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Deliverable D4.1

Implementation Guidelines

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2	12/12/2017	Reviews of single inputs sent to partners for update
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6	13/04/2018 – 20/04/2018	Integration of VTT Tampere test site and integration of partners' input. Final review by all involved partners
7	27/04/2018	Integration of the final feedbacks of partners
8	30/04/2018	Ethical and final review

Consortium - List of partners

Partner No	Short name	Name	Country
1	UIC	International Union of Railways	France
2	VTT	VTT Technical research centre of Finland Ltd	Finland
3	NTNU	Norwegian University of Science and Technology	Norway
4	IFSTTAR	French institute of science and technology for transport, development and networks	France
5	FFE	Fundación Ferrocarriles Españoles	Spain
6	CERTH-HIT	Centre for Research and Technology Hellas - Hellenic Institute of Transport	Greece
7	TRAINOSE	Trainose Transport – Passenger and Freight Transportation Services SA	Greece
8	INTADER	Intermodal Transportation and Logistics Research Association	Turkey
9	CEREMA	Centre for Studies and Expertise on Risks, Environment, Mobility, and Urban and Country planning	France
10	GLS	Geoloc Systems	France
11	RWTH	Rheinisch-Westfaelische Technische Hochschule Aachen University	Germany
12	UNIROMA3	University of Roma Tre	Italy
13	COMM	Commsignia Ltd	Hungary
14	IRU	International Road Transport Union - Projects ASBL	Belgium
15	SNCF	SNCF	France
16	DLR	German Aerospace Center	Germany
17	UTBM	University of Technology of Belfort-Montbéliard	France

Executive summary

The objective of WP 4 within the project SAFER-LC is to evaluate the positive and negative impact of tested safety measures implemented or piloted at level crossings in the frame of SAFER-LC project. The effectiveness of safety measures can be evaluated in various testing environments, provided by the partners, ranging from simulators to evaluations in the real world traffic context of living labs.

	SAFER-LC Testsites
Simulation	**DLR** Driving Simulators
	RWTH – mock-up LC field + rail vehicle
	CEREMA Rouen test site for monitoring and remote maintenance
	VTT Tampere – self driving vehicles
	DLR mobile traffic surveillance system
	TRAINOSE + CERTH mobile communications testing, living lab, trains
Real World	**INTADER** level crossings

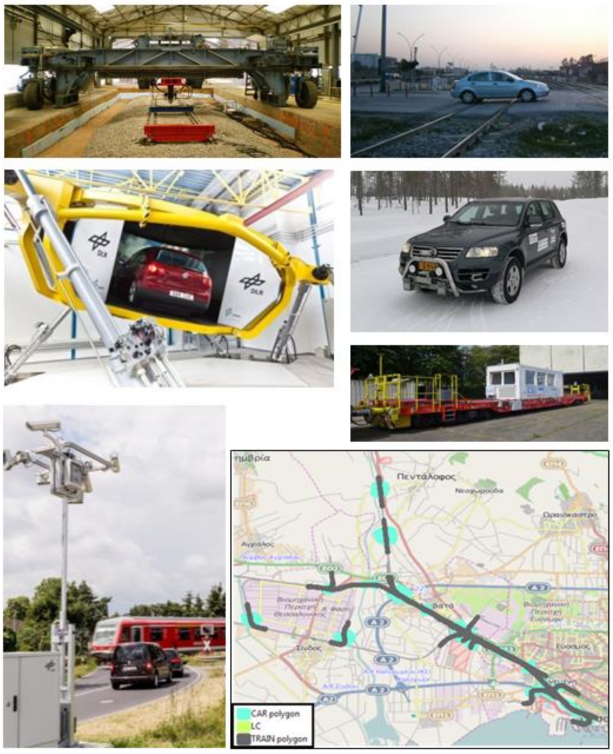

Figure 1: SAFER-LC Test Sites

The purpose of this deliverable is to provide an overview of the major testing environments in SAFER-LC that will be used for research purposes around level crossing (LC) safety. The variety of test sites enables tests of various safety measures with different levels of maturity. While safety measures on a very conceptual level can be implemented in a simulation environment, more mature measures can be tested under real traffic- or close to real traffic circumstances. At all test sites in SAFER-LC, special attention will be paid with regard to privacy and data protection standards.

In order to analyse the effectiveness of innovative safety measures in potentially dangerous situations at level crossings, driving simulators operated by German Aerospace Centre (DLR) offer the possibility to run experiments under standardized and reproducible conditions. To deal with the challenge of testing safely and efficiently under realistic circumstances, DLR provides driving simulators for road and rail traffic.

At RWTHs rail testing track situated at RWTH Aachen University's Institute for Rail Vehicles (IFS), a mock-up level crossing will be used to evaluate technological measures developed in SAFER-LC under close to real situations. The test site comprises of a large road/rail intersection area where different level crossing scenarios can be implemented depending on the needs in SAFER-LC.

Research Vehicles on the rail- and roadside are part of the Aachen test site. Specific hazardous situations that are too dangerous or complex to test in real traffic can be implemented on RWTHs testing site. These scenarios can be used, for example, as an input for the development of smart video detection systems. Academic and industry partners involved in the project such as e.g., Commsignia, will deploy equipment and implement specific scenarios for showcasing novel technical and methodological contribution of SAFER-LC to the enhancement of safety in LCs. These scenarios can be used e.g., as Input for the development of smart video detection systems and aims at the evaluation and demonstration of the use of vehicle-to-infrastructure (V2X) communication technologies and applications in the daily operation of rail/road level crossings, showing the benefits of communication and information sharing in the compliance and enhancement of safety measures defined by other work packages of this project, validating their feasibility and testing the performance.

