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D5.2

Description of the driving simulator experiment for identifying safety tolerance zones and the performance of in-vehicle interventions

Safe tolerance zone calculation and interventions for driver-vehicle-environment interactions under challenging conditions

iDREAMS

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Glossary and abbreviations

Word / Abbreviation	Description
ADAS	Advanced driver-assistance systems
CAN	Controller Area Network
DH	Distance headway
DT	Detection time
ECG	Electrocardiogram
ESS	Epworth Sleepiness Scale
FCA	Forward Collision Avoidance
HIL	Hardware-in-the-loop
KSS	Karolinska Sleepiness Scale
LA	Lateral acceleration
LP	Lateral position
OBD-II	On-board diagnostics protocol Version 2
OEM	Original equipment manufacturer
PPG	Photoplethysmography
PWM	Pulse width modulation
RT	Reaction time
SDLA	Standard deviation of longitudinal acceleration
SDLP	Standard deviation of lateral position
SIL	Software-in-the-loop
STZ	Safety Tolerance Zone
SU	Signal use
SV	Steering variability
TH	Time headway
TTC	Time to collision
VRU	Vulnerable road user
VSS	Vehicle Speed Signal

Executive Summary

The i-DREAMS project aims to establish a framework for the definition, development, testing and validation of a context-aware safety envelope for driving called the “Safety Tolerance Zone’. Taking into account driver background factors and real-time risk indicators associated with the driving performance as well as the driver state and driving task complexity indicators, a continuous real-time assessment will be made to monitor and determine if a driver is within acceptable boundaries of safe operation. Moreover, safety-oriented interventions will be developed to inform or warn the driver in real-time as well as on an aggregated level after driving, through an app-and web-based gamification coaching platform (post-trip intervention).

The conceptual framework of the i-DREAMS platform integrates aspects of monitoring (such as context, operator, vehicle, task complexity and coping capacity), to develop a Safety Tolerance Zone for driving. In-vehicle interventions and post-trip interventions will aim to keep the drivers within the Safety Tolerance Zone as well as provide feedback to the driver. This conceptual framework will be tested in simulator studies and three stages of field trials in Belgium, Greece, Germany, Portugal and the United Kingdom with over 600 participants representing car, bus, truck and tram and train drivers.

The aim of this deliverable is to elaborate a detailed design for each of the simulator trials, based on design recommendations and specifications that were presented previously in D3.4: Experimental Protocol. The two main goals of the simulator trials are to pilot test i-DREAMS technology and to validate the effectiveness of the real-time interventions (i.e., in-vehicle warnings). By including these simulator trials in the i-DREAMS development cycle before (large scale) on-road field trials, potential issues with technology or effectiveness of the real-time interventions can be identified and solved and acceptability and user experience aspects investigated. Driver feedback and experiment results can be used as a first benchmark and to further optimize the i-DREAMS system.

To achieve this, multiple simulator trials in five countries will be performed for different driving modes (Belgium – Truck, Germany – Car, Greece – Car, Portugal – Bus, United Kingdom – Tram & Train). Five different simulators will be used for these trials. Two simulators, a car simulator and a heavy vehicle simulator were designed and built for trials in Belgium, Germany and Portugal. In Greece, another car simulator will be used, while in the United Kingdom the trials will take place in professional train and tram simulators that were built for driver training. For all these simulators, an architecture was developed that allows the simulators to interface with i-DREAMS equipment in real-time. This was done in such a way that key equipment such as Mobileye, gateway, CardioWheel and a real-time intervention device for display of the warnings is almost completely interchangeable between simulator and vehicle to avoid having to develop a completely separate i-DREAMS system for the simulators only.

A generic design for all simulator trials was made to ensure consistency between the different trials, taking into account the specifications that were defined in D3.4: Sample size of 30 participants per mode, the experimental design will be fractional factorial and within subject, one session will take no longer than two hours and consists out of two practice drives and three experimental drives. During the first practice drive (5 min) the participant gets the chance to familiarize with the simulator, during the second practice drive (5 min) the participant will be subjected to several events and will be asked to perform some tasks. The first experimental drive will be used as a monitoring scenario to get a benchmark of driving behaviour without i-DREAMS. After receiving information about the technology and real-time interventions, i-DREAMS technology will be turned on for the second and third experimental drive. The third experimental drive is used to widen the scope of the simulator trials and introduce a condition (sleepiness, distraction, weather) that would change the timing of the real-time interventions.

Before, during and after the session, the participant will be asked to fill out questionnaires that poll for demographic information and technology acceptance.

For each trial, a three step process was followed. As the first step, general information such as research (sub)goals was collected to provide an overview of what could be investigated. The second step was exploring how these research goals could be achieved, this included identifying risk factors (e.g., tailgating, speeding, etc.) that are relevant for each respective mode and assigning one or two risk factors and an additional condition (e.g., distraction, weather, sleepiness) to each simulator trial. This was done in such a way that when combined, the simulator trials cover all the risk factors that are most relevant within i-DREAMS. An overview of the different trials and distribution of risk factors is given in Table 1. As step three, a detailed description for each drive that will be used during the sessions for all trials was created. Each drive will include 3 dangerous events of which the order will be different between participants to decrease the possibility of order effects, other road users that trigger the dangerous events will be randomized to reduce learning effects. Additionally, masking events and filler pieces will also be used. Variables of interest that can be collected in the simulator were defined for each trial, they mostly depend on the risk factor that is to be investigated. Furthermore, a detailed description of roadway environment and dangerous events was created.

Table 1: Overview of simulator trials and distribution of risk factors

Country	**Mode**	**Participants**	**Risk Factors**	**Condition**
Belgium	Truck	30	Tailgating, speeding	Sleepiness
Germany	Car	30	Tailgating, VRU	Distraction
Greece	Car	30	Tailgating, Overtaking	Weather
Portugal	Bus (coach)	15	Tailgating, Overtaking	Distraction
Portugal	Bus (Bus)	15	Tailgating, VRU	Distraction
United Kingdom	Rail (Tram)	15	VRU, speeding	Sleepiness
United Kingdom	Rail (Train)	15	Speeding, signal passed at danger	Sleepiness

These detailed descriptions for each trial, session and drive will be used as guidelines in the preparation of and during the simulator trials. Currently, the simulator drives are being programmed and technical preparations are being made according the information provided by this deliverable.

The results of the simulator trials will be presented at a later stage during the project in D7.2: Effectiveness evaluation of the interventions.

1 Introduction

1.1 About the project

The overall objective of the i-DREAMS project is to setup a framework for the definition, development, testing and validation of a context-aware safety envelope for driving ('Safety Tolerance Zone'), within a smart Driver, Vehicle & Environment Assessment and Monitoring System (i-DREAMS). Taking into account driver background factors and real-time risk indicators associated with the driving performance as well as the driver state and driving task complexity indicators, a continuous real-time assessment will be made to monitor and determine if a driver is within acceptable boundaries of safe operation. Moreover, safety-oriented interventions will be developed to inform or warn the driver real-time in an effective way as well as on an aggregated level after driving through an app- and web-based gamified coaching platform. Figure 1 summarises the conceptual framework, which will be tested in a simulator study and three stages of on-road trials in Belgium, Germany, Greece, Portugal and the United Kingdom with a total of 600 participants representing car driver, bus driver, truck drivers and rail (tram + train) drivers.

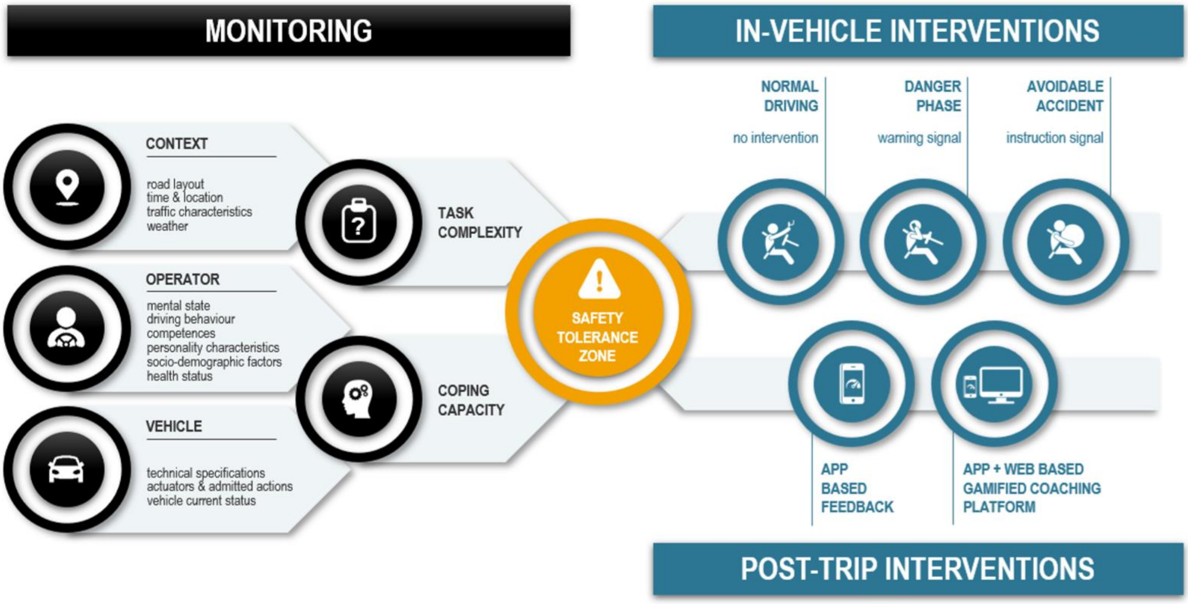

Figure 1: Conceptual framework of the i-DREAMS platform.

The key output of the project will be an integrated set of monitoring and communication tools for intervention and support, including e.g., in-vehicle assistance and feedback and notification tools as well as a gamified platform for self-determined goal setting working with incentive schemes, training and community building tools. Examples of the technology which are likely to be implemented include a context aware road monitoring system (Mobileye), OBD-II data logger (or other telematics unit if available in the vehicle), dash camera and electrocardiogram (ECG) or photoplethysmography (PPG) technology (CardioWheel/ Wristband), all except the CardioWheel/ Wristband and the gateway (for sensor data fusion and the triggering of the real-time interventions in the vehicle) will be commercially available off the shelf products.

1.2 Deliverable overview and report structure

Within the i-DREAMS project there are five technical work areas: state of the art (monitoring and interventions), Methodological development, Technical development, Trials and Analysis. This deliverable describes the simulator experiments within the area of Trials.

This deliverable (D5.2) follows directly on Methodological development and the guidelines for driving simulator trials that were outlined in Deliverable 3.4: Experimental Protocol (Pilkington-Cheney et al., 2020). The current Deliverable 5.2 describes in detail the different simulator trials within the i-DREAMS project. It is meant to be used as a road book during preparations for the trials and describes preparations that were already made at the time of writing. This includes the design of the different simulator drives and technical developments that are required to pilot test and evaluate a prototype version of the i-DREAMS system. Results of the simulator trial will be presented in Deliverable 7.2: Effectiveness evaluation of the interventions.

Section 2, Purpose of driving simulator trials in i-DREAMS, focusses on usage of simulation within the automotive (and ADAS) development cycle, this will be related to the specific case of the i-DREAMS development cycle. The link between the simulator trials and the on-road field trials will also be discussed.

Technology that will be used for the simulator trials is described in section 3, **Overview of technology for the driving simulator trials.** This includes a short description of the different driving simulators that will be used for all transport modes. Technological developments that have been made in preparation for the simulator are presented, together with schematic overviews of the different simulator architectures that are needed to collect data from the different simulators.

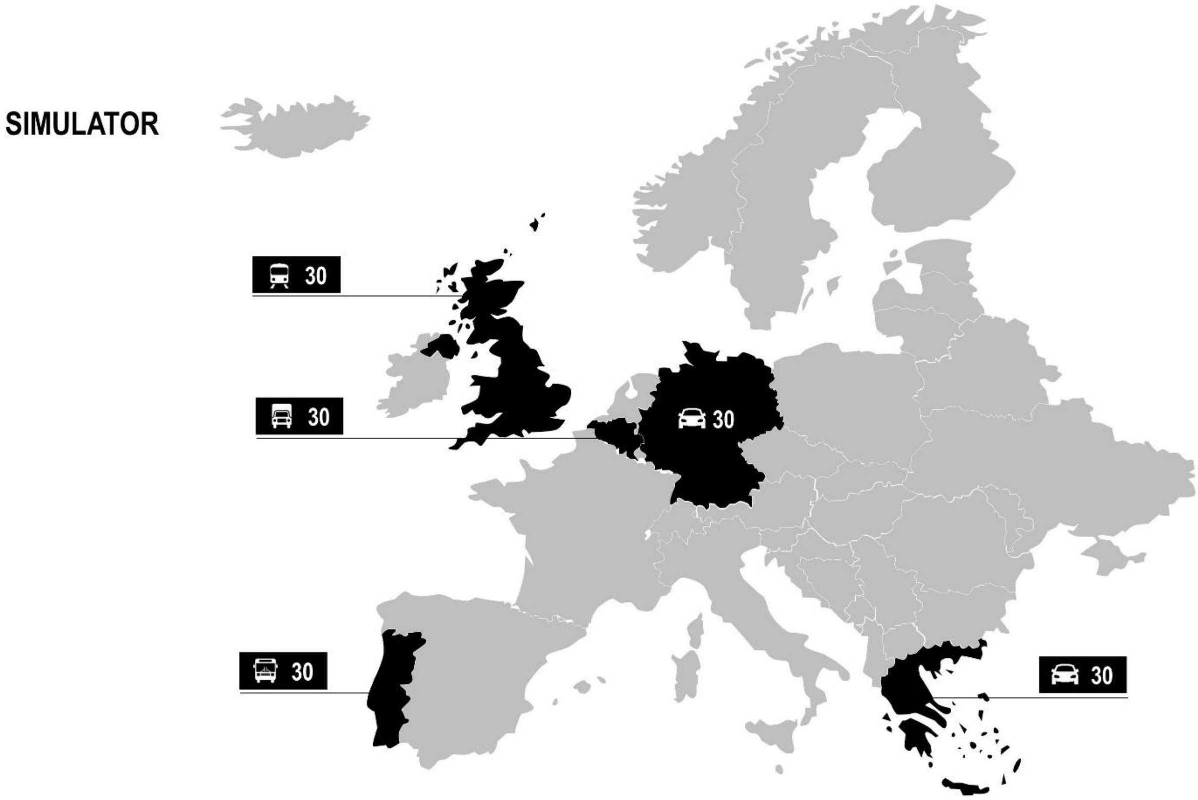

Figure 2: Map highlighting the location and target participant numbers for the i-DREAMS simulator trials

i-DREAMS simulator trials will be performed in five countries, for four modes, an overview of these countries, modes and participant numbers is shown in Figure 2. Section 4, **Overview of driving simulator trials in i-DREAMS,** describes in detail the design of the different trials. First, a generic design that ensures consistency between the different simulator trials is presented. This is followed by a description of methods for monitoring and intervening during the simulator trials. The general procedure for each simulation session (consisting of multiple drivers per participant) will also be presented. Based on objectives for the simulator trials, a strategy is elaborated to achieve the desired results, and variables of interest are identified. This includes a description of how simulator drives are built and structured to focus on the desired dangerous events and how conditions can be manipulated to evaluate the variable nature of real-time interventions (i.e., warnings). Finally, the elaborate strategy will be applied to the five simulator trials in a detailed description of each trial.

