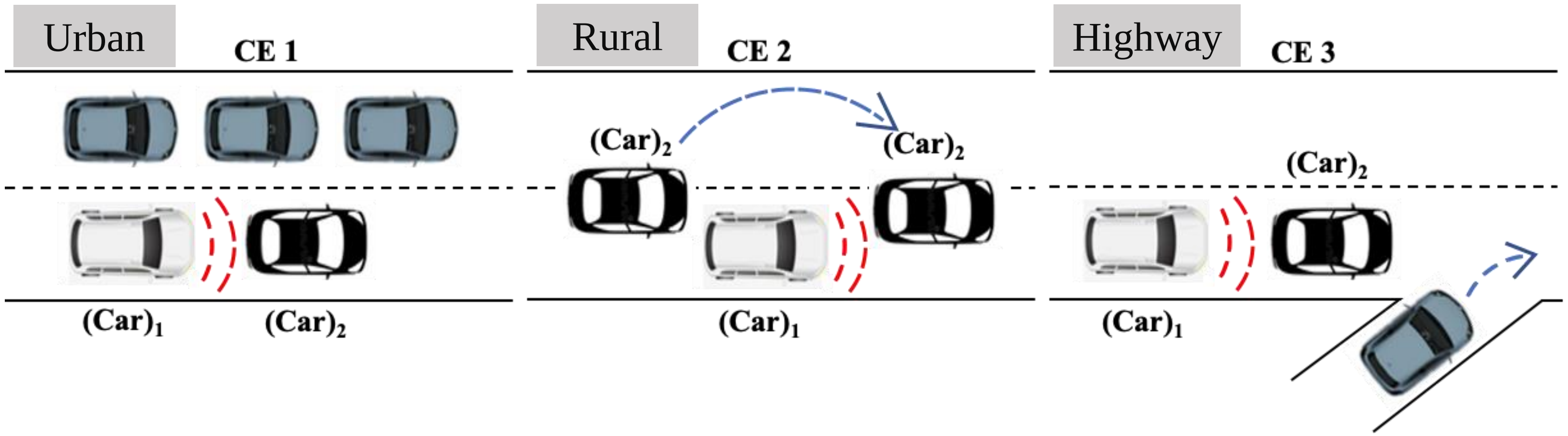

Fig. 3. A schematic overview of risky events of tailgating

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To investigate **illegal overtaking**, risky events will be included whereby an illegal overtaking manoeuvre is provoked as follows (Fig. 4):

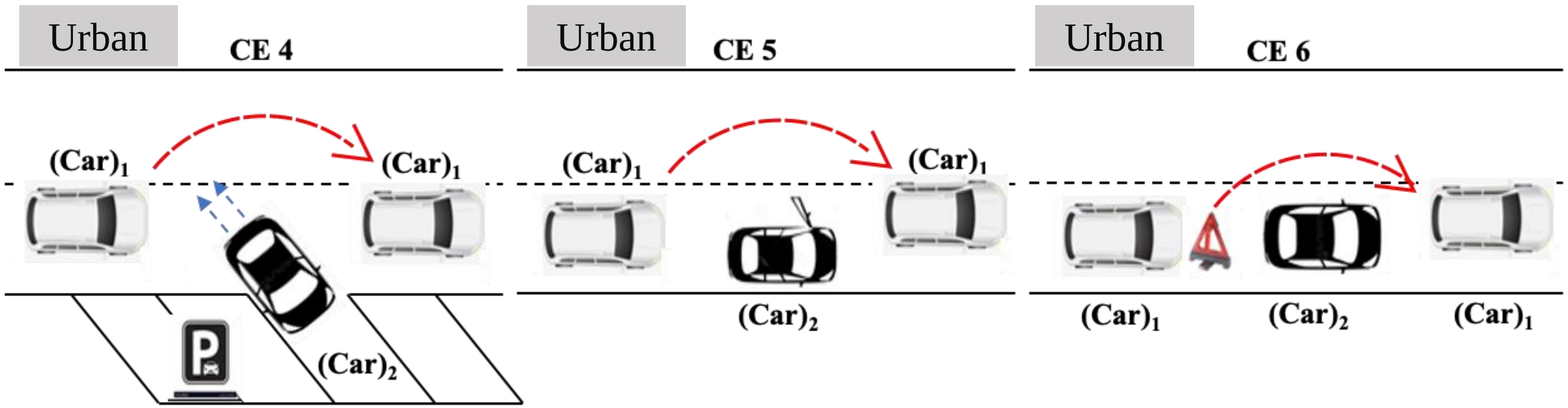

Fig. 4. A schematic overview of risky events of illegal overtaking

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Development of Risky Scenarios – VRU Collision (TUM)