At the CEREMA test site in Rouen, smart and embedded wireless sensor networks can be used to gather accurate information about the condition of the LC. The test site is specialised on full scale experiments of structural behaviour using instrumentation and in developing measuring devices for assessment of infrastructure state and earthwork construction machines. The structural behaviour and structural deformation of railway tracks, road infrastructure, and dike infrastructure can be tested, including environmental and natural risks with specific parameters.

Beyond experiments in simulator environments and at test-tracks, certain research activities can be conducted in real-world testing environments. In Greece, a total of 30 level crossings in the surroundings of Thessaloniki will be used for testing communications technologies like 3G or 4G mobile to increase safety at LCs. This test under the scientific lead of CERTH will involve taxis, trucks as well as regional, suburban and freight trains of TRAINOSE that will be equipped accordingly. The trains will provide real-time data about their location, speed and their estimated time of arrival when approaching the LCs.

VTT has two vehicles that serve as research platforms for the development of connected and self-driving cars. Both vehicles are equipped with lidar, radar and camera sensors for environment perception as well as GNSS, inertial and odometria. For connectivity, both vehicles has ITS-G5, LTE and pre-5G communication units on board.

In Germany, level crossings in real traffic can be equipped with DLR’s AIM Mobile Traffic Acquisition system. With this video acquisition platform, motorized as well as non-motorized road users are detected, tracked and classified as e.g. cars, trucks, railways and pedestrians and cyclists. The related video and numerical trajectory data can be used to evaluate the effect of safety measures based on specific performance indicators connected to the behaviour of the identified traffic participants.

In Turkey, a series of technological and non-technological measures will be tested under the lead of INTADER on five different level crossings that are frequently used especially by the vulnerable road users (in this case refugees, persons with reduced mobility, elderly and children). Surveillance camera systems will serve the analysis of measures to enhance safety, that will be focussing especially on vulnerable road users.

The implementation guidelines of the SAFER-LC test sites in this document serve as an overview of the available test environments as well as a starting point for the implementation for technical and non-technical safety measures. Based on the descriptions of the test sites, the suitable environment to test innovative measures that aim at enhancing level crossing safety can be chosen.

Table of content

1. INTRODUCTION

SAFER-LC aims to improve safety of level crossings (LCs) by minimizing the risk of level crossing accidents. This will be done by developing innovative and user-centered solutions and tools. A toolbox that contains technological as well as non-technological safety measures will be a key result of the project. The overall project results are meant to help both rail and road managers to improve safety at level crossings. While the work packages (WP) 2 and 3 are designed to understand the human factor at level crossings and to design countermeasures, the central task of WP 4 is to evaluate the proposed safety measures.

As the first step towards the evaluation, WP4 starts with the definition of the "evaluation framework". This framework serves as a basis for the evaluation of safety measures that will be described and developed in the SAFER-LC project. The evaluation framework will describe in detail all proposed test sites that can be used within the project. These test sites range from simulations to real world sites, to allow a wide variety of innovative safety measures to be tested at different stages of their development.

The purpose of this document is to serve as an overview and a handbook for the researchers that are planning to carry out evaluations within the test sites in SAFER-LC. The document will support the researchers in selecting the safety measures which can be reasonably tested at existing test site. This deliverable will describe in detail for each test site:

- Guidelines to pilot implementation, operation and monitoring
- Description of data that can be acquired and indicators that can be assessed in the test site
- Description of tools that are used for data collection within the site
- Examples of safety measures that can be evaluated in test site
- Prerequisites and boundary conditions of test site use

In the following sections, the test sites that can be used in SAFER-LC are described in detail. The deliverable is structured with regard to the level of abstraction of the test sites. It will start with chapters containing the guidelines to the more controlled and artificial testing environments like the driving simulators (chapter 2) and the test tracks in Aachen (chapter 3) and Rouen (chapter 4). Next, the controlled experimental test sites, and the guidelines to the real-world pilots will be introduced with chapters containing the AIM traffic acquisition system (chapter 6), the Thessaloniki living lab (chapter 7) and the level crossings chosen for the SAFER-LC research purposes in Turkey (chapter 8).

2. SIMULATORS AT DLR

2.1. Simulators at DLR at a glance

- **Test site location / address:** DLR e.V. (German Aerospace Center e.V.), Institute of Transportation Systems, Lilienthalplatz 7, 38108 Braunschweig, Germany
- **Accessibility:** Private Test sites (located on company grounds)
- **Test site contacts:** Jan Grippenkoven, jan.grippenkoven@dlr.de, Annika Dreßler, annika.dressler@dlr.de
- **Company that owns Test site:** DLR e.V. (German Aerospace Center e.V.), Institute of Transportation Systems

Integrated safety systems in transportation systems need to be reliable, understandable, easy to use and may not be a safety risk when being implemented in a vehicle or in the traffic environment. Testing is required for evaluation as well as validation before implementing safety systems in practice. Challenges exist due to testing under realistic test-circumstances and the pressure to test in a cost and time efficient manner. In SAFER-LC an aim is to develop integrated cross-modal solutions and tools, which help to improve safety and minimize risk at level crossings. Systems with different complexities need to be tested under realistic circumstances before implementing and testing them in the real traffic context in a way that is as well cost as time efficient and reproducible. To handle this challenge, DLR provides a variety of driving simulators for road and rail traffic. Parts of the simulation infrastructure are the *RailSET* (Railway Simulation Environment), the *VRLab* (Virtual-Reality-Laboratory) and the *DynSim* (Dynamic Driving Simulator) (see Figure 2 to Figure 4). The simulation infrastructure enables to test the effects of safety measures that e.g. make use of assistance systems in vehicles, changes in the traffic infrastructure, V2X or I2X communication.