1.3 The COVID-19 Pandemic

At the time of writing this deliverable, the COVID-19 pandemic is ongoing. Therefore, it is important to recognise that this situation may have potential implications for the i-DREAMS project. It is possible there will be delays to the beginning of the simulator trials and potential restrictions in terms of testing with human participants and social distancing measures. This may be in the form of delays in ethical approval for work with human participants, restrictions in visiting external simulator sites, or delays in recruitment. Additional risk assessments will likely be required to ensure that the experiments and the trials are conducted in a safe manner. The plans and timelines here do not currently take into account potential delays caused by the pandemic, as currently the full extent of its impact cannot be predicted. Instead, what is presented here is the planned case intended by the project. It may be, as a result of this situation there are changes to be made to the plans and protocols outlined in this deliverable, for example extended risk assessments and ethics submissions and movement of start and end date of the simulator trials. This will be updated in future deliverables.

2 Purpose of driving simulator trials in i-DREAMS

2.1 Driving simulation in the ADAS development cycle

Simulation technologies are an integral part of the automotive development cycle throughout different development stages and for a wide array of applications. The main reasons why simulation is used in product development are that it has the potential of reducing development time, reducing development costs, and improving the final design. This is achieved by the possibility to replicate highly controllable conditions that allow to make design choices early in the development cycle, based on rapid evaluation of multiple design concepts. Simulation, in most cases, effectively reduces the need for (expensive) prototyping.

In the context of ADAS development there are different types of vehicle simulation, which can be distinguished by the level of integration (software, hardware, and driver). All these types of simulation are built upon a physical simulation model that represents the vehicle. The complexity of this model can vary and is usually based on specific research requirements and available resources. The vehicle model is essentially a set of mathematical equations which translates a set of external inputs (i.e., throttle pedal position) and input conditions (i.e., starting velocity) to a set of output conditions for a given time-frame. By using the output conditions from the previous time-frame as input conditions for the next time-frame, a loop is created which can be used to describe transient vehicle conditions in time.

It is possible to include specific control software (Traction Control, Stability Control…) in the simulation loop to create software-in-the-loop simulation (SIL). For the application of ADAS development, this type of simulation can be used early in the development cycle, without having to develop, build and implement any specialized hardware. SIL simulation also has the advantage that it is possible to generate and control conditions that are relevant to the specific control algorithm. SIL simulation creates a platform for software development where custom algorithms can rapidly be tested, validated and debugged.

Later in the development cycle, hardware can also be included in the simulation loop to create hardware-in-the-loop simulation (HIL). HIL simulation is useful to test and validate controllers, sensors, actuators, interfaces or even complete hardware systems.

By including a human driver in the simulation loop, driver-in-the-loop simulation (DIL) is created, also known as driving simulation. For ADAS system development it is very important to understand interaction between human and the ADAS-system and how the ADAS system might influence human behaviour. Driving simulation offers an ideal platform for initial testing of human-machine interaction. ADAS systems often aim to operate on the limit, or even beyond the limit of safety, meaning that some of the operating conditions for ADAS systems are impossible to recreate in the real world because of ethical reasons (e.g., injury risk) or because the results could possibly lead to the destruction of costly equipment.

2.2 Driving simulation in the i-DREAMS project

The i-DREAMS system, as opposed to many other ADAS systems will not actively intervene on the vehicle level, instead it aims to intervene only on the driver level. The two methods to intervene are through real-time interventions (i.e., in-vehicle warnings) and post-trip interventions. The real-time interventions are presented to the driver during the driving task itself with the purpose of having an instantaneous effect on driving behaviour in order to avoid dangerous situations (i.e., to keep the driver within the area of ‘normal driving’ of the Safety Tolerance Zone[1]). The post-trip interventions are not given to the driver during the driving task,

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[1] See section 3.2 in Deliverable 3.1 for more info on the different stages (i.e., normal, danger, avoidable accident) of the Safety Tolerance Zone

but instead aim to change driving behaviour on the long term. This aspect of long-term behavioural change makes the post-trip interventions less suitable for testing and validation with driving simulation.

Driving simulation within the i-DREAMS project will therefore focus on the real-time interventions. There are two main reasons why driving simulation will be used, both in preparation of the on-road field trials. Firstly, to pilot test the i-DREAMS system and equipment and secondly to examine the effect of the i-DREAMS real-time interventions, triggered by the i-DREAMS algorithm on driving behaviour. This means that the driving simulation study within the project will be a combination of hardware-in-the-loop (HIL) and driver-in-the-loop (DIL) simulation. Because the i-DREAMS system only intervenes on the driver-level and not on the vehicle-level, it is not required to integrate i-DREAMS control software in the simulation loop. Instead, i-DREAMS software will be implemented directly on the i-DREAMS hardware.

The driving simulator trials will be the first real test for the part of the i-DREAMS algorithm that triggers real-time interventions (in-vehicle warnings) and how simulator participants react to them. I-DREAMS will use different intervention types, such as headway monitoring, illegal overtaking warning, vulnerable road user warning, etc. The simulator is a highly controllable environment. As a result, it allows to independently test these intervention types. There will be multiple simulator trials, run by different partners that each have their specialization in terms of mode (car, truck, bus, train/tram). This creates a platform of independent, but synchronized simulator trials, where each trial can focus on a pre-defined set of intervention types that is most relevant to the specific mode in which each partner is specialized.

In order to avoid having to develop different systems for the simulator and the actual vehicles, it was decided to make the integration of the i-DREAMS system in the simulator as similar as possible to the integration in an actual vehicle. Meaning that the complete set of hardware that is required for creating real-time interventions in the actual vehicle will also be used and integrated in the simulator. This includes the use of a Mobileye system, coupled with the i-DREAMS gateway and the i-DREAMS intervention device. This also creates the option to perform extensive testing of the complete i-DREAMS system and identify any potential issues or problems before actual implementation on a large scale during the on-road field trials.

Additionally, driving simulation will be used to evaluate certain aspects that are impossible to evaluate during the on-road field trials, for instance the additional inclusion of eye-tracking metrics or haptic interventions, which were, given the available resources, both found to be unachievable for the large number of vehicles that will be included in the on-road field trials.

2.3 Link with i-DREAMS on-road field trials

The simulator trials will be run prior to the on-road field trials. This makes the simulator trials a flexible testing ground. Any critical issues with the system, including both hardware and software, can be detected and solved before the on-road field trials. Data collected in the simulator trials will be used as a basis to further optimize the i-DREAMS algorithm before the on-road field trials and to get a benchmark for the effectiveness of the i-DREAMS real-time interventions for different modes.

The simulator trials are run prior to the on-road field trials; it creates the opportunity to test out the real-time interventions in a safe environment while there is still room for change or optimization. How the real-time interventions change driving behaviour depends heavily on the intervention design. Designing an intervention with the correct level of intrusiveness and timing for each warning stage is key to achieve a high level of performance and acceptance. The initial design will be based on research, but will be verified in the simulator and optimized (e.g., in terms of visual appearance, or timing of the warning) where needed.

The main advantage of simulator experiments, is that the collection of multiple driving parameters allows an objective measurement of driving behaviour. Positive effects of the i-DREAMS interventions such as reduced collision rate or increased headway time would serve as a first indication or benchmark of the effectiveness of the i-DREAMS system and could already make a case to prove that the i-DREAMS system is relevant in order to increase road safety. In addition, the driving simulator set-up in the current project allows that each participant can be closely monitored during the complete experiment, something that is difficult to achieve in the on-road field trials. Therefore, the effect of the i-DREAMS system on the driver can immediately be recognized. Negative effects such as startling, annoyance or distraction by the real-time intervention can be addressed, which is essential before implementing the system on a larger scale in actual vehicles. Finally, the collected driving parameters and the observation of behaviour can be supplemented by additional objective measures such as eye-tracking, or subjective measures such as questionnaires.

2.4 Evaluation

Within the simulator trials, several evaluations will be conducted, including both outcome and process evaluation.

2.4.1 Outcome evaluation

Outcome evaluation, also called effect evaluation, applies to whether targeted factors changed as a result of the intervention or not, hence, it focuses on the effectivity of the intervention. Within the outcome evaluation, it will be investigated whether the intervention impacted the outcomes proposed in the logic model of change, i.e., **“safety outcomes”, “safety promoting goals”, and “performance objectives”.** Although it would be ideal to detect statistically significant impact on safety outcomes (e.g., crash occurrence), this is not possible within the simulator trials. The occurrence of impact can be expected as more likely for safety promoting goals and performance objectives. In addition, there will be a focus on **“user acceptance”** and “**user acceptability**” within this outcome evaluation, since both are important for the adoption and effectiveness of the interventions. While acceptability relates to whether drivers have the intention, and are open, to use this system, acceptance has to do with how they experience the actual use of a new system. The adoption of a new in-vehicle safety technology can only be successful if the technology is effective in reducing the target risk and when it is also used efficiently by the driver. If the driver does not accept the technology, misuse or disuse of the technology is evident (Parasuraman and Riley, 1997). It is therefore important to measure and reach a high level of acceptability and acceptance.

2.4.2 Process evaluation

Process evaluation aims to determine which parts of the intervention were effective and which not and as a result, focuses on the quality of material designs, the quality of implementation, and the adoption of the intervention. As described in detail in D7.1, the criteria proposed by Linnan and Steckler (2002) will be used in order to conduct a process evaluation.

2.4.3 Conceptual framework

Below within Figure 3, a conceptual framework in order to develop research questions is displayed. At the top of the figure, the different components (i.e., safety outcomes, safety promoting goals, performance objectives) together constituting the logic model of change behind the real-time intervention that is offered during the simulator trials are shown. The real-time intervention format is linked to these outcomes of the model of change in the i-DREAMS project (i.e., safety outcomes, safety promoting goals, performance objectives). It is important to take into account potential moderators and/or mediators. Moderators affect the relation between two variables, while mediators (partly or fully) explain the relation between two variables. Possible variables that could moderate or mediate the impact of the intervention on the outcomes appearing in the i-DREAMS model of change (i.e., safety outcomes, safety promoting goals, performance objectives) are technology acceptability, safety culture/climate and participant profile. Technology acceptability can be defined as “the degree to which an individual incorporates the system in his/her driving”. Safety culture/climate can be defined as “an organization’s approach to safety”. This is applicable to professional drivers like truck and bus drivers and train and tram operators. While “safety culture” mostly refers to individual and group values, attitudes, perceptions, competencies regarding safety, “safety climate” is mainly used to describe the expressed ideas, the tools and techniques used in general by the organization in order to confirm its compliance to safety. Participant profile can be defined as “the characteristics of a person”.

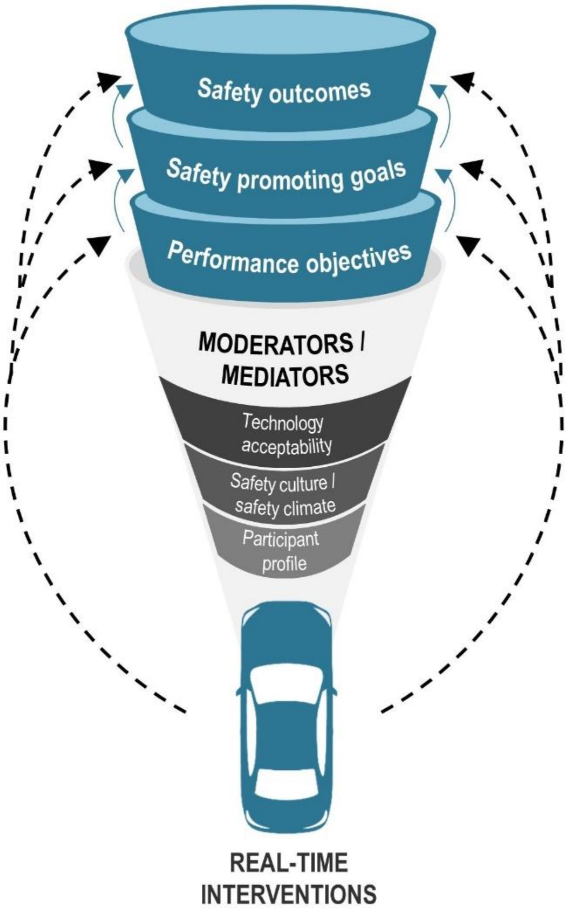

Figure 3: Conceptual framework for research questions

2.5 Research questions, indicators and measures, and methodological design

Within this section, research questions, indicators and measures and a methodological design is proposed for both the outcome and process evaluation among cars, trucks, buses, trains, and trams. After this, the design evaluation plan can be developed.

Outcome evaluation

Research questions

There are five main research questions related to the simulator trials. Each main research question consists of one or multiple sub-questions. Within research question 1, we focus on 'tailgating' among trucks as an illustration.

1. What is the baseline performance on outcomes appearing in the i-DREAMS logic model of change?
    1.1. What is the baseline performance on safety outcomes?
    E.g., What is the performance in terms of frontal crashes for trucks?
    1.2. What is the baseline performance on safety promoting goals?
    E.g., What is the performance in terms of sharing the road with others for trucks?
    1.3. What is the baseline performance on performance objectives?
    E.g., How many risky tailgating events are there among trucks?
2. What is the impact of the real-time intervention on outcomes appearing in the i-DREAMS logic model of change (including driver acceptance)?
    2.1. What is the impact of the real-time intervention on safety outcomes?
    E.g., Does the performance in terms of frontal crashes significantly improve for trucks equipped with and exposed to the i-DREAMS interventions?
    2.2. What is the impact of the real-time intervention on safety promoting goals?
    E.g., Does the performance in terms of sharing the road with others significantly improve for trucks equipped with and exposed to the i-DREAMS interventions?
    2.3. What is the impact of the real-time intervention format on performance objectives? E.g., Do truck drivers reduce risky tailgating events?
3. Are there variables that moderate/mediate the impact of the real-time intervention on outcomes appearing in the i-DREAMS logic model of change?
    3.1. Does safety climate moderate/mediate the impact of the real-time intervention offered to the truck driver on outcomes appearing in the i-DREAMS logic model of change?
4. Is there empirical support for the causal links inside the i-DREAMS logic model of change?
    4.1. Are there (causal) links between the safety promoting goals and the safety outcomes?
    4.2. Are there (causal) links between the performance objectives and the safety promoting goals?
5. How do users evaluate the real-time intervention offered to them in terms of acceptability (with inclusion of the intention to use the interventions)?
    5.1. How do drivers evaluate the real-time intervention offered to them in terms of acceptability (with inclusion of the intention to use the interventions)?

Indicators and measures

Related to research question 1 and 2, some indicators and measures are proposed for the safety outcomes, safety promoting goals, and performance objectives below. The change (or absence of change) in driver behaviour in response to the interventions will be an indication of acceptance.