The **VRU collision** is investigated by triggering three crash prone events between pedestrian and vehicle (Fig. 5):

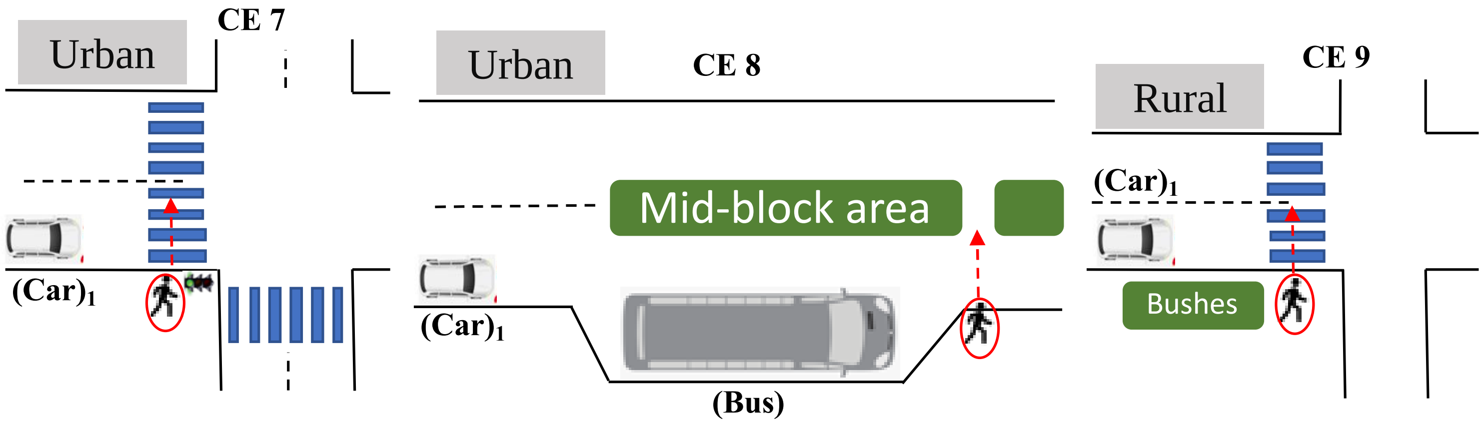

Fig.5. A schematic overview of risky events of VRU collision

Development of Risky Scenarios – Drive-3

- **Driver distraction and adverse weather conditions** (i.e., rain and fog) will be tested during the drive-3 scenario for all participants.
- In total, eight text messages at two levels of simple and complex will be sent by the operator to the participants during the **drive-3 trial**.

Tab.1. Example of distraction design in Drive-3 scenario - TUM

Distance (m)	CE	Distraction	Complexity Level	Text Message (TM)
13150	CE 7	Reading TM	Simple	"50% discount on online orders! Today only!"
14100	No event	Reading and replying TM	Complex	"What are two things you enjoy doing the most?"
14700-15000	CE 1	Reading and replying TM	Complex	"27+32=?"

Development of Risky Scenarios

- Sections are used to **counterbalance between scenarios**.

- Several **‘neutral’ events** (filler pieces) are embedded creating a realistic driving scenario and minimising confounding effects (e.g., order / learning effects).

- Three scenarios are designed using similar components, but with different order of events to **minimise learning effects**.

- A **Balanced Latin square method** is applied to equally distribute the scenarios between the participants.

Development of Risky Scenarios

- Examples of the designed CE and precursor event (PE) in the **drive-1 scenario**:

Fig.6. A screenshot of CE7 in the drive-1 scenario – Germany

Fig.7. A screenshot of PE in the drive-1 scenario – Germany

Development of Risky Scenarios

- Eye tracker recording of the designed CE9 in the **drive-3 scenario** in Germany during the pilot experiment:

Considerations and Challenges

- **Simulation sickness** of participants and dropout rates need to be limited during the span of the experimental procedures, to obtain consistent results for all risk factors.

- Using different simulators in Germany and Greece may result in data with different resolution and quality and, consequently, in contradicting results. Therefore, analyses methods that can **accommodate different data resolutions**, as well as cultural and population characteristics are going to be investigated.

- Finally, the **effect of the COVID-19 pandemic** on the successful completion of the experiments is also a crucial factor that should be proactively contemplated.

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