Figure 2: RailSET (Railway Simulation Environment)

Figure 3: VRLab (Virtual-Reality-Laboratory)

Figure 4: DynSim (Dynamic Driving Simulator)

2.2. Technical description of the test site

All three driving simulators introduced in the previous section consist of the same three essential visible components. The three essential visible components of the simulators are (1) a **visualization of the environment outside the vehicle**, (2) a **vehicle** within the simulated environment and (3) **an experimenter working station** outside the simulated environment to run the experiment in the role of the investigator. During an experiment the investigator monitors and (if not automated) operates the overall experiment from the experimenter working station. The participant is located within a vehicle (train or car) during the experiment which is located within a projection space that displays the simulated driving environment.

The underlying software is a DLR developed variation of the system *Dominion*. Attributes of Dominion are easy usable standardized user-interfaces and the possibility to integrate (third party) applications and components into the simulators. Dominion is compatible with the software SUMO, which is a traffic flow simulation software developed by DLR. The combination of those software tools enables the integration of a realistic traffic environment into the simulators.

In the following section features of the three simulators *RailSET* (Railway Simulation Environment), the *VRLab* (Virtual-Reality-Laboratory) and the *DynSim* (Dynamic Driving Simulator) are described in more detail.

Similarities between the three simulators

- In all of the simulations different components of the traffic environment (including level crossings) can be combined to almost any needed visual simulation of a driving route as well as environment. For the VRLab and the DynSim an exact replica of parts of the city of Braunschweig can be used as an environment. Likewise, in the RailSet the realistic railway line between the cities of Braunschweig and Gifhorn can be used.
- Driving simulations enable a relatively exact reproducibility and a high level of standardization of certain traffic scenarios for each participant in an experiment. This increases the internal validity and generalizability of statistical results, due to a decreased error variance.
- The working station enables the investigator to monitor the test subject, the simulated environment and the function of assistance system during experiments.

The RailSET (Figure 2)

- The mock-up within the RailSET represents a driver's real cabin (model BR424) of a German regional train in an ETCS-certified accuracy, containing an exact replica of an operation panel. To make it more adaptable, it contains three touch displays, different adaptable physical control units and front as well as side windows.
- Besides ETCS, the punctiform train protection system that is still widely used in Germany can be simulated within the train driving simulation.

The VRLab (Figure 3)

- The environment is simulated using a 360°-front-projection visualization. Rear gates of the lab can be opened to exchange the vehicle that is supposed to be used within the visualization environment. If closed, the rear gates are part of the 360° surrounding screen, which is used to simulate the 360° environment. The VRLab has a resolution of 1200x1920 pixels per each 30° projection angle.

The DynSim (Figure 4)

- The environment is simulated using a 270°-back-projection visualization. The DynSim has a resolution of 1400x2100 for each 30° projection angle. In combination with the visualization a moving-base hexapod platform can be used to simulate motion to give a direct feedback of the driving dynamic. The motion characteristics of the dynamic simulation system are listed under Table 1.

Table 1: Motion characteristics

	Position	*Velocity*	*Acceleration*
Longitudinal	±1,50 m	±2 m/s	±10 m/s²
Lateral	±1,40 m	±2 m/s	±10 m/s²
Vertical	±1,40 m	±1 m/s	±10 m/s²
Pitch	±20 °	±50 °/s	±250 °/s²
Roll	±21 °	±50 °/s	±250 °/s²
Yaw	±21 °	±50 °/s	±250 °/s²

2.3. Safety measures that can be evaluated in test site

In all of the driving simulators typically human reactions to modifications in the vehicle (like advanced driver assistance systems) or in the traffic environment are tested. Safety related systems can be tested in various experimental scenarios. In the simulators tests have been conducted with regard to usability, perceptibility, driving performance as well as user acceptance of prototypical measures in- and outside the vehicle. Furthermore, the influences of emotions, workload or fatigue have been tested with regard to the driving performance.

Technical measures that have been tested in the past contain measures of hardware and/or software designed to support automated driving functions. Examples are a dynamic control stick with haptic feedback for speed control in a train, LED strips for displaying the status and changes of automation of highly automated cars of the future and automated driving functions of a train. Beyond that, V2X-interaction measures can be integrated in the simulations and the effect of certain messages on the user can be tested.

Typical research questions are for instance:

- What is the influence of an assistance system on driver behaviour?
- Does the investigated human machine interface (HMI) influence the drivers' performance?
- How does a driver react in a specific traffic scenario?
- How does a certain emotion influence the drivers' performance?
- How does a specific stimulus in- or outside the vehicle influence drivers' driver performance?

Conducting an experiment in a driving simulator requires a detailed description of the measure that is supposed to be tested. Beyond that, a clear research question should be formulated. Based on the research question suitable performance indicators and if needed additional tools to answer it can be identified. Subsequently, the sample size of participants for the experiment is defined and participants are recruited. Based on the experimental data obtained, appropriate statistical analyses are used to analyse effects of interest. Within SAFER-LC various safety measures might be tested. These measures might as well be hardware solutions as software based systems that transmit visual or auditory information to a driver during the approach towards a level crossing. However, there are limitations with regard to systems that can be tested within the driving simulators. The feasibility of simulating certain features has to be analysed beforehand.