Indicators and measures for the safety outcomes, safety promoting goals, and performance objectives:

1. Safety outcomes will not only be measured by means of crash occurrence, but by additional surrogate safety measures like Time-To-Collision (TTC) as well to allow robust enough statistical analyses.
2. Safety promoting goals will be measured by scores provided by the i-DREAMS platform. These scores will be based on the detection of events while driving.
3. Performance objectives will be measured by score provided by the i-DREAMS platform. These scores will be based on the detection of events while driving.

Related to research question 3, the same indicators and measures will be used in combination with some additional ones. For example, safety culture/climate will be investigated with a short survey. One well-known survey to capture the level of variety in this regard, is the so-called Safety Culture Ladder (see for instance Taylor, 2010).

Related to research question 4, the same indicators and measures as mentioned above will be used.

Related to research question 5, information on how the drivers evaluate the i-DREAMS technology will be gathered. Therefore, items were selected from Osswald et al. (2012) and Ghazizadeh et al. (2012). The survey (see Annex 2: Technology acceptance questionnaire) can be applied at the end of each trial, or additionally in the first half of each trial, to trace how acceptability value change over time and with longer term use of the i-DREAMS technologies. The items have a 5-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree”. There is a focus on eleven constructs: “Performance expectancy”, “Ease of use / effort expectancy”, “Attitude towards using technology”, “Social influence”, “Facilitating conditions”, “Self-efficacy”, “Anxiety”, “Perceived safety”, “Perceived Usefulness”, “Trust”, and “Behavioural Intention to Use”. Each construct consists of at least 2 items. As such, the internal consistency can be investigated. Only the items applicable to the real-time interventions (34 items) will be asked during the simulator experiments. However, in order to prevent “respondent fatigue” (a phenomenon that occurs when respondents become fatigued by answering surveys), a selection of these items will be made.

Methodological design

Both quantitative and qualitative measures are included when conducting the outcome evaluation. Quantitative measures are especially used to answer the first four research questions (i.e., the baseline measurement of outcomes appearing in the i-DREAMS model of change, the impact of the intervention formats on the outcomes appearing in the i-DREAMS model of change, moderators/mediators, and causal links). For example, tailgating behaviour of truck drivers can be measured by parameters recorded by Mobileye (e.g., number of headway monitor warnings). Qualitative measures are especially used to answer the fourth research question (i.e., user acceptability).

In order to answer the above mentioned research questions, several **statistical analyses** will be conducted. Below, some example analyses are given:

- AN(C)OVA will be conducted in order to investigate pre-test data, for example:
    - Tailgating, illegal overtaking and VRU detection among car drivers
    - Tailgating among truck drivers
    - Tailgating, illegal overtaking and VRU detection among bus drivers
    - Speed and VRU detection among tram drivers
    - Speed among train drivers
- ANOVA will be conducted in order to compare performance on risk factors that modes have in common. For example:

    - Tailgating within car drivers from Germany and car drivers from Greece
    - Tailgating and VRU detection within car drivers and city bus drivers
    - Tailgating and illegal overtaking within car drivers and coach drivers
    - Tailgating within city bus drivers and coach drivers
    - Tailgating within all modes of road transport: car, truck, (city & coach) bus
    - VRU detection within car, city bus and tram
    - Speed within tram and train
- Repeated measures analyses of variance (ANOVA) will be conducted in order to compare pre-test data with post-test data:
    - Performance objectives (e.g., as measured by Mobileye) will be compared before and after receiving warnings
- ANOVA will be conducted in order to investigate post-test data:
    - User acceptability will be investigated

Process evaluation

Research questions

Based on the criteria (excluding 'implementation') of Linnan and Steckler (2002), the following 6 research questions can be asked related to the process evaluation:

1. What are the aspects of the larger social environment that may affect implementation? (i.e., context)
2. What is the proportion of truck drivers to whom the intervention is actually delivered? (i.e., reach)
3. What is the amount of intended units of each intervention component that is delivered? (i.e., dose delivered)
4. What is the extent to which truck drivers engage with the intervention? (i.e., dose received)
5. Was the extent to which the intervention was delivered as intended? (i.e., fidelity)
6. What kind of approach was used in order to attract truck drivers? (i.e., recruitment)

Indicators and measures

Related to these research questions, some examples of indicators and measures are proposed. An example of an indicator and measure for 'context' related to professional drivers is the safety culture/climate of the organization, in a sense that it might moderate/mediate the effect of the real-time intervention on the targeted outcomes (i.e., safety outcomes, safety promoting goals, performance objectives). An example of an indicator and measure for 'reach' is the dropout rate at the end of the intervention, preferably, in combination with the reasons to drop-out, which could be inventoried during the simulator trials. An example of an indicator and measure for 'dose delivered' is the number of warnings and goals that a driver has received during the period where participants were exposed to the real-time intervention. An example of an indicator and measure for 'dose received' is the number of times participants appropriately reacted to warnings triggered by the i-DREAMS in-vehicle warning system. Technical failures or system deficiencies that possibly might occur during the simulator trials can be inventoried and considered as an indicator for 'fidelity' in a sense that they undermine the implementation of the i-DREAMS real-time intervention as originally planned. An example of an indicator and measure for 'recruitment' could be the extent to which the originally foreseen objectives in terms of sample size and composition have been realized (or not).

Methodological design

Both quantitative and qualitative measures are included when conducting the process evaluation. For example, the number of times participants appropriately reacted to warnings triggered by the i-DREAMS in-vehicle warning system (used in order to measure dose received) is a quantitative measure, while the reasons for drop-out (used in order to measure reach) is a qualitative measure. In order to answer the above-mentioned research questions, several **statistical analyses** will be conducted. For example, comparisons will be made between dose delivered and dose received.

3 Overview of technology for the driving simulator trials

Different simulator trials will be executed by different partners and for different modes. In order to get the best possible results, the driving simulator setups should resemble the actual vehicle for each mode as close as possible. To achieve this, different simulators will be used that have been specifically designed for each mode. The use of multiple simulators also helps to speed up the process of the simulator trials, with multiple trials running simultaneously in different locations. An overview of the different simulator trials and simulators is provided in Table 2: Overview of simulators, used in the i-DREAMS simulation trials.

Table 2: Overview of simulators, used in the i-DREAMS simulation trials

Partner	Country	Mode	Number of Participants	Simulator
BARRA	Portugal	Bus	30	DSS Heavy Vehicle Simulator
LOUGH	United Kingdom	Train	15	Train Simulator
LOUGH	United Kingdom	Tram	15	Tram Simulator
NTUA	Greece	Car	30	FOERST Driving Simulator FPF
TUM	Germany	Car	30	DSS Car Simulator
UH	Belgium	Truck	30	DSS Heavy Vehicle Simulator

The following sections will provide an overview for each of the different simulators. A general overview of the simulators will be provided, together with the most relevant specifications. The system architecture of the simulators, and how they interface with other i-DREAMS equipment will illustrated.

3.1 DSS Simulators

Two complete driving simulators were custom designed and built by DSS for i-DREAMS. One car simulator and one heavy vehicle simulator. The shape and size of the two simulators are different, the car is based on an actual passenger car, while the heavy vehicle simulator resembles the experience of driving a truck or bus as closely as possible. While the mechanical design of the simulators is different, the architecture and functionalities of both simulators are almost identical.

3.1.1 DSS Car Simulator overview

The DSS car simulator, as shown in Figure 4 was designed and built for the i-DREAMS project. The simulator is based on a Peugeot 206 and uses many original parts, such as the complete dashboard, a working instrument cluster and driving seat to recreate the cockpit of the actual vehicle. At the heart of this simulator runs STISIM Drive 3 software, which is visualized on a triple monitor setup consisting of three 49 inch 4K monitors, providing an 135° Field of View.

Figure 4: DSS Car Simulator

3.1.2 DSS heavy vehicle simulator overview

The DSS heavy vehicle simulator is depicted in Figure 5: DSS heavy vehicle simulator. It was designed and built for the i-DREAMS project. The simulator was designed to resemble as closely as possible the driving position of large/heavy vehicles such as busses and trucks. It is built around a frame of aluminium t-slot profiles that make the simulator easy to expand and also allow the simulator to be dismantled for transport. Certain OEM parts, like a large 50cm steering wheel and a sprung driving seat are used. The simulator uses a digital instrument cluster that can be modified. Like the DSS Car simulator, the DSS heavy vehicle simulator also runs on STISIM Drive 3 software. The visual setup consists out of three 43 inch 4K monitors. The system is also equipped with a haptic feedback module in the driving seat.

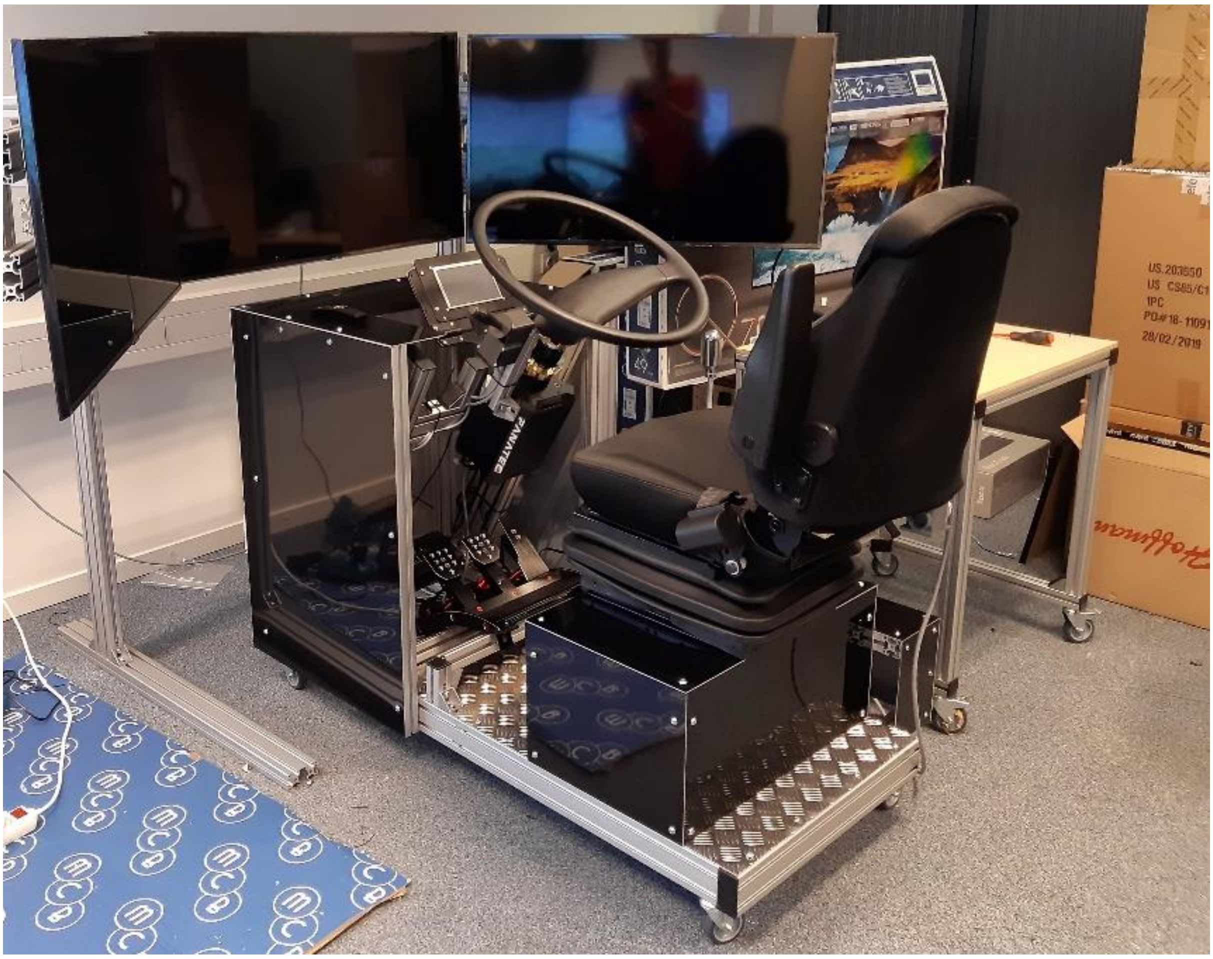

Figure 5: DSS heavy vehicle simulator

3.1.3 Simulator Architecture: DSS Simulators

An overview of the architecture of the DSS car simulator/DSS heavy vehicle simulator and how the simulators interface with i-DREAMS equipment is given in Figure 6. In the simulator, a Mobileye camera, a Cardiowheel and the simulator software itself are used as sensors to capture data in real-time. Additionally, external equipment like eye-tracking and video recording can be used to get more insight into driving behaviour. Just as in the real vehicle, the i-DREAMS gateway is responsible for triggering real-time interventions, which will be given to the driver by the i-DREAMS intervention device. For the DSS simulators, data will not be collected by the gateway, neither will it be stored in the cloud. Instead, the gateway sends all the data it collects and calculates back to the driving simulator in real-time through a serial interface. This data from the gateway is synchronized and combined with simulation variables and stored locally on the simulator pc. Serial data between the gateway and driving simulator flows only in the direction of gateway to simulator, meaning that there is no direct input of simulation variables (variables that are calculated as part of the simulation loop) to the gateway. This choice was made in order to make data collection from sensor in the simulator as similar as possible to the actual vehicle.

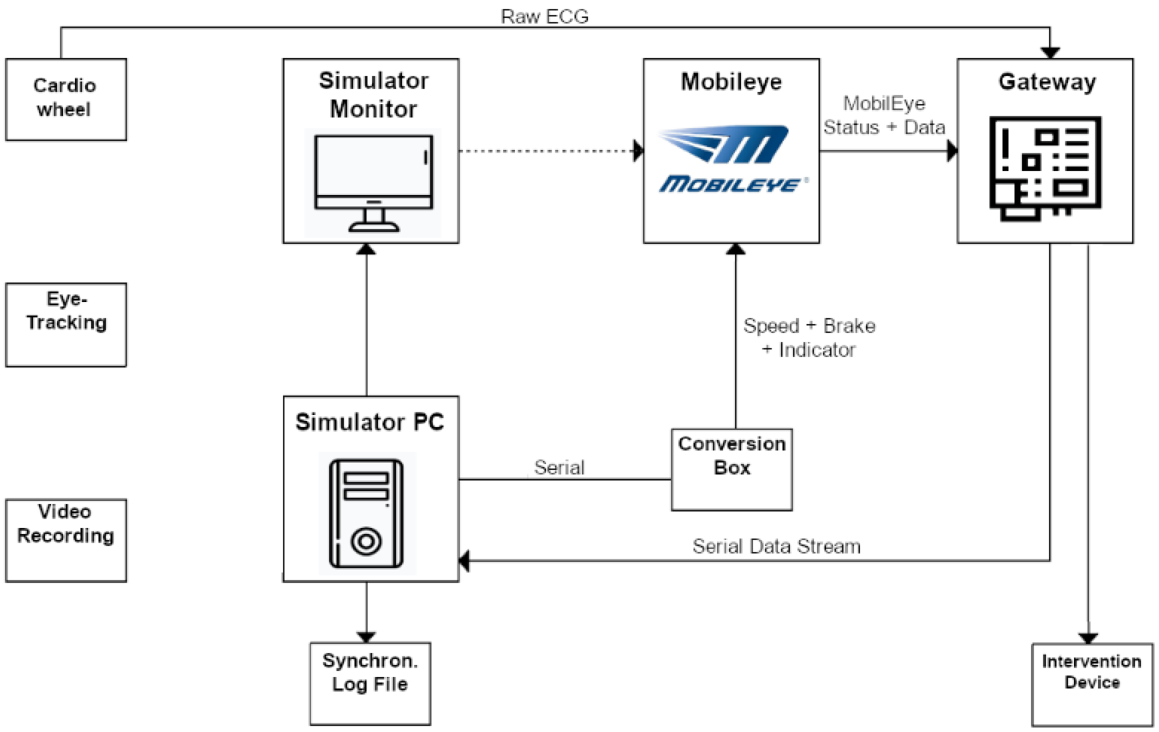

Figure 6: DSS Car Simulator Architecture Overview

Similar to the real vehicle set-up, vehicle data such as speed, brake position and indicator usage is collected through Mobileye. Mobileye uses these values for its own calculation of interventions, but also makes them available to the gateway as CAN-messages. Since speed, brake position and indicator usage are required by Mobileye in order to function properly, these simulated driving parameters need to be converted to a signal that is accepted by Mobileye. The conversion is handled by an external controller that receives simulation variables through a serial interface and transforms them to physical signals for speed, brake switch and turn indicator signal. A schematic is given in Figure 7. The speed signal is the replication of the raw VSS signal in vehicles, usually generated by a hall- or similar type of sensor that converts rotation to a pulse signal. The sensor can be located at the outgoing gearbox axle, or be a part of the ABS system to measure the rotational speed of each wheel. The signal itself is a 12V frequency modulated square pulse signal. The brake signal and turn indicator signal are digital on/off signals. Mobileye accepts signals with a wide voltage range, from 5V up to 24V and only draws minimal current, therefore it is convenient and possible to use a direct digital 5V output from the same controller that also handles the speed signal conversion.