2.4. Data and indicators that can be acquired

Data which can be acquired contain driving (performance) data (like time to collision, lane keeping, distance keeping, speed, acceleration, angel of the steering wheel, pressure on pedals, and so on), reaction times, control panel input, movement and orientation of head and eyes (Eyetracking), physiological data (e.g. EEG and ECG), elector dermal activity and test subject's performance on secondary tasks.
It is possible to use questionnaires (for instance NASA TLX) and/or interviews as well as any visible and hearable video and audio data before, during and after the experiment.
Data related to technology performance can be acquired, for instance the reaction of an assistance system of a vehicle to a certain situation.
Examples for relevant indicators in the context of a level crossing are for example whether a driver stops in case a train is coming or not, the focus of his visual attention during approach or his speed choice. Effects measured by relevant performance indicators can be compared between a baseline condition and an experimental condition.

2.5. Description of tools that are used for data collection within the site (technical details)

Specific tools that are used contain software and electromechanical devices, which record driving (performance) data as a combination of physical activities of test subjects and of the actual situations within the simulation. Eyetracking is conducted through systems that either work remotely through cameras located in a vehicle or via a head mounted system that is worn by participants. Physiological data are acquired through external recording devices that receive their input usually through electrodes that are temporarily glued on the skin of a participant. Data concerning test subjects' performance on secondary tasks are usually collected through external media like tablet computers or laptops. Time stamped driving data are collected via specific recording modules in each of the simulators. They are stored in the backend system Dominion. Theoretical and practical training with the test site is a necessary prerequisite to be able to run the simulators and to use the data. Experiments can only be conducted by staff of the DLR e.V. Institute of Transportation Systems.

2.6. Guidelines to pilot implementation, operation and monitoring

2.6.1. Pilot implementation guidelines

The test sites are ready for use. Still, they need to be adapted to potential measures and systems that are supposed to be tested. If a measure is supposed to be tested, it is required to describe testing requirements in detail and send requests (including the measure and questions that are supposed to be answered regarding the measure) to DLR.
The first step after a test is requested is a feasibility analysis by DLR. Detailed requirements of the to be tested equipment and / or scenario are a necessary precondition. If the experiment is feasible, a timeline is set up.
Experiments using the driving simulators are exclusively supervised by DLR staff. If certain hardware needs expert supervision it might be necessary that an external expert is present during testing hours.

2.6.2. Operation and monitoring guidelines

Certain operating and monitoring guidelines have to be taken into account when using the driving simulators:

- Only DLR staff is responsible for conducting tests within the driving simulators.
- Collected data are temporarily stored in the backend system at DLR Institute of Transportation Systems.
- Data is analysed an aggregated to answer the research questions before transferring it to partners. Raw data cannot be handed out to partners. Especially data that can be related to individual persons will never be handed out to third partners.
- The privacy and voluntary participation of subjects in experiments are of uttermost importance. No data are stored without an informed consent of participants.
- Maintenance work as well as monitoring is done by DLR staff.

2.7. Prerequisites and boundary conditions of test site use

In order to use the driving simulators, it is required to provide a detailed description of the measure that is planned to be tested as well as the related research questions and hypotheses. Based on this information it can be checked whether the described measure can be implemented and tested within the simulators. Experience in the field of leading experiments and with the driving simulators are necessary to successfully run an experiment. Therefore, the experiments are exclusively lead by DLR staff.
The test site is ready to be used. However, it has to be considered that other research activities make use of the test site as well and that it takes certain time to adapt a simulator to a new measure. The test of a new measure must be scheduled under consideration of these circumstances. Therefore, it is important to hand in a testing request as early as possible to avoid waiting time.

The participation of test subjects in the experiment always happens voluntarily. Participants are informed that they can abort an experiment at any time. Data of participants will not be handed out to third parties and only be used for analytical purposes in the experiment. Data will be condensed so that no inferences can be drawn about the person that the data stems from. After the analysis of the condensed data and documentation of overall results all raw data (especially video material) will be deleted.

When planning a simulator study, it has to be taken into account that some persons react to simulators with what is called 'simulator sickness' (nausea). In case of nausea of participants experiments are stopped immediately.

2.8. Use of Simulators in SAFER-LC

In SAFER-LC WPs2 and 3 innovative user-centred measures will be described, which are supposed to improve safety and minimize the risk at level crossings. This will lead to a toolbox of smart technological as well as non-technological solutions in field of road traffic, railway and the interface between both. In WP4, the above described test site can be used to analyse the measures. Testing of measures within the described simulators is safe as well as cost- and time efficient. It happens under standardized, reproducible conditions.

2.9. References

Brandenburger, N., & Jipp, M. (2017). Effects of expertise for automatic train operations. *Cognition, Technology & Work*, S. 699-709.

Dziennus, M., Kelsch, J., & Schieben, A. (2016). Ambient Light: An integrative, LED based interaction concept for different levels of automation. *VDI-Berichte 2288*, S. 103-110.

Stein, J., & Naumann, A. (2016). Monotony, Fatigue and Microsleeps - Train driver' daily routine: a Simulator study. *Rail Human Factors* (S. 96-102). Braunschweig: ITS Automotive Nord.

Unni, A., Ihme, K., Jipp, M., & Rieger, J. W. (2017). Assessing the Driver's Current Level of Working Memory Load with High Density Functional Near-infrared Spectroscopy: A Realistic Driving Simulator Study. *Frontiers in Human Neuroscience*, S. 1-14.