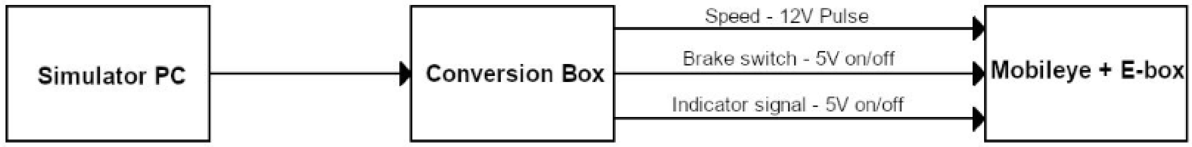

Figure 7: Signal conversion from DSS car simulator to mobileye

For the DSS simulators, all data will be stored locally (compliant with the principles of data protection as set out in the project's Data Management Plan). In order to make this data useful for analysis it is important that external data (from gateway) is synchronized in time with simulation data. To achieve this, the simulation loop was modified to receive data from the gateway and combine it with simulation data at every time step (simulation frame). The result is synchronized data which is also written to a log file at every frame. A custom protocol, where variables are sent as JSON objects was defined and created. A schematic overview of this procedure is given in Figure 8: procedure to synchronize simulation data with external data.

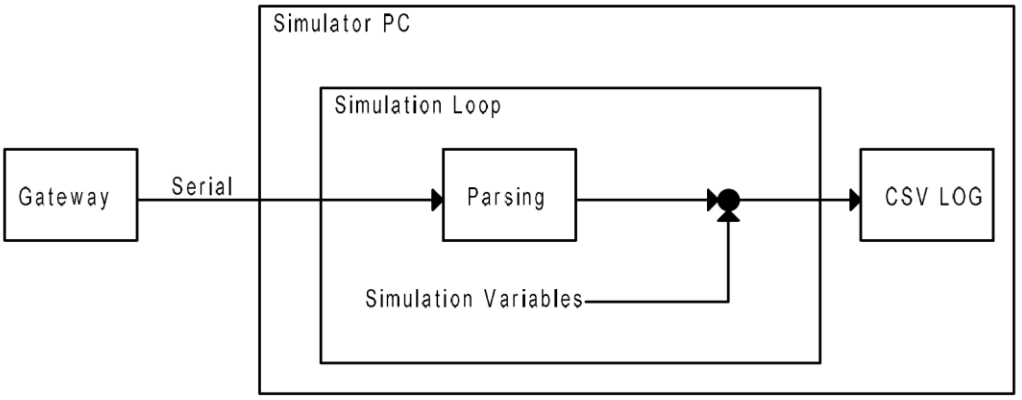

Figure 8: procedure to synchronize simulation data with external data

3.2 FOERST Driving Simulator FPF

The FOERST driving simulator FPF will be used for the simulator trials in Greece at NTUA. These trials will focus on passenger cars. An overview of the simulator is given below.

3.2.1 Simulator Overview

The Foerst GmbH is a DIN ISO 9001-certified company and the Foerst Driving Simulator FPF F10P has been manufactured by the FOERST Company (FOERST, 2020) in order to serve research purposes.

The driving simulator consists of 3 LCD wide screens 40’’ (full HD: 1920x1080pixels), driving position and support motion base. The dimensions at a full development is 230x180cm., while the base width is 78cm and the total field of view is 170 degrees. It features adjustable driver seat, steering wheel 27cm diameter, pedals (throttle, brake, clutch), dashboard (tachograph, tachometer) and two external and one central mirror that appear on the side and on the main screen, and display in real time objects and events that are happening behind the 'vehicle'. The controls available to the driver are: 5 gears plus reverse gear, flash, wipers, lights, horn, brake and starter.

The virtual - animated road environment is generated by computer programming tool and displays the road environment. Users can drive along the road under realistic conditions. It is highlighted that driving conditions in the simulator cannot be absolutely identical to those perceived by the driver in real driving, but the change of the driver behavior does not necessarily affect the relative influence of various parameters.

Moreover, in the simulator it is possible to simulate many conditions between alternative types of roads (urban-interurban road, highway) in different traffic conditions (normal - less - without - just oncoming traffic), and under different environment (good weather, fog, rain, snow, night). While, according to the experimental requirements we can select to simulate various dangerous situations like unexpected appearance of an animal during driving or unexpected course of a leading vehicle at predetermined or random points along the route. Figure 9 provides an overview of the FOERST Driving Simulator FPF.

Figure 9: FOERST Driving simulator FPF

3.2.2 Simulator Architecture: FOERST Driving simulator FPF

The architecture for data collection and interfacing with i-DREAMS equipment will be very similar to the architecture that was already designed for the DSS simulators. An overview of this architecture was already given in section 3.1.3 Simulator Architecture: DSS Simulators. There will be minor differences, because other software is used for driving simulation, a new application will be developed to handle extraction of variables from the driving simulator to the i-DREAMS equipment (vehicle speed, brake switch, turn indicator) and to handle the fusion of data that is produced by the simulator itself and data that is collected on the i-DREAMS gateway.

3.3 Tram Simulator

3.3.1 Simulator Overview

The tram simulator used in the project was designed and created by Ian Rowe Associates for Croydon Tram and is used as part of their driver training and assessment. The simulator software was developed in house by Avansim LTD (the sister company to Ian Rowe Associates) using mainly the Unity Games engine for animation, written in C-plus. The software is geospecific for environments- modelled on Croydon for Croydon Trams. The driver performance analysis software and hardware were also developed in-house. Fabrication of the metal simulator frame was contracted externally but to Ian Rowe Associates' design. The set-up consists of a simulator station where drivers conduct their simulated drives (Figure 10) with a linked training station where assessors can measure and record their performance. Panels replicate both Bombardier and Stadler tram control systems, both of which operate on the line. Touchscreens are used to allow control layout to change between the two tram types. The set-up provides a front field of view only, displayed on a single 65 inch 4k screen.

Figure 10: Croydon Tram simulator

3.3.2 Simulator Architecture

For the i-DREAMS project the existing Croydon Tram simulator will be used but adapted to allow the i-DREAMS technology suite to be integrated with it. CardioID and DSS will assist Loughborough University in getting the set-up to be compatible with the i-DREAMS technology suite. This will involve providing a pulse generator, dashcam, wearable and intervention device. All of the data will be recorded through the gateway and will be set up as shown in Figure 11. Additional equipment such as eye tracking devices could be used for further insight into driving behaviour if deemed useful. A splitter will be required for the screens so that a dedicated screen can be used for Mobileye and the normal screens for the driver.

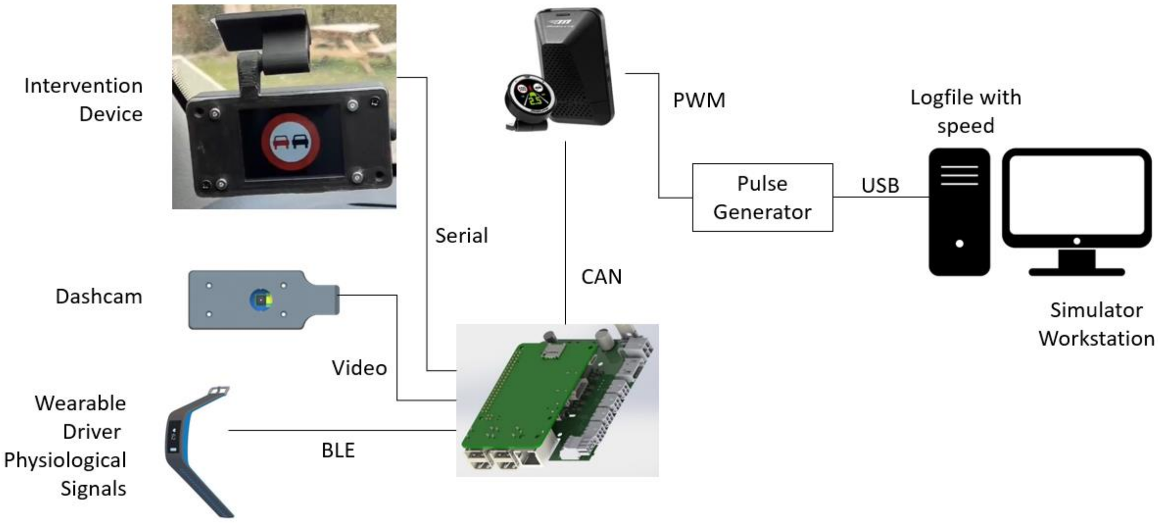

Figure 11: Tram simulator architecture overview

While driving, the Mobileye device works as a sensor to detect events, such as a pedestrian crossing in front of the tram and the calculates measures such as time headway. This data is transmitted in real-time to the i-DREAMS gateway through a CAN-bus network. The data from Mobileye is used as an input for the i-DREAMS safety tolerance zone algorithm, together with data logged from other sensors (e.g., sleepiness measures collected by wearable). The gateway also controls the intervention device that is used to trigger warnings based on the current status of the safety tolerance zone calculations (normal driving, dangerous driving, avoidable accident.)

The tram simulator does not have a default method of outputting simulation data. However, this data is required in real-time by Mobileye. The tram simulator logs data to a log file at fixed time intervals, an application will be developed to run simultaneously with the driving simulation software on the simulation workstation to read simulation data from the log file as soon as it is updated and convert this data to a serial output stream that can be used as input to a pulse generator or as input for data collection/fusion on the gateway or an external computer.

3.4 Train Simulator

The train simulators are based at the company Abellio's premises in Stratford, London. There are two different simulators, replicating the two new rolling stock train models which run on their lines. Both types of simulator use true scale cabs that are accurate representations of the controls for the trains used in service. The first uses software by Sydac, an Australian company, and replicates Bombardier cabs (Figure 12). The second uses software by TransUrb, a Belgium company, to replicate Stadler cabs (Figure 13, Figure 14, Figure 15). These simulators are leased by Abellio and used for driver training purposes. In both designs routes and events can be pre-programmed and conditions and events can also be changed during the simulation session.

Figure 12: Bombardier train cab simulator

Figure 13: Simulated Stadler display screen

Figure 14: Simulated Stadler left-hand controls

Figure 15: Simulator Stadler right-hand controls

4 Overview of driving simulator trials in i-DREAMS

4.1 Generic design of simulator trials

The three main goals of the driving simulator trials in i-DREAMS are: to test driving behaviour and validate the STZ mathematical model, to test the monitoring equipment and real-time intervention technologies in assessing the STZ, and to obtain user feedback about these technologies. Considering the extent and the size of the i-DREAMS project, i.e., four transport modes across five countries, it is very important to systematically design the drives to avoid experimental errors, which can cause delays or biases in the full implementation of the project. As a result, the simulator trials in i-DREAMS are designed based on several principles derived from previous literature (Fisher et al., 2011; Tipton et al., 2014; Box & Hunter, 1961) including definition of outcomes, predictors and hypotheses, selection of sample size and statistical power, selection of design type, distribution of risk scenarios among participants, selection of drive durations to avoid simulator sickness, avoidance of order and learning effects, and consideration of confounding effects. In line with these design principles, the generic design principles of simulator experiments (thoroughly discussed in section **2.2.1** of deliverable **D3.4**) are the following:

1. The outcomes are defined as the real-time interventions (i.e., in-vehicle warnings) based on STZ thresholds and the predictors are defined as risk factors associated with the STZ, including speeding, tailgating, overtaking, and vulnerable road user detection. The hypotheses are defined in order to test whether the STZ can be detected and real-time interventions can be triggered using the above described risk factors;
2. The experimental design is a fractional factorial design;
3. The experimental design is a within-subject design;
4. The experiment includes two practice drives and three experimental drives;
   Note: As the used tram and train simulators will be those that are routinely used for training purposes, the tram/train operators will already be familiar and, therefore, the first level of familiarisation will not be necessary
5. The order of events is randomized within each drive and among participants;
6. The total duration of each session (i.e., all the drives) per participant is less than two hours, with each experimental drive up to 15 minutes and a 10-minute break after the second experimental drive;
7. The third drive is defined to extend the scope of simulator trials in order to test the confounding effects of sleepiness, distraction, and bad weather conditions. There will be no interventions (i.e., real-time warnings) for the risk factors that are used as conditions in this drive;
8. The sample size for simulator trials are pre-defined as follows: 30 participants for passenger cars, 30 for trucks, 30 for buses, and 30 for trams/trains. These are acceptable sample sizes when compared with available experimental studies on driving simulation (e.g. Fisher et al., 2011). All participants will make three experimental drives in the simulator. Within all these drives, there is a simultaneous focus on 2 risk factors. Moreover, participants to the simulation experiments will be excluded from the field trial in order to avoid biased results (due to repeated exposure to the same treatments).

Table 3 presents the generic design of simulator trials in the i-DREAMS project. The specific design for each transport mode (conducted by each country) is also shown in this table to better understand the risk factors included in each drive. The details of these specific designs are discussed in the next section. Although this will be adapted for each mode, some small changes can be made dependent on the mode (e.g., truck drivers and tram & train operators only 1 practice drive, due to familiarity with simulators).

Table 3: Generic design of simulator trials in i-DREAMS

# Drive	Transport mode	Partner/Country	Risk factors	Intervention	Duration	Timeline (accumulated)
Briefing (Filling in questionnaires if needed)						
Practice drive 1	Passenger cars, trucks and buses	All partners/countries except LOUGH (UK)	No events	X	5 minutes	5 minutes
Practice drive 2	All modes	All partners/countries	With basic tasks / events	X	5 minutes	10 minutes
Experimental drive 1 Monitoring scenario	Passenger cars	TUM (Germany)	Tailgating VRU detection	X	15 minutes	25 minutes
	Passenger cars	NTUA (Greece)	Tailgating Overtaking	X		
	Trucks	UH (Belgium)	Tailgating, speeding	X		
	Trams	LOUGH (UK)	VRU detection Speed behaviour Sleepiness	X		
	Trains	LOUGH (UK)	Speed Signal passed at danger (SPAD) Sleepiness	X		
	Buses: coaches	BARRA (Portugal)	Tailgating Overtaking	X		
	Buses: city buses	BARRA (Portugal)	Tailgating VRU detection	X		
Break: (Participant receives information about the intervention device, questionnaires if needed)					5 minutes	30 minutes
Experimental drive 2 Intervention scenario – driver state independent	Passenger cars	TUM (Germany)	Tailgating VRU detection	✓	15 minutes	45 minutes
	Passenger cars	NTUA (Greece)	Tailgating Overtaking	✓		
	Trucks	UH (Belgium)	Tailgaiting	✓		
	Trams	LOUGH (UK)	VRU detection Speed behaviour Sleepiness			
	Trains	LOUGH (UK)	Speed Signal passed at danger (SPAD) Sleepiness	✓		
	Buses: city buses	BARRA (Portugal)	Tailgating VRU detection	✓		
Break (Filling in questionnaires if needed)					10 minutes	55 minutes
Experimental drive 3 Intervention scenario – driver state dependent	Passenger cars	TUM (Germany)	Tailgating VRU detection, with distraction as a condition	✓	15 minutes	70 minutes
	Passenger cars	NTUA (Greece)	Tailgating Overtaking with bad weather as a condition	✓		
	Trucks	UH (Belgium)	Tailgating Speeding with sleepiness as a condition	✓		
	Trams	LOUGH (UK)	VRU detection speed behaviour with sleepiness as a condition	✓		
	Trains	LOUGH (UK)	Speed Signal passed at danger (SPAD)	✓		
	Buses: coaches	BARRA (Portugal)	Tailgating Overtaking with distraction as a condition	✓		
	Buses: city buses	BARRA (Portugal)	Tailgating VRU detection with distraction as a condition	✓		
Ending (Filling in questionnaires if needed)						

4.2 Procedure simulator trials

Although the procedure will be the same for each mode, some small changes can be made dependent on the mode. As can be also derived from Table 3: Generic design of simulator trials in i-DREAMS, there is a briefing in which:

- researcher gives a general introduction to the participant about the simulator trial (e.g., information sheet including data protection and privacy issues)
- participant signs an informed consent
- researcher explains the questionnaire(s) scales to the participant
- participant completes the **entry questionnaire**, consisting of items related to demographic information such as gender, age, driving experience, and items from the Karolinska Sleepiness Scale (KSS) and the Epworth Sleepiness Scale (ESS)
- researcher explains the operation of the driving simulator to the participant

After this introduction, the participant drives through the two practice scenarios. Subsequently, the participant drives through the first experimental drive (i.e., monitoring scenario) in the driving simulator.

Following this, there is a short break, during which the participant completes questionnaire(s), (e.g., KSS) and the researcher explains the functionalities of the warning device to the participant.

Subsequently, the participant drives through the second experimental drive (driver-state independent intervention scenario) in the driving simulator.

Afterwards, there is again a short break, where the participant completes questionnaire(s), e.g., technology acceptance questionnaire with items derived from Osswald et al. (2012) and Ghazizadeh et al. (2012), see Annex 2: Technology acceptance questionnaire.

Then the participant drives through the third experimental drive (i.e., driver-state dependent intervention scenario) in the driving simulator.

Finally, there is an ending of the trial, where the participant completes the **exit questionnaire**, consisting of items related to technology acceptance derived from Osswald et al. (2012) and Ghazizadeh et al. (2012), see Annex 2: Technology acceptance questionnaire.

In total, a full session will take approximately 1.5h (2h max). The part where participants drive in the simulator will take approximately 1h, the part where participants fill in documents or have a brake will take approximately 0.5h.

4.3 Monitoring and intervening within simulator trials

As described above, the simulator trials will focus on monitoring driving behaviour and the impact of real-time interventions (i.e., in-vehicle warnings) on driving behaviour.

4.3.1 Monitoring

Within the i-DREAMS project, driving behaviour will first be monitored while encountering dangerous events without receiving any interventions. In this way, a baseline measurement of driving behaviour can be obtained, which can be compared with driving behaviour when receiving real-time interventions (in-vehicle warnings).

4.3.2 Interventions

Although the i-DREAMS project focuses on both real-time interventions and post-trip interventions, the simulator trials only focus on **real-time interventions**. These interventions will be offered by using an in-vehicle warning system. With real-time interventions, drivers have almost no time to think about their actions, hence, a **nudging approach** is used for these kinds of interventions. Within this approach, heuristics (i.e., mental shortcuts) and manipulations of cues within a social or physical environment are being used in order to activate and influence non-conscious thought processes involved in human decision making. In the i-DREAMS project, the respective environment relates to the in-vehicle warning system.

The purpose of the i-DREAMS interventions is to effectively **increase driver safety** by supporting the driver in their driving task. To this end, information that will be used within the interventions will be based on the safety tolerance zone (STZ). Based on the STZ, a driver can be in three different phases: (1) normal driving phase, (2) danger phase, and (3) avoidable accident phase.

In case a driver can be situated within the first phase of normal driving, no real-time interventions are necessary. In the second phase (i.e., danger phase), a warning signal (e.g., visual warning like a message) will be presented. In the third phase (i.e., avoidable accident stage), a more intrusive / instruction signal (e.g., visual warnings like flashes, and auditory warnings like beeps) will be offered. More details on the design of these warning signals can be found in Deliverable 3.3 'Toolbox of recommended interventions to assist drivers in maintaining a safety tolerance zone'.

The purpose of the i-DREAMS interventions is to ensure that the driver remains in the first phase as long as possible. In case this is not possible, and the driver transfers to the second phase, to prevent that a driver subsequently would transfer from the second phase to the third phase in the STZ.

These interventions aim to improve the outcomes proposed in the logic model of change (see Figure 16). These outcomes target 4 different levels of driver safety. The highest level targeted by the interventions are the **safety outcomes**, for instance, the likelihood of crash occurrence (e.g., forward crashes and rear-to-end crashes). The second highest level are the **safety promoting goals**. These are the behaviours that need to change in order for the safety outcomes to be realized. The second lowest level are the **performance objectives**. These are the more specific actions or behavioural parameters that need to change in order for the safety promoting goals to be achievable. The lowest level are the **change objectives**. These are the underlying behavioural determinants that need to change for the performance objectives to become realizable. However, within the simulator experiments, there is no focus on these change objectives. For a detailed description, see Deliverable 3.3.

Figure 16: Outcomes proposed in the logic model of change for the simulator trials

Due to the large number of safety promoting goals and performance objectives, only an illustration will be offered for truck drivers within

Figure 17 and

Table 4: Illustration of a safety outcome, safety promoting goal, and performance objective for trucks.

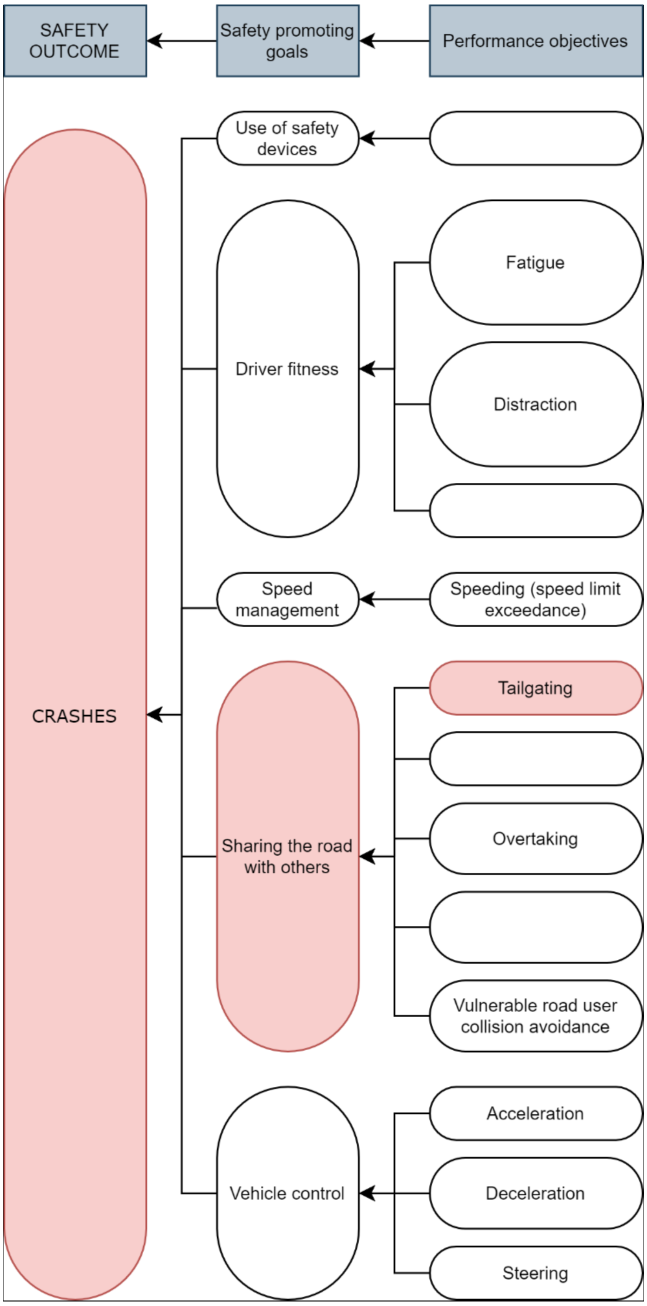

Figure 17: Illustration of a safety outcome, safety promoting goal, and performance objective for trucks.

Table 4: Illustration of a safety outcome, safety promoting goal, and performance objective for trucks.

Safety Outcome:
The likelihood of trucks equipped with and exposed to the i-DREAMS interventions to be involved in a frontal crash will significantly reduce.
Safety Promoting Goal:
Performance in terms of sharing the road with others (expressed as a numerical score) will significantly improve for trucks equipped with and exposed to the i-DREAMS interventions.
Performance Objective:
Performance in terms of tailgating (expressed as a numerical score) will significantly improve for trucks equipped with and exposed to the i-DREAMS interventions.

4.3.2.1 Signals during real-time interventions

During the real-time interventions, the effect of the in-vehicle warning on driving behaviour will be investigated (e.g., stopping for a vulnerable road user), however, other aspects will also be investigated.

First of all, **the symbol of the warning** will be investigated (e.g., symbol of a coffee cup for fatigue/sleepiness), in addition, **the modality of the warning** will be investigated (e.g., haptic, auditory, visual signal). Finally, **the timing of the warning** will be investigated. Regarding this aspect, multistage warnings will be tested (e.g., early and late warnings). Research has indicated that early warnings could be beneficial, for example during a first stage in order to inform the driver, and during a second stage in order to pre-warn the driver (Winkler, Werneke & Vollrath, 2016). In addition to a multi-staged timing strategy with fixed threshold levels, situation-adaptive timing strategies (i.e., variable threshold levels) will be investigated. For example, threshold levels that are based on a multi-factorial real-time assessment of coping capacity and task load. In this way, warnings for a specific performance objective, such as tailgating are triggered at different dynamically changing thresholds. For example, if higher levels of sleepiness and/or distraction are being detected, this implies that tailgating warnings should be triggered sooner. In order to reach this goal, conditions like sleepiness, distraction and bad weather will be used.

4.3.2.2 Targeted risk factors within real-time interventions

The targeted risk factors depend on the mode under investigation.

Although there are similarities among the on-road vehicles, there are also differences between them, hence the risk factors for car, bus and truck vary. In addition, rail-driven transportation has different operations compared to road transportation, and therefore different risks factors need to be considered.

In total, there will be a focus on five different risk factors, based on crash statistics (i.e., tailgating, illegal overtaking, VRU detection, speed, SPAD), and three different conditions (i.e., distraction, sleepiness, bad weather).

Road transport will focus on three risk factors (i.e., tailgating, illegal overtaking, VRU detection) and three conditions (i.e., distraction, sleepiness, bad weather) during the simulator trials. **Rail-driven transport** will focus also focus on three risk factors (i.e., VRU detection, speed, signal passed at danger - SPAD), but only on 1 condition (i.e., sleepiness).

Although there will be no interventions for the risk factors that are used as conditions (i.e., distraction, sleepiness, bad weather), **driver's opinions about the 'sleepiness signal'** will be assessed. This will not be investigated during, but after, a simulator drive. During this assessment questions like 'What do you think that this signal means?' and 'What would you do when receiving this signal?' will be asked.

4.4 Simulator trials

Within this section, general information about the objective, scenario, and variables of interest is given. In addition, similarities and differences between modes and the test locations are discussed.

4.4.1 Objective

Although the objective of the simulator trials is the same across modes and countries, the monitoring equipment and intervention technologies depend upon the risk factors under investigation. For example, tailgating will be monitored by Mobileye, and the intervention technologies are related to the signal of 'tailgating' and the thresholds used to give a warning will be based on time headway (TH).

4.4.2 Scenario description

As mentioned within D3.4, in order to harmonise the approach across partners, a three-step process was followed to develop the risk scenarios. In step one, general information such as the research (sub)goals was collected in order to provide an overview of possible investigation targets. In the second step, information was gathered exploring how the research goals could be investigated. More specifically, information about risk factors (e.g., following distance, illegal overtaking, speeding, and sleepiness), number of scenario(s), duration of simulator drives, procedure, weather conditions (e.g., rain), and data (e.g., time headway) was collected. After gathering information, bilateral meetings took place between partners in order to discuss the proposed scenarios. During these meetings, it was agreed that, from the available list of performance objectives (see Figure 18 in D3.3, Brijs et al., 2020), at least four objectives would be addressed in the simulator trials. Some of these objectives were shared across partners working on a certain mode (e.g., both NTUA and TUM work on cars and will investigate tailgating), while others were specific for a partner (e.g., NTUA will also work on illegal overtaking, while TUM will also work on vulnerable road user (VRU) collisions).

In the third step, detailed information about the road environment, number of events, and type of events were collected and translated into a script. See Annex 1: Script simulator drives for cars – Germany for an example of a script for the simulator scenario for car in Germany.

4.4.2.1 Events

Every drive focuses on one to two risk factors and includes three dangerous events/risk factors that are associated with real world crashes (e.g., rear-end collision) or violations and would require a driver/operator to take action (e.g., braking). Within these events, there is a distinction between **soft braking events and harsh braking events**. The difference between these events is the presence of a **precursor** (i.e., road element that makes it possible to predict a dangerous event). While harsh braking events do not include a precursor, soft braking events do include one (e.g., signal use by leading car).