3. RWTH AACHEN TEST SITE

3.1. RWTH Aachen Test Site at a glance

- **Test site location / address:** Institute for Rail Vehicles and Transport Systems, Seffenter Weg 8, 52074 Aachen, Germany
- **Accessibility:** Private Test site
- **Test site contacts:** Florian Eßer <florian.esser@ifs.rwth-aachen.de>
- **Company that owns Test site:** RWTH Aachen University
- **Partners intended to use this test site:** Commsignia,

RWTHs rail testing track is situated at RWTH Aachen University's Institute for Rail Vehicles (IFS). A mock-up LC will be set up to demonstrate SAFER-LC equipment that can be used on a real rail vehicle.

On the mock-up LC different pieces of equipment will be installed:

- The smart detection system which consists of one or two video sensors connected to a processing computer. The main aim of this system is to detect some dangerous scenarios, partially described in deliverable D1.3. Those scenarios involve vehicles that stop on the rails of a LC, vehicles that are queuing in front of a LC, and specific behaviours of pedestrians.
- A second piece of equipment that will be set up will represent the interface between the video system and a communication system. This equipment will be connected to the video detection system.
- A telecommunication system will be installed close to the two pieces of equipment previously described. This equipment is supposed to send the information coming from the video system to a train, cars and an artificial control center set up in the office building nearby.
- Partners will optionally deploy and integrate their own proprietary technology in the test site infrastructure for testing and demonstration purposes. This may include sensing and communication equipment and central system demonstrators that can be operated as part of the native test site infrastructure.

Some pieces of equipment will be installed in the RWTH office building nearby the set up LC outdoor: this office will be used as an artificial control center. There will be an exchange of data between the level crossing and this control center in the test site.

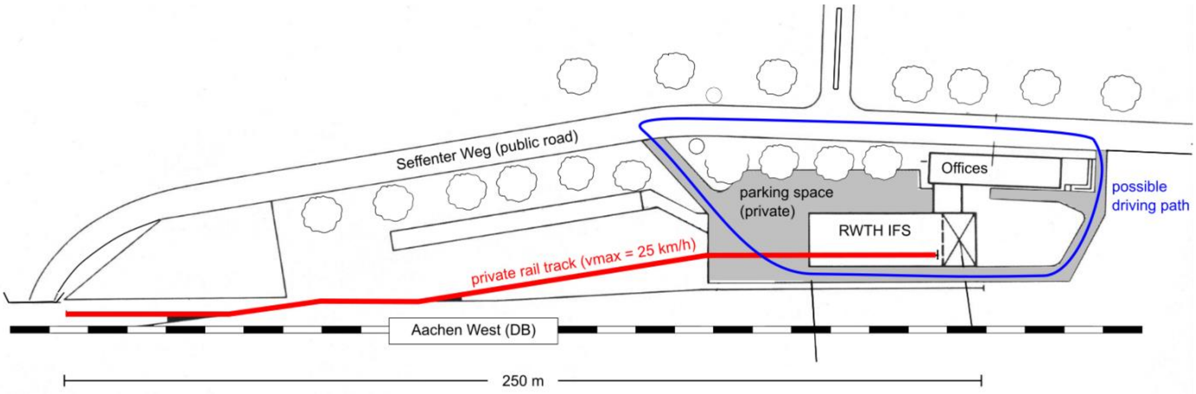

Figure 5: Map of the facilities

Figure 6: Aerial image of the test site

Figure 7: Road/rail intersection area at Aachen test site

Figure 8: Testing rail vehicle

3.2. Technical description of the test site

Figure 5 shows a map of the facilities. The test site is located near the “Aachen West” railway station. It features 200 m of private railway track with a maximum permitted speed of 25 km/h. The track features a large road/rail intersection area where different level-crossing scenarios can be implemented for research purposes within SAFER-LC. Parts of the tracks are located in a workshop hall that offers possibilities for mounting mechanical and electronic components to the testing rail vehicles.

The road area in this test site will be used to install a mock-up level crossing in order to run experiments. Currently, no lanes or road markings are present on the road surface.

A round-trip circuit for research from an automotive perspective, crossing the rails at an angle of approximately 45 degrees, could be implemented by using the rear exit of the testing facility and the public road next to it (see blue line in Figure 5). Depending on the driving direction, the level crossing would be either in plain sight of the approaching car (when driving counter-clockwise on the blue path depicted in Figure 5) or hidden behind a corner of the workshop building (when driving clockwise).

3.3. Safety measures that can be evaluated in test site

The scope of testing measures on the Aachen test site depends on the requirements developed during earlier work packages within SAFER-LC. In general, all tests or scenarios that road/rail interaction with real rail vehicles can be tested, as far as they do not require train velocities exceeding 25 km/h or road vehicle speeds above 30 km/h.

Since the Aachen test site is located on a private protected area, it is possible to artificially stage many different safety critical scenarios that could be including cars, pedestrians, interactions between cars and pedestrians, objects on the rails of the LC. Those scenarios can be repeated as often as needed in order to obtain an appropriate statistical accuracy. Furthermore, scenarios might be staged under different weather conditions.

For the smart detection system it is important to test during sun periods, during rain periods and snowy conditions if possible. The train and its velocity are in full control of the test site operator which is convenient to run scenarios. The test site was previously used for train detection tests, implementation tests of various features and sensory systems of IFS's testing vehicles in private projects for the railway industry as well as for teaching purposes.

The main objective of this test site is to demonstrate the total processing chain from the smart detection systems involving communication and driver warning by implementing the test scenarios in compliance of the set of KPIs defined in the deliverable *D4.2 Evaluation Framework.*

3.4. Tools and data that can be acquired

By default, the test site is not equipped with any sensors; those are usually installed based on individual project requirements.