The order of events are randomized within each drive and among participants in order to **decrease the possibility of order effects**. Order effects are differences in driving behaviour that are the result of the order of events and drives that are presented to them (Shaughnessy et al., 2000). Since the order of events is randomized within each drive, each drive contains the same events, but these events have a different order. Furthermore, since the order of events is also randomized across participants, participants with an even id number will have another order of events compared to participants with an uneven id number. See Table 5 for an illustration.

Table 5: illustration randomization of order of events within each drive and among participants

	Drive 1	Drive 2	Drive 3
Participant 1	Event 1-2-3	Event 2-1-3	Event 3-1-2
Participant 2	Event 3-1-2	Event 1-2-3	Event 2-1-3
Participant 3	Event 1-2-3	Event 2-1-3	Event 3-1-2
Participant 4	Event 3-1-2	Event 1-2-3	Event 2-1-3

Similar to the order effects, to **decrease the possibility of learning effects** (i.e., the change in driving behaviour caused by repetition of the same event in the trial (Fisher et al., 2011)), the road user involved in the critical event will be randomized (e.g., red car, yellow bus).

In addition to the dangerous events that are used to investigate the risk factor, **masking events** are used. These are events that also trigger a reaction from the participant, but do not contain manoeuvres of interest for analysis purposes. They are used in order to mask the true purpose of the trial. An example of a masking event for car drivers is a green traffic light at an intersection, while an example of a masking event for train operators is VRU’s standing still close to track in an urban section.

In addition, **filler pieces** that do not trigger a reaction from the participant are used, to make conclusions about ‘driving behaviour under safe driving conditions’, hereby providing a baseline measurement. An example of a filler piece for car drivers is a road segment without any road elements (e.g., other vehicles, intersections). An example of a filler piece for tram & train transport is a track segment without any track elements (e.g., no VRU near the track, no stations or signals).

4.4.2.2 Manipulations of conditions used to vary the timing of interventions

In the design logic of the i-DREAMS real-time interventions (i.e., warnings for illegal overtaking, sleepiness, tailgating, and speeding) the timing of the triggering of these warnings is dependent on real-time task demand and coping capacity information. For example, risk factors such as weather conditions, sleepiness and distraction will determine if a warning is triggered sooner or later. The variation in the timing of such warnings implies that it is necessary to manipulate the conditions that will be used in the interventions within the third experimental drive (i.e., distraction, sleepiness and bad weather).

To this end, the conditions should be (de)activated within the i-DREAMS system. In the case of sleepiness, ideally a certain level of sleepiness should be induced. However, as sleepiness induction requires very specific circumstances and/or instructions (e.g., instructions and detailed monitoring of participant’s sleep in home or laboratory setting prior to participation), which are not feasible in the current experimental setting due to practical reasons (e.g., professional drivers not available for work after sleep deprivation). Hence participants will be explained that they will experience warnings during the trial for which the timing of the triggering of the warnings is set *as if they were sleepy*. The idea behind this instruction is that participants are aware of the fact that the i-DREAMS system will operate according to the respective level of sleepiness that is assigned to the participant, as indicated by a KSS score. For example, a KSS score of 4 or 5 to indicate of moderate level of sleepiness, or a KSS score of 6 or 7 to indicate a high level of sleepiness. In the case of ‘distraction’ a secondary task will be included at certain locations within the simulator drive. For analysis purposes, the secondary tasks will be flagged in a manner that is not visible to the participant. In the case of ‘bad weather’, bad weather (e.g., rain, reduced visibility) will be included within the simulator drive.

4.4.2.3 Road environments

For cars, trucks and buses, three road environments are considered: highway, rural, and urban environments. For rail-driven transport, the environments include mixed traffic (urban) and segregated (suburban) rail segments. In addition, whereas the environment for road transport will include intersections, the environment for rail transport will include stations and rail crossings.

See Figure 18: Example of an intersection in STISIM Drive 3 for an example of a road environment.

Figure 18: Example of an intersection in STISIM Drive 3

4.4.2.4 Simulator sickness

Since participants in driving simulator trials sometimes report feeling ill (e.g., eye strain, headache, postural instability, sweating), which can severely influence the behaviour and performance of participants and thus can lead to invalid results (Casali, 1986), the duration of each drive, and the use of turns and curves are limited.

Each drive has a duration of approximately 20 minutes. As a result, dependent on the speed limit, each drive has a length between 15 km and 27 km. Whereas car and city bus drivers will drive through relatively short drives (i.e., around 15 km) within relatively low speed zones (e.g., 50 km/h), coach and truck drivers will drive through longer drives (i.e., around 25 km) within higher speed zones (e.g., 100 km/h). In this way, the simulator drives are more representative.

By limiting the length of the drive, not only will the risk of simulator sickness be limited, but it will also prevent participants from getting exhausted.

4.4.3 Variables of interest

The variables of interest for each simulator trial depend upon the risk factor under investigation. Therefore, for each simulator study, specific variables of interest are indicated in the sections below.

However, in addition to these specific variables of interest, a common set of parameters will be saved by the simulator within all high-risk drives: average speed (AS), (standard deviation of) lateral acceleration ((SD)LA), (standard deviation of) lateral position ((SD)LP), steering variability (SV), edge line crossings, detection time (accelerator release) (DT), reaction time (press brake pedal) (RT), signal use (SU), time headway (TH) (and distance headway - DH), violations (e.g., speeding, defined as above the limit or inappropriate for the context), crashes, and surrogate safety measures such as TTC.

In addition to the simulator, some partners will make use of **additional hardware that allow for a deeper exploration of underlying mechanisms of driving behaviour**. For instance, an eye tracker is able to provide indications of attention allocation processes.

4.4.4 Similarities and differences between modes

As mentioned above, there are both similarities and differences between the road transport modes under investigation (i.e., car, truck, bus). As a result, both the same, as well as different, risk factors will be investigated within the simulator drives, with the former allowing for comparisons between transport modes.

Common risk factors under investigation for road transport:

- VRU detection is investigated within car, city bus and tram drivers
- illegal overtaking is investigated within both car drivers and coach drivers
- tailgating is investigated within all modes of road transport: car, truck, (city & coach) bus

Compared to road transport, rail transport focuses on 2 additional risk factors: speed and SPAD. Speed is a common risk factor under investigation for rail transport (i.e., investigated by both tram and train).

In addition, two consortium partners (TUM and NTUA) instead of only one will conduct simulator trials for the car mode in order to investigate and compare driving behaviour. Although it is the purpose to have a broad range of data to allow for several conclusions about driving behaviour of car drivers (i.e., tailgating, VRU detection and illegal overtaking), the countries have one risk factor in common (i.e., tailgating) in order to conduct comparisons between the countries.

4.4.5 Test location

Although most simulator trials will be conducted at the location of the partner (e.g., NTUA, TUM, Barra), some trials will be conducted at another location, for example at an education centre for truck drivers (instead of at UH) and in training centers for tram and train operators (instead of LOUGH).

4.5 Simulator study per mode

Below, detailed information about the simulator trial per mode will be given, i.e., objectives, simulator drive description (including the dangerous events and experimental manipulation of the conditions used to offer driver-state dependent interventions and variables of interest.

4.5.1 Simulator trial for Car – Germany

4.5.1.1 Objectives

The objectives of the simulator trial for car drivers in Germany are to:

- investigate driving behaviour of car drivers with a focus on tailgating and vulnerable road user (VRU) detection, and validate the STZ mathematical model for them (drive 1),
- test the monitoring equipment (i.e., Mobileye) and intervention technologies targeting tailgating and VRU detection, with warnings either or not based on a distracted driver-state (drive 1, 2, 3)
- obtain feedback from car drivers about these technologies (questionnaires)

4.5.1.2 Simulator drive description

Road environment

The simulator drive has a total distance of approximately 15km and will include urban, rural and highway environments.

The urban environment will contain a speed limit of 50 km/h (road with 2 lanes: 1x1 and 4 lanes: 2x2).

The rural environment will contain a speed limit of 70 km/h (road with 2 lanes: 1x1 and 4 lanes: 2x2).

The highway environment will contain no speed limit (road with 6 lanes: 3x3).

Tailgating behaviour will be investigated within these 3 road environments, while VRU detection will only be investigated within the urban and rural environments.

Dangerous events

Since the focus is on tailgating and VRU detection, there will be a leading vehicle driving in front of the driver within parts of the simulator drive in order to investigate tailgating. VRU detection will be investigated with pedestrians. Although it would be interesting to investigate the reaction on several VRU's, since the reaction from a driver can depend on the type of VRU, no other VRU's will be used for these events, due to the detection capability of Mobileye and the display of warnings (i.e., pedestrian sign).

In order to investigate their tailgating behaviour in case of a dangerous event, the vehicle in front of the driver will perform a brake manoeuvre, and as a result, the driver also needs to brake in order to avoid a crash. In this way, 'Forward Collision Avoidance' (FCA) will also be investigated. Based on literature, the driver in front of the driver will brake smoothly with 2-3 m/s^2 or harsh with 5 m/s^2 (Koustanai et al., 2010).

Since both 'tailgating' and 'VRU detection' will be investigated as a risk factor, three dangerous events are selected per risk factor, hence six events will be investigated in total.

- Tailgating:

    - Urban environment: A vehicle is driving with a low speed (i.e., 20 km/h) in front of the driver, while the available gap in the opposite traffic is not long enough for an overtaking manoeuvre. The driver has to follow the vehicle for a specific distance, until the leading vehicle suddenly brakes (Abou-Zeid et al., 2011).
    - Rural environment: A vehicle overtakes both the driver and a leading vehicle that is driving in front of the driver. Suddenly, the overtaking car merges into the lane in front of the leading vehicle, with the result that the leading vehicle needs to adjust the driving speed (and as a result, also the driver).
    - Highway environment: A vehicle entering the highway in front of the leading vehicle, with the result that the leading vehicle needs to make a harsh brake.
- VRU detection:
    - Urban environment: A pedestrian crosses the road illegally -the traffic light does not permit crossing- when the driver is approaching the intersection on green phase.
    - Urban environment: At a mid-block crossing, a pedestrian (walking at a speed of 1.86 m/s) - visually obstructed from the driver’s view by a bus - attempts to cross the road while the driver is approaching (Oza et al., 2005).
    - Rural environment: A pedestrian -initially obstructed from the driver’s view by bushes- crosses the road at crossing, while the driver is approaching.

4.5.1.3 Condition used in order to vary the timing of intervention signals

Since car drivers are often distracted, **distraction** will be used as a condition in order to vary the timing of intervention signals within the third experimental drive.

More precisely, the **use of a mobile phone to send and read text messages** will be investigated. In this way, data can be compared with data obtained within the field trials by the OSeven smartphone app.

According to relevant literature, drivers who used their mobile phones to read and send text messages had slower response to stimuli on the road, more missed response events, reduction in speed, poor lane keeping, and fewer glances ahead. The use of mobile phones can also increase the reaction time (by approx. 35%) and reduce the ability to maintain a safe distance from the vehicle ahead. Consequently, drivers who are texting and driving are more prone to be involved in a "safety-critical event", i.e., an event leading to unintentional lane deviations, a crash-avoidance manoeuvre, a near crash or a crash. Although assessing the causal relationship between mobile phone use and crash risk is not easy, some previous studies estimated the increased risk, from between two to nine (Dingus et al., 2016; Klauer et al., 2014; WHO, 2011; McEvoy et al., 2005). In addition, the results from the Second Strategic Highway Research Program Naturalistic Driving Study (SHRP2) showed that hand-based mobile phone interactions increase crash risk, with odds ratios indicating that texting increases crash risk by ~6.1.

Experimental manipulation

In order to induce/include distraction, participants will **perform a secondary task** (i.e., sending and reading text messages) during the third drive. **Flags** (not visible to the participant) will be integrated in the 2 versions of the third drive so that ‘distraction’ is activated in the i-DREAMS system, allowing it to know *when* a participant is distracted (e.g., prior to and during a dangerous event). In this manner, the timing of the interventions can be adapted according to the implemented i-DREAMS intervention logic.

Although the main purpose is to investigate the effect of distraction on the timing of real-time interventions and the reaction of the participants to these interventions, **a moderate level of sleepiness (e.g., KSS of 4 or 5)** will also be configured within the i-DREAMS system. In this way, there is a multiplying effect of distraction and sleepiness. In the German car simulator trials, 'Bad weather' will not be activated within the i-DREAMS system.

4.5.1.4 Variables of interest

Related to tailgating, the variables of interest are:

- time headway (TH)
- distance headway (DH)
- detection time (i.e., accelerator release) (DT)
- reaction time (i.e., brake press) (RT)

Related to VRU detection, the variables of interest are:

- detection time (i.e., accelerator release) (DT)
- reaction time (i.e., brake press) (RT)
- time to collision (TTC)

4.5.2 Simulator trial for Car – Greece

4.5.2.1 Objectives

The objectives of the simulator trial for car drivers in Greece are to:

- investigate driving behaviour of car drivers with a focus on **tailgating and illegal overtaking**, and validate the STZ mathematical model for them (drive 1),
- test the monitoring equipment (i.e., Mobileye / i-DREAMS gateway) and intervention technologies targeting tailgating and illegal overtaking, with warnings either or not based on **bad weather conditions** (drive 1, 2, 3)
- obtain feedback from car drivers about these technologies (questionnaires)

4.5.2.2 Simulator drive description

Road environment

The simulator scenario has a total distance of approximately 15km and will include urban, rural and highway environments.

The urban environment will contain a speed limit of 30 km/h (road with 4 lanes: 2x2).

The rural environment will contain a speed limit of 70 km/h (road with 4 lanes: 2x2).

The highway environment will contain a speed limit of 130 km/h (road with 6 lanes: 3x3).

Tailgating behaviour will be investigated within these 3 road environments, while illegal overtaking will only be investigated within the urban environment.

Dangerous events

Since the focus is on tailgating and illegal overtaking, there will be a leading vehicle driving in front of the driver within the parts of the simulator drive in order to investigate tailgating and a vehicle performing a manoeuvre in front of or next to the driver within the parts of the drive in order to investigate illegal overtaking.

In order to investigate their tailgating behaviour in case of a dangerous event, the leading vehicle will perform a brake manoeuvre, and as a result, the driver also needs to brake in order to avoid a crash.

Since both ‘tailgating’ and ‘illegal overtaking’ will be investigated as a risk factor, three dangerous events are selected per risk factor, hence six events will be investigated in total.

- Tailgating:
    - Urban environment: A leading vehicle is driving at a low speed of 20 km/h in front of the driver in a four-lane urban road, while the available gap in the opposite traffic is not long enough for an overtaking manoeuvre. The driver has to follow the vehicle for a distance of 350m
    - Rural environment: A vehicle overtakes the driver and suddenly merges into the lane in front of the driver with the result that the driver needs to adjust the driving speed
    - Highway environment: A vehicle entering the highway in front of the leading vehicle, with the result that the driver needs to make a harsh brake
- Illegal overtaking (urban environment)
    - A vehicle suddenly exiting a parking space, with the result that the driver needs to make an illegal overtaking or a harsh brake in order to avoid a potential crash risk
    - The door of a parked vehicle suddenly opening in front of the driver, while the driver is approaching
    - A leading vehicle experiences an unexpected incident, which is in front of the driver, and as a consequence, abruptly reduces the driven speed, with the result that driver needs to adjust the driving speed and do a manoeuver

4.5.2.3 Condition used in order to vary the timing of intervention signals

Since car drivers often drive under **bad weather conditions**, **rain** will be used as a condition in order to vary the timing of intervention signals within drive 3. Research has indicated that, due to rain, there is a significantly increased risk for road accidents (Focant et al., 2016).