Within the SAFER-LC project, the main sensory and communication components are provided by the project partners. Contributing partners will optionally deploy and integrate their own technology in the test site infrastructure for testing and demonstration purposes. In particular these are the sensing and smart detection system, the required interfaces with the communication system, the equipment of the communication systems (vehicle on-board units and stationary infrastructure elements) as well as the central system demonstrators. Equipment provided by heterogeneous sources shall be interoperable and operated as part of the native test site infrastructure.

Forwarded from the smart detection system, the data obtained will contain the status of the LC (obstacle, no obstacle, presence of objects, presence of pedestrians, etc.). This status will be represented by numerical data which could subsequently be shared with cars, train and the control center. The smart detection system will also be able to provide video data about the event detection. These video data will be very useful for the control center. The quantity of video data to send depends on the telecommunication system and its capacities. The scope and nature of information exchange between the LC and other entities (cars, train and control center) will be discussed, defined and evaluated between the technical teams in WP3.

3.5. Guidelines to pilot implementation, operation and monitoring

3.5.1. Pilot implementation guidelines

The test site is ready for operation. However, depending on the measures to be tested, the equipment for a mock-up level crossing (barriers, signs, light signals etc.) has to be implemented first. Approximately one month before the actual testing starts, a rough testing plan should be discussed with the responsible safety manager on site.

3.5.2. Operation and monitoring guidelines

The current local project manager for the SAFER-LC project is responsible for testing and evaluations within the test site. Additionally, the site owner (RWTH Aachen University's Institute for Rail Vehicles, IFS) has its own railway safety manager who is responsible to supervise all safety-relevant work at the testing site.

Only instructed personnel are allowed to operate rail vehicles on the track. Currently, three employees of IFS are certified for train operation on the test site.

Data storage works on local computer systems depending on the testing setup. It is possible for partners to use their own storage systems and computers.

The test site has a high-speed internet connection (up to 1 GBit/s) that can be used via the German national research and education network, so testing data can be transferred from the test site to the partners that need it via the internet.

3.6. Prerequisites and boundary conditions of test site use

The test site is part of RWTH Aachen University's Institute for Rail Vehicles and Transport Systems and can be used during normal working hours of the institute. Only persons within the project consortium will take part in the tests. All video recordings have to be done according to privacy and data protection standards that are used within Shift2Rail projects, e.g. having a written permission of all participants involved. All persons involved in the tests are required to participate in a railway-specific safety instruction prior to accessing the railway area. Tests can only be conducted if at least one employee of RWTH is present and involved. In order to provide required documents and prepare the testing site, a preparation time frame of about four weeks should be planned prior to tests.

3.7. Use of RWTH Aachen Test Site in SAFER-LC

Specific hazardous situations that are too dangerous or complex to be tested in real traffic circumstances can be implemented on RWTHs testing sites. Beside V-2-X-equipped testing cars, RWTH Aachen University as well operates two research rail vehicles that are equipped with sensor systems, satellite positioning and customisable MMI displays that will be utilised for the SAFER-LC pilots.

4. CEREMA TEST SITE

4.1. Cerema – experimental test site

- **Test site location / address:** Cerema\CeremaNC\DERDI\CER - Experimental and Research Center 10 chemin de la poudrière, CS90245 76121 LE GRAND QUEVILLY cedex near ROUEN-PARIS
- **Accessibility:** Private Test site located on Cerema grounds
- **Test site contacts:** Delphine JACQUELINE, delphine.jacqueline@cerema.fr
- **Company that owns Test site:** Cerema

The Cerema experimental test site is part of Cerema (a public establishment research institute) located at the Cerema Normandy Center (Cerema NC) of Rouen 150 km to the west of Paris, inside the CER (Experimental and Research Center). The location of the CER is shown in Figure 9. The test site, which was started in 1960's, contains a testing structure to examine infrastructure technical questions. It is specialised in full scale experiments of structural behaviour using instrumentation and in developing measuring devices for assessment of infrastructure state and earthwork construction machines.
The CER studies the structural behaviour and structural deformation of railway tracks (60%), road infrastructures (10%), and dike infrastructures (20%), including environmental and natural risks with specific parameters.

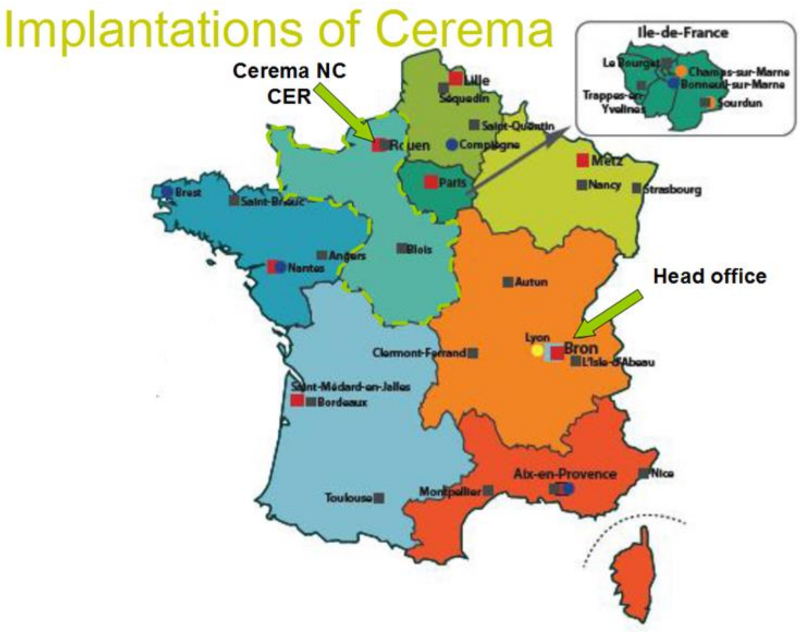

Figure 9: Location of the CER

The CER uses several heavy devices to generate dynamic loadings for experimentations on railway tracks and/or road structural behaviour and structural responses for different excitations. Figure 10 and Figure 11 show a hydraulic jack fixed on a mechanical structure and a portancemeter to measure the rigidity of a railway track. The testing structures can also be instrumented with different sensors such as temperature sensors, strain gauges, optical fibre, and accelerometers to assess the behaviour of the structures.

Figure 10: A hydraulic jack fixed in a loading gantry

Figure 11: Portancemeter

4.2. Technical description of the test site

The condition of the road and rail infrastructure is usually assessed by human inspection, which requires an access to the infrastructure by the inspectors and hence an interruption of the infrastructure operation during the inspection. However, railway infrastructure owners and operators would prefer to carry out dynamic non-intrusive measurements of their infrastructure through instrumenting a moving vehicle or the structure itself. Nowadays even the use of a drone appears to be a realistic goal.

Figure 12: Aerial image of the Cerema test site.

As defined in deliverable D1.3, the road surface profile and the geometrical degradation of the road surface are scenarios that will be studied in this project. The Cerema NC test site is able to simulate level crossing (LC) degradations in order to recreate a representative structure with situations which are prone to accident occurrence. An aerial image of the experimental LC is shown in Figure 12. In this experimental test site, the feasibility of photogrammetric, thermo-infrared and seismic methods will be studied to monitor the road/railway infrastructure surface condition and to detect any deterioration of the LC.

An existing road infrastructure on the Cerema NC grounds will be used to integrate an experimental LC. The Cerema team will prepare a flexible structure by digging an unused part of the existing road of the Cerema NC site. The railway structure will be composed of LC systems, lying on wooden blocks placed under the railway sleepers to simulate road and railway degradation and maintenance operations (Figure 13). This experimental structure will generate different LC surface geometries following maintenance operations, pavement degradation, etc.

Wooden blocks under the set of sleepers provide a flexible structure which can easily generate varying surface geometries of the infrastructure. This will allow for an investigation of accident-prone conditions with blocked vehicles on the LC due to poor LC surface geometry, as specified in deliverable D1.3. On top of the wooden blocks, a railway track panel (rails with sleepers) covered by rail crossing systems will be used to integrate acceleration and displacement sensors as shown in Figure 13. This structure will be dynamically stressed by a moving truck (Figure 12) to observe the behaviour of the vehicle according to the state of degradation compared with the measurements of the seismic sensors.

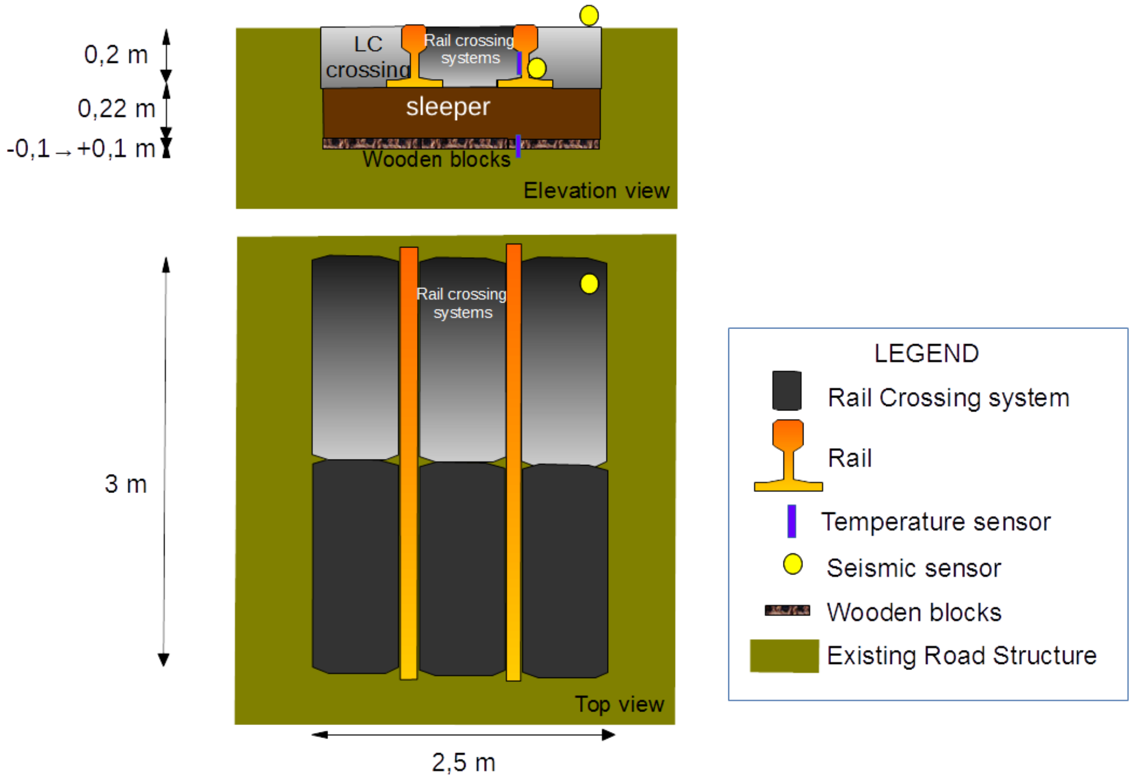

Figure 13: Experimental structure with instrumentation

Additional sensors that will be installed in the experimental structure (Figure 13):

1. Acceleration sensors installed on the road and rail structures to assess the structural condition of the LC: the measurements by these sensors will be compared with another measurement using the photogrammetric and thermoinfrared used to assess the degradations of the LC surface condition. These sensors will be developed and implemented by our partner NTNU. It is expected to be ready in June 2018.
2. Temperature sensors installed inside the structure to correlate their data with the data obtained in by the thermoinfrared method.
3.