Experimental manipulation

In order to manipulate bad weather conditions, the third drive will include bad weather and within the i-DREAMS system, ‘bad weather’ will be activated. In this way, the i-DREAMS system knows that a participant is driving under bad weather conditions and the timing of the interventions can be adapted according to the implemented i-DREAMS intervention logic.

Although the main purpose is to investigate the effect of bad weather conditions on the timing of real-time interventions and the reaction of the participants to these interventions, **a moderate level of sleepiness (e.g. KSS of 4 or 5)** will also be configured within the i-DREAMS system. In this way, there is a multiplying effect of bad weather conditions and sleepiness. In the Greek car simulator trials, ‘distraction’ will not be activated within the i-DREAMS system.

4.5.2.4 Variables of interest

Related to tailgating, the variables of interest are:

- time headway (TH)
- distance headway (DH)

- detection time (i.e., accelerator release) (DT)
- reaction time (i.e., brake press) (RT)

Related to illegal overtaking, the variables of interest are:

- Average speed (AS)
- Lateral acceleration (LA), and its standard deviation (SDLA)
- Lateral position (LP), and its standard deviation (SDLP)
- Steering variability (SV)
- Signal use (SU)

4.5.3 Simulator trial for Truck – Belgium

4.5.3.1 Objectives

The objectives of the simulator trial for trucks are to:

- investigate driving behaviour of truck drivers with a focus on tailgating and speeding, and validate the STZ mathematical model for them (drive 1),
- test the monitoring equipment (i.e., Mobileye) and intervention technologies targeting tailgating, with warnings either or not based on the driver-state of sleepiness (drive 1, 2, 3)
- obtain feedback from truck drivers about these technologies (questionnaires)

4.5.3.2 Simulator drive description

Road environment

The simulator drive has a total distance of approximately 25km.

As truck drivers mainly drive outside city centres, the drive will include rural and highway environments.

The rural environment will contain a:

- speed limit of 70 km/h (road with 2 lanes: 1x1), and
- speed limit of 90 km/h (road with 4 lanes: 2x2)

The highway environment will contain a speed limit of 120 km/h (road with 6 lanes: 3x3). Although Belgium imposes a general speed limit of 120 km/h on highways, trucks (+3.5 tons) are only allowed to drive at a maximum speed of 90 km/h on highways in Belgium and are fitted with a speed limiter to ensure this.

Dangerous events

The focus is on speeding and tailgating. Related to tailgating, there will be a leading vehicle driving in front of the driver, within the entire simulator drive. In this way, the tailgating behaviour of the participant can be measured.

In order to investigate their tailgating behaviour in case of a dangerous event, the leading vehicle will perform a brake manoeuvre, and as a result, the driver also needs to brake in order to avoid a crash. In this way, we also investigate 'Forward Collision Avoidance' (FCA). Based on literature, the driver in front of the driver will brake smoothly with 2-3 m/s^2 or harsh with 5 m/s^2 (Koustanai et al., 2010).

Since only 'tailgating' will be investigated as a risk factor, two dangerous events are selected per road environment, hence six events will be investigated in total.

The type of event differs between the environments:

- Highway environment:
  - A car, that was overtaking the driver and a leading vehicle in front of the driver, suddenly merges into the lane in front of the leading vehicle.
  - A car, coming from the hard shoulder, suddenly merges into the lane in front of the car that is driving in front of the driver.
- Rural environment (90 km/h)
  - A car, exiting a parking lot, merges into the lane in front of the leading vehicle.
  - The leading vehicle suddenly brakes in order to turn right to visit a gas station.
- Rural environment (70 km/h)
  - A pedestrian that suddenly crosses the road in front of the leading vehicle.
  - The leading vehicle needs to brake (although the traffic light is green), since a car coming from the right ignores the red traffic light.

4.5.3.3 Condition used in order to vary the timing of intervention signals

Since truck drivers often experience sleepiness and/or fatigue due to driving for a long time in monotonous road environments, sleepiness will be used as a condition in order to vary the timing of intervention signals within drive 3.

4.5.3.4 Variables of interest

Since the experiment is related to speeding and tailgating, the variables of interest are:

- mean driving speed
- speeding tickets
- time headway (TH)
- distance headway (DH)
- detection time (i.e., accelerator release) (DT)
- reaction time (i.e., brake press) (RT)

Sleepiness will be measured by the CardioWheel that uses an electrocardiogram (ECG) reading. Alongside this measure, participants will complete the KSS survey to indicate their perceived level of sleepiness before, during and after each drive. The KSS is a 9-point subjective scale ranging from 1 = extremely alert to 9 = extremely sleepy (Åkerstedt & Gillberg, 1990). An overall sleepiness score will be derived from CardioWheel in order to compare with the subjective KSS assessment.

Experimental manipulation

Although it would be interesting to induce sleepiness (e.g., induce sleep deprivation), due to practical implications in the target group of professional truck drivers (e.g., time of participation to the experiment, availability for work after participation, insurance issues) this is not feasible.

In order to still include sleepiness as a condition, participants will receive an instruction such as: *"Image that you have not been sleeping well for a couple of night(s). Although you feel somewhat tired, you estimate that you are still fit to drive your truck. The i-DREAMS system, however, is able to detect a certain level of sleepiness and will respond by delivering a warning(s)."* In addition to this instruction, **a relatively high level of sleepiness (e.g., KSS of 7-8)** will be configured within the i-DREAMS system. Since it is the purpose to only investigate the effect of sleepiness on the timing of real-time interventions and the reaction of the participants to these interventions, ‘distraction’ and ‘bad weather’ will not be activated within the i-DREAMS system.

4.5.4 Simulator trial for Bus – Portugal

The simulator trial for bus will be divided into two separate trials, since a distinction is made between city bus drivers and coach drivers. Whereas coaches drive for long distances between cities or for international travel, city bus drivers mainly drive for shorter distances inside city centres.

4.5.4.1 Objectives for city bus drivers

The objectives of the simulator trial for city bus drivers in Portugal are to:

- investigate driving behaviour of city bus drivers with a focus on tailgating and vulnerable road user (VRU) detection, and validate the STZ mathematical model for them (drive 1),
- test the monitoring equipment (i.e., Mobileye) and intervention technologies targeting tailgating and VRU detection, with warnings either or not based on a distracted driver-state (drive 1, 2, 3)
- obtain feedback from city bus drivers about these technologies (questionnaires)

4.5.4.2 Simulator drive description for city bus drivers

Road environment for city bus drivers

The simulator drive has a total distance of approximately 18 km and will include an urban environment. This environment will contain a speed limit of 50 km/h (road with 4 lanes: 2x2).

Dangerous events for city bus drivers

Since the focus is on tailgating and VRU detection, there will be a leading vehicle driving in front of the subject driver during parts of the simulator drive in order to investigate tailgating, and vulnerable road users in order to investigate VRU detection.

In order to investigate their tailgating behaviour in case of a dangerous event, the leading vehicle will perform a brake manoeuvre, and as a result, the driver also needs to brake in order to avoid a crash. In this way, we also investigate ‘Forward Collision Avoidance’ (FCA).

Since both ‘tailgating’ and ‘VRU detection’ will be investigated as a risk factor, three dangerous events are selected per risk factor, hence six events will be investigated in total.

- Tailgating:
  - A cyclist crosses the road from the left side in front of the leading vehicle. As a consequence, the leading vehicle ahead performs a harsh brake and stops.
  - A van suddenly stops and turns on the emergency signals, forcing the leading vehicle to break suddenly
  - At an intersection with priority to the right, the leading vehicle breaks unexpectedly and performs a stop despite the lack of traffic from the right.
- VRU detection:
  - Two pedestrians cross the road without using a zebra crossing. They appear at the right side of the driver, from behind an obstacle like a car or bush
  - People are chatting near a crosswalk, suddenly one person decides to cross the road, just when the bus driver is approaching

    - The bus driver turns right. At the meantime, a pedestrian that is walking on a dedicated path crosses the road at the zebra crossing that is located in front of the driver's path

4.5.4.3 Condition used in order to vary the timing of intervention signals for city bus drivers

Since city bus drivers are often distracted, distraction will be used as a condition in order to vary the timing of intervention signals within drive 3. A realistic type of distraction among bus drivers will be selected (e.g., talking to a passenger).

Experimental manipulation

In order to induce distraction, participants will **perform a secondary task** during the third drive. Moreover, 'distraction' will be activated within the i-DREAMS system, so that the system knows *that* the driver is distracted. In addition, **flags** (that are not visible to the participant) will be integrated within (the two versions of) the third drive. In this way, the i-DREAMS system knows *when* a participant is distracted (e.g., prior to and during a dangerous event) so that the timing of the interventions can be adapted according to the implemented i-DREAMS intervention logic.

Although the main purpose is to investigate the effect of distraction on the timing of real-time interventions and the reaction of the participants to these interventions, **a moderate level of sleepiness (e.g., KSS of 4 or 5)** will be configured within the i-DREAMS system. In this way, there is a multiplying effect of distraction and sleepiness. 'Bad weather' will not be activated within the i-DREAMS system.

4.5.4.4 Variables of interest for city bus drivers

Related to tailgating, the variables of interest are:

- time headway (TH)
- distance headway (DH)
- detection time (i.e., accelerator release) (DT)
- reaction time (i.e., brake press) (RT)

Related to VRU detection, the variables of interest are:

- detection time (i.e., accelerator release) (DT)
- reaction time (i.e., brake press) (RT)
- time-to-collision (TTC)

4.5.4.5 Objectives for coach drivers

The objectives of the simulator trial for coach drivers in Portugal are to:

- investigate driving behaviour of car drivers with a focus on tailgating and illegal overtaking, and validate the STZ mathematical model for them (drive 1),
- test the monitoring equipment (i.e., Mobileye / i-DREAMS gateway) and intervention technologies targeting tailgating and illegal overtaking, with warnings either or not based on a distracted driver-state (drive 1, 2, 3)
- obtain feedback from coach drivers about these technologies (questionnaires)

4.5.4.6 Simulator drive description for coach drivers

Road environment for coach drivers

The drive has a total distance of approximately 27km and will include rural, motorway and highway environments.

The rural environment will contain a speed limit of 90 km/h (road with 2 lanes: 1x1 or with an overtaking lane: 1x2-2x1). However, coach buses are only allowed to drive at a maximum speed of 80 km/h on rural roads in Portugal.

The motorway environment will contain a speed limit of 100 km/h (road with 2 lanes: 1x1 or with an overtaking lane: 1x2-2x1). However, coach buses are only allowed to drive at a maximum speed of 90 km/h on motorways in Portugal.

The highway environment will only contain a speed limit of 120 km/h (road with 4 lanes: 2x2, and 6 lanes: 3x3). However, coach buses are only allowed to driver at a maximum speed of 100 km/h on highways in Portugal.

Dangerous events for coach drivers

Since the focus is on tailgating and illegal overtaking, there will be a leading vehicle driving in front of the driver within parts of the drive in order to investigate tailgating.

In order to investigate their tailgating behaviour in case of a dangerous event, the leading vehicle will perform a brake manoeuvre, and as a result, the driver also needs to brake in order to avoid a crash. In this way, we also investigate ‘Forward Collision Avoidance’ (FCA).

Moreover, road segments will be offered where overtaking is not legal in order to investigate illegal overtaking.

Since both ‘tailgating’ and ‘illegal overtaking’ will be investigated as a risk factor, three dangerous events are selected per risk factor, hence six events will be investigated in total.

- Tailgating:
    - Highway environment:
        - Shortly after merging into the highway, a vehicle suddenly appears in front of the bus to perform a road exit
        - A vehicle from the left lane merges into the central lane and forces the leading vehicle to brake
    - Motorway environment: A vehicle that is performing an illegal overtaking manoeuvre forces the leading vehicle to break harshly
- Illegal overtaking:
    - Motorway environment (2 lanes: 1x1): The bus drivers follows a slow driving truck driver
    - Rural environment (2 lanes: 1x1):
        - The bus is blocked behind a very slow moving lead vehicle on a road section where overtaking is illegal. Another vehicle signals the bus driver that (s)he should do an overtaking manoeuvre
        - The bus is driving behind a slow moving car

4.5.4.7 Condition used in order to vary the timing of intervention signals for coach drivers

For coach drivers, distraction will be used as a condition in order to vary the timing of intervention signals within drive 3. A realistic type of distraction among bus drivers will be selected (e.g., talking to a passenger).

Experimental manipulation

In order to induce distraction, participants will **perform a secondary task** during the third drive. Moreover, 'distraction' will be activated within the i-DREAMS system, so that the system knows *that* the driver is distracted. In addition, **flags** (that are not visible to the participant) will be integrated within (the 2 versions of) the third drive. In this way, the i-DREAMS system knows *when* a participant is distracted (e.g., prior to and during a dangerous event) and the timing of the interventions can be adapted.

Although the main purpose is to investigate the effect of distraction on the timing of real-time interventions and the reaction of the participants to these interventions, **a moderate level of sleepiness (e.g., KSS of 4 or 5)** will be configured within the i-DREAMS system. In this way, there is a multiplying effect of distraction and sleepiness. 'Bad weather' will not be activated within the i-DREAMS system.

4.5.4.8 Variables of interest for coach drivers

Related to tailgating, the variables of interest are:

- time headway (TH)
- distance headway (DH)
- detection time (i.e., accelerator release) (DT)
- reaction time (i.e., brake press) (RT)

Related to illegal overtaking, the variables of interest are:

- Average speed (AS)
- Lateral acceleration (LA), and its standard deviation (SDLA)
- Lateral position (LP), and its standard deviation (SDLP)
- Steering variability (SV)
- Signal use (SU)

4.5.5 Simulator trial for Rail-bound Vehicles – United Kingdom

The simulator trial for rail-bound vehicles will be divided into two separate trials, since a distinction is made between tram operators and train operators. Whereas tram operators drive in a mixed mode environment, train operators do not.

In contrast to car drivers, truck drivers and bus drivers, which are mostly not familiar with driving simulators, tram and train operators are already familiar with simulators since they are routinely used for training purposes.

4.5.5.1 Objectives for tram operators

The objectives of the simulator trial for tram operators in the United Kingdom are to:

- investigate driving behaviour of tram operators with a focus on speed and vulnerable road user (VRU) detection, and validate the STZ mathematical model for them (drive 1),
- test the monitoring equipment (i.e., Mobileye / i-DREAMS gateway) and intervention technologies targeting speed and VRU detection, with warnings either or not based on the driver-state sleepiness (drive 1, 2, 3)
- obtain feedback from tram operators about these technologies (questionnaires)

4.5.5.2 Simulator drive description for tram operators

Road environment for tram operators

The simulator drive will have a total distance of approximately 25km and will include an urban mixed traffic environment and a suburban segregated environment. The standard routes are suburban/segregated – Urban/Mixed – Suburban. Specific speeds are set for a station/road crossing and single-track segregated section.

Dangerous events for tram operators

In order to investigate VRU detection, the following 3 dangerous events will be included:

- VRU detection:
    - A pedestrian on the tracks in a suburban section
    - A pedestrian crossing the tracks in close proximity to the tram in an urban section
    - A pedestrian crossing in front of the tram at the station

In addition, some other dangerous events will be included:

- Two stations: one requiring left hand doors to open, one requiring right hand door to open
- One signal: signal set to stop requiring the tram to stop
- One road crossing

During these events (and during other segments of the track), speed will be investigated.

4.5.5.3 Condition used in order to vary the timing of intervention signals for tram operators

Avoiding driver's driving while sleepy has been a key focus of the rail industry in recent years. As driving while sleepy is likely to lead to increased reaction times (Durmer and Dinges, 2005), sleepiness will be used as a condition in order to vary the timing of intervention signals within drive 3.

Experimental manipulation

Although it would be interesting to induce sleepiness (e.g., induce sleep deprivation), due to some practical implications in the target group of professional tram drivers (e.g., time of participation to the experiment, availability for work after participation, insurance issues) this is not feasible.

In order to still include sleepiness as a condition, participants will receive an instruction such as: *"Image that you have not been sleeping well for a couple of night(s). Although you feel somewhat tired, you estimate that you are still fit to operate your vehicle. The i-DREAMS system, however, is able to detect a certain level of sleepiness and will respond by delivering a warning(s)."*

In addition to this instruction, **a relatively high level of sleepiness (e.g., KSS of 6 or 7)** will be configured within the i-DREAMS system. Variables of interest for tram operators

Related to speed, the variables of interest are:

- average speed, speeding events

Related to VRU detection, the variables of interest are:

- detection time, reaction time

Sleepiness will be measured by the wearable that uses a photoplethysmography (PPG) reading. Alongside this measure, participants will complete the KSS survey to indicate their perceived level of sleepiness before, during and after each drive. An overall sleepiness score will be derived from wearable in order to compare with the subjective KSS assessment.

4.5.5.4 Objectives for train operators

The objectives of the simulator trial for train operators in the United Kingdom are to:

- investigate driving behaviour of train operators with a focus on speed and interactions with existing train safety systems. Behaviour related to signals will also be observed to assess the feasibility of including interventions relating to Signals Passed at Danger (SPADs) in future versions of the i-DREAMS platform (drive 1).
- test the monitoring equipment (i.e., wearable) and simulated[2] intervention technologies targeting speed and SPAD with driver-state independent warnings (drive 1, 2, 3)
- obtain feedback from train operators about these technologies (questionnaires)
- In addition, since there are already some safety systems integrated within a train, also the use of safety systems will be explored.

4.5.5.5 Simulator drive description for train operators

Due to the COVID-19 pandemic, the simulated drive for train operators is not yet finalised, however, a rough outline will be given. The drive will probably have a total distance of approximately 25km.

Road environment for train operators

The simulator drive will include a high-speed section with a minimum of two station stops per drive with equal distance between stops. Several signals should be on the route with some ‘safe’ and some ‘set to danger’.

Dangerous events for train operators

Suggestions in order to investigate speed and SPADs in trains include:

- stopping at a station
- signals set at danger/warning

The use of safety systems will be investigated by observing the drivers’ interaction with those fitted on the train as standard.

4.5.5.6 Condition used in order to vary the timing of intervention signals for train operators

Experimental manipulation

In order to explore existing safety systems in the context of speed and SPADs more thoroughly, options are currently being explored about how to appropriately manipulate driver behaviour. One option is to ask the drivers to drive faster than they would normally on the approach to a signal or to driver over the track speed limit. The appropriateness and feasibility of these options are currently being explored with the operator.

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[2] Due to the nature of the train mode, it was not possible to integrate the Cardio Gateway with monitoring sensors and interventions. Instead, warnings will be triggered in relation to the simulator output either manually or preferably automatically.

4.5.5.7 Variables of interest for train operators

Related to speed, the variables of interest are:

- Absolute speed, compared to speed limit
- Variability of speed
- acceleration/deceleration
- emergency brake use
- signal status (risk factors)

Related to the use of safety systems, the variables of interest are:

- safety system alert and driver response
- video of driver use of controls/safety systems inside the simulator

Sleepiness will be measured by the wearable I that uses a photoplethysmography (PPG) electrocardiogram (ECG) reading. Alongside this measure, participants will complete the KSS survey to indicate their perceived level of sleepiness before, during and after each drive. An overall sleepiness score will be derived from the wearable in order to compare with the subjective KSS assessment.

5 Summary

The purpose of this deliverable was to describe in detail the simulator trials that are part of WP5 in the i-DREAMS project. It builds on the specifications and recommendations that were outlined in D3.4: Experimental protocol. This document should be used as a guideline in preparation of the simulator trials.

The technology and driving simulators that will be used for the simulator trials was presented in chapter 3, together with a proposed architecture to interface driving simulators with i-DREAMS equipment in a way that makes key equipment interchangeable between vehicle and simulator. Five different driving simulators will be used for the simulator trials, 2 car simulators, 1 heavy vehicle simulator a tram simulator and a train simulator.

In chapter 4, a generic design for all simulator trials was elaborated, followed by a detailed individual description for each of the different trials. Earlier it was decided that the simulator trials would be a fractional factorial and within-subject design, based on the recommendations from D3.4, a generic protocol was presented. This includes two practice drives where the participant gets the chance to get familiar with the simulator and will be asked to perform some basic tasks. The practice drives will be followed by 3 experimental drives. During the first drive, i-DREAMS technology will be de-activated and the participant will be monitored in order to collect benchmark data. During the second drive, i-DREAMS technology (real-time interventions) will be activated and 1 or 2 risk factors (tailgating, VRU's) will be included in the drive in the form of 3 dangerous events per risk factor. For each trial, the focus of risk factors was narrowed down to 1 or 2 risk factors, based on what is relevant for the mode that the trial is focussing on. But together, the combination of trials covers all risk factors that are relevant within i-DREAMS. In the third and final experimental drive, an additional condition (distraction, bad weather, sleepiness) that changes the timing of the real-time interventions according to the implemented i-DREAMS intervention logic will be introduced.

The selection of risk factors and additional condition for the simulator trials is as follows:

Country	Mode	Participants	Risk Factors	Condition
Belgium	Truck	30	Tailgating, speeding	Sleepiness
Germany	Car	30	Tailgating, VRU	Distraction
Greece	Car	30	Tailgating, Overtaking	Weather
Portugal	Bus (coach)	15	Tailgating, Overtaking	Distraction
Portugal	Bus (Bus)	15	Tailgating, VRU	Distraction
United Kingdom	Rail (Tram)	15	VRU, speeding	Sleepiness
United Kingdom	Rail (Train)	15	Speeding, signal passed at danger	Sleepiness

For every drive within each trial, multiple versions are being created in order to minimize the effects that result from learning or a particular order of events. A detailed schematic overview for each trial was created and is being used as guide for programming the simulator drives. This description consists of "building blocks" such as dangerous events, masking events, and filler pieces that can be placed in a certain order. It also contains detailed information about roadway environment and other driving conditions.

Current status and next steps

At the time of writing, preparations for the simulator trials are ongoing. The car and heavy vehicle simulators (used at TUM, UHASSELT and BARRA) are already fully equipped with i-DREAMS equipment and successful pilot tests have been performed. Action is currently ongoing to install i-DREAMS equipment in the other simulators (NTUA, LOUGH). With the detailed description of all simulator drives now available, scenario programming has started.

With a detailed procedure and time schedule for each session now available, participant recruitment and follow up can continue and scheduling of sessions can start. The simulator trials are planned to start in November 2020 and run through June 2021. Results of the simulator trials will be presented in D7.2: Effectiveness evaluation of the interventions.

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Annex 1: Script simulator drives for cars – Germany

Run in	Lane	Road environment	Speed limit (km/h)	0	Symbol	Event
	1x1	Rural	70	500		
section 1	1x1	Rural	70	750	🟨 +	Intersection giving right of way to the driver
	1x1	Rural	70	1050	🟩 +	unsignalised intersection + caution for cyclist" sign - cyclist from right (precursor VRU collision event 1)
	1x1	Rural	70	1500	🟨 +	Intersection giving right of way to the driver
	1x1	Rural	70	1850	CE	critical event 1 - cyclist from right (VRU collision event 1)
section 2	2x2	Rural	70	2250-2350	car in front of driver	low speed car in front of driver
	2x2	Rural	70	2650-3000	a car overtakes the leading car in front of	a car overtakes the driver and the leading car in front of driver, and merges into the lane in front of them
	2x2	Rural	70	3000		leading car applies a soft brake due to the overtaking manoeuvre (precursor tailgating event 2)
	2x2	Rural	70	3500	🟨 ↰	curve to the left - 2350, C, 300, 150, 130
	2x2	Rural	70	4100-4400	a car overtakes the leading car in front of	a car overtakes the driver and the leading car in front of driver, and merges into the lane in front of them
	2x2	Rural	70	4400	CE	critical event 2 - leading car applies a harsh brake due to the overtaking manoeuvre (tailgating event 2)
section 3	3x3	Highway	no speed limit	4700	merging/entering highway	driver enters a highway
	3x3	Highway	no speed limit	5200-5700	car in front of driver	low speed car in front of driver
	3x3	Highway	no speed limit	6300-7000	car in front of driver	low speed car in front of driver - gap in the adjacent lane is not enough for overtaking manoeuvre
	3x3	Highway	no speed limit	7000	a car coming from entry lane and merging	leading car applies soft brake (precursor tailgating event 3)
	3x3	Highway	no speed limit	7500-8500	car in front of driver	low speed car in front of driver
	3x3	Highway	no speed limit	8500	CE	critical 3 - leading car applies harsh brake as a car merges into the lane from the entry lane (tailgating event 3)
section 4	3x3	Highway	no speed limit	9000	Exit highway	driver exits highway
	2x2	Urban	50	9300	🟧 +	car at yellow traffic lights in front of driver
	2x2	Urban	50	9700	☰	pedestrian from right, pedestrian from left at pedestrian crossing
	2x2	Urban	50	10150-10190	3 lanes	bus at bus stop (=3rd lane) - a pedestrian crosses in front of the car at bus station (precursor VRU collision event 2)
	2x2	Urban	50	10550-10650	car in front of driver	green car in front of driver
	2x2	Urban	50	11000	🟧 +	driver turns right when a pedeatrian from right crosses the road that driver enters (precursor VRU collision event 1)
section 5	2x2	Urban	50	11450	🟩 +, STOP	car from left at stop sign
	2x2	Urban	50	11850-11890	3 lanes	bus at bus stop (=3rd lane)
	2x2	Urban	50	11890	CE	critical event 4 - a pedestrian crosses in front of the car at bus station (VRU collision event 2)
	2x2	Urban	50	12350	🟧 +	car at red traffic lights in front of driver
	2x2	Urban	50	12750	☰	pedestrian from right at pedestrian crossing
	2x2	Urban	50	13150	CE	critical event 5 - driver truns right when a pedestrian crosses the road that driver enters (VRU collision event 1)
section 6	1x1	Urban	50	13500	🟨 +	motorcycle from right at intersection with right of way
	1x1 + parking lar	Urban	50	13800-14000	car in front of driver	yellow car in front of driver with slow speed - gap in the opposite traffic is not enough for overtaking manoeuvre
	1x1 + parking lar	Urban	50	14000	☰	yellow car applies a soft brake as approaches the crossing (precursor tailgating event 1)
	1x1 + parking lar	Urban	50	14350	🟩 +, STOP	car from right at stop sign
	1x1 + parking lar	Urban	50	14700-15000	car in front of driver	green car in front of driver with slow speed - gap in the opposite traffic is not enough for overtaking manoeuvre
	1x1 + parking lar	Urban	50	15000	CE	critical event 6 - green car applies a harsh brake as a pedestrians walks into the road in front of it (tailgating event 1)
End scenario (ES)	1x1	Urban	50	15500		

Symbol	Description	Number of times within scenario
🟨 +	Intersection giving right of way	3
🟩 +, STOP	Intersection stop sign	2
🟧 +	Intersection traffic light	3
CE	Critical event	6
☰	Pedestrian crossing	3
🟨 ↰	Curve to the left (distance, curve,	1
🟩 +	Unsignalised intersection	1

Annex 2: Technology acceptance questionnaire

Technology acceptance questionnaire

Please think about the [in-vehicle information and prompts that were presented to you during driving] / [the intervention platform].

To which extent do you agree or disagree with the following statements (Strongly Disagree', 'Disagree', 'Slightly Disagree', 'Neutral', 'Slightly Agree', 'Agree' or 'Strongly Agree')

Construct / items	Real-time intervention	Post-trip intervention
Performance expectancy *		
The system is useful while driving.	X	
Using the system increases my driving performance.	X	x
If I use the system, I will reach my destination safely.	X	
Ease of use / effort expectancy		
My interaction with the system is clear and understandable. *		x
It was easy for me to become skillful at using the system. *		x
I find the system easy to use. *		x
Learning how to operate the system is easy for me. *		x
I think the i-DREAMS system is easy to use +	X	
I think the i-DREAMS system is easy to understand +	X	
I think the i-DREAMS system is annoying +	X	
Attitude towards using technology *		
Using the system is a good idea.	X	x
The system makes driving more interesting.	X	x
Interacting with the system is fun.		x
I like interacting with the system.		x
Social influence *		
I would be proud to show the system to people who are close to me.	X	x
People whose opinions are important to me would like the system too.	X	x
In general, people who I like would encourage me to use the system.	X	x
Facilitating conditions *		
While using the system I can maintain safe driving behavior.	X	
I have the knowledge necessary to use the system.		x
Self-efficacy * I could complete a task or activity using the system ...		

Construct / items	Real-time intervention	Post-trip intervention
... if there was no one around to tell me what to do.		x
... if I could call someone for help if I got stuck.		x
… if I had a lot of time.		x
… if I had just the built-in help facility for assistance.		x
Anxiety *		
I have concerns about using the system.	X	x
I think I could have an accident because of using the system.	X	
The system is somewhat frightening to me.	X	
I fear that I do not reach my destination because of the system.	X	
I am afraid that I do not understand the system.	X	x
I am confident that the system does not affect my driving in a negative way.	X	x
Perceived Safety *		
I believe that using the system information is dangerous.	X	
Using the system information requires increased attention.	X	
The system distracts me from driving.	X	
I feel save while using the system information.	X	
Using the system information decreases the accident risk.	X	x
I can use the system information without looking at it.	X	
Perceived Usefulness + I think using the i-DREAMS system ...		
... makes me a safer driver.	X	x
... makes it easier to drive.	X	x
... makes me more aware of my surroundings (other vehicles, lane position, etc.).	X	
... reduces distractions.	X	x
... improves my driving.	X	x
Trust +		
I trust the information I receive from the i-DREAMS system.	X	x
I think I can depend on the i-DREAMS system.	X	
I will feel more comfortable doing other things (e.g., adjusting the radio) with the i-DREAMS system.	X	
Behavioral Intention to Use +		
If I had a choice, I would continue to use the i-DREAMS system.	X	x
I would recommend the i-DREAMS system to other drivers.	X	x

* adapted from Osswald et al. (2012); + adapted from Ghazizadeh et al. (2012)