The results from these measurements can be used as an input for road and rail managers to take actions such as putting appropriate signage with required geometrical information to inform potentially risky vehicles not to be stuck at the LC, or prohibiting the passage of specific vehicles to improve safety at LC zone.

4.3. Safety measures that can be evaluated in test site

The Cerema experiment is a non-intrusive mobile system to make acquisitions on the cross sectional profile to determine the degradations and variations of the LC geometry. Due to degradations on the LC surface, the LC's profile could be a conflict point for some road vehicles that may be unable to cross. The experimental structure should test the effectiveness of the Photogrammetric method, the

Thermoinfrared method, and the Instrumentation with seismic and temperature sensors for the prevention of conflict points at LCs.
The photogrammetric device can measure displacement and deterioration of the road surface to assess the risk of road vehicles of getting stuck at the LC due to the geometry of the surface profile. In addition, the information from the photogrammetric device will be combined with thermal infrared data to enhance the interpretations of the potential disorders as cracking, high permeability zones that generate a thermal anomaly of several degrees.
The use of smart and embedded wireless sensor networks to gather accurate information about the LC's condition will be investigated. Vibration and temperature sensors will be installed on the rail/road components. Relevant data will be transmitted, using an alert threshold to the relevant bodies (LC operator to inform the status of the LC components). The vibration level for a normal operation of the LC will be categorised in several thresholds for predictive maintenance applications. Furthermore, in case of major faults, malfunctions or damages on the LC structure (road structure, rail structure or the underlying layers) that may lead to a safety risk for the LC users, the system will be able to send alerts to track infrastructure managers, train operators, road traffic managers, etc., to prevent any possible safety risks due to the infrastructure deformation.

4.4. Data and indicators that can be acquired

This experimental structure allows to measure the surface condition indicators with three methods (deformations with the photogrammetry, temperature gradient with the thermoinfrared method, and vibration level with the LC surface instrumented method). The experiments provide a high resolution photogrammetric data (millimetre to centimetre) in order to obtains different models and compare them to information on the topography of the LC zones (conflict point). High resolution photogrammetric data enables to detect any potential risk of vehicles blocked at the LC.
Various tests will be carried out to find the best device configuration (angle inclination of the camera objectives, speed of the vehicle, adjustment of the shutter speed of the camera sensor, etc.).
After the experimental measurements, actual on-site railway measurements will be conducted (two LCs geometrically recorded by the SNCF, see references of LCs and figure) to compare the results with the experimental measurements and study the feasibility on site of the photogrammetric method.
The thermoinfrared method measures potential disorders such as cracked surfaces, high permeability zones, or main drain water that generate a thermal anomaly of several degrees. Visible information from the photogrammetric measurement will be combined with thermal infrared data to enhance the interpretations of the potential disorders and to assess the characteristics of potential surface degradations.
Temperature gradients will be observed during deformation basins on a diurnal cycle to get the temperature evolution during the day. Such survey may be combined with 3D visible models obtained by photogrammetry and numerical modelling of conductive-radiative processes available at the Cerema lab (using Comsol Multiphysics) to fully understand the link between the surface temperatures and the fracturing.
Additionally, using a wireless sensor network, acceleration levels will be recorded during the vehicle passing and the vibration trend will be analysed for different LC surface degradation levels. Alert threshold for the vibration level will be set based on the safety risks to assess the status of the LC components.

4.5. Description of tools that are used for data collection within the site (technical details)

The different tools that will be used within the Cerema test site are illustrated in Figure 14. Examples of expected results from such measurement tools are shown in Figure 15.

<table>
<tr>
<td>
Several cameras with fixed lenses:
photogrammetric method on the bottom of a vehicle developed by Cerema</td>
<td>
Drone with thermoinfrared camera:
thermoinfrared method developed by Cerema</td>
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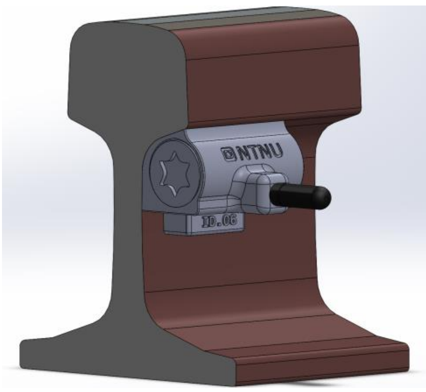
<td colspan="2">

Accelerometer sensors fixed at the rail web:
Vibration measurement method developed by NTNU</td>
</tr>
</table>

Figure 14: Measurement tools to be used in the Cerema test site

The first measurement tool is a photogrammetric tool with cameras on the bottom of the vehicle. This system is developed and implemented by Cerema. Several high-frequency reflex cameras with a fixed lens will be installed on the bottom of a vehicle at a height of 2-3m on a ramp with stabilizers to auscultate the scene corresponding to one road direction. The cameras will operate in burst mode. The cameras' writing speed won't lead to the saturation of their memories. The data obtained from different surface states will be integrated in a software tool developed by Cerema to obtain the evolution of the surface state. An example of an LC photogrammetric model is shown in Figure 15.

A threshold value of peak-to-peak amplitude of the deformations will be set according to the chassis of the vehicle passing the LC (distance limit between the two axes of the exceptional transport and ground clearance) (Exceptional transports, Setra 1982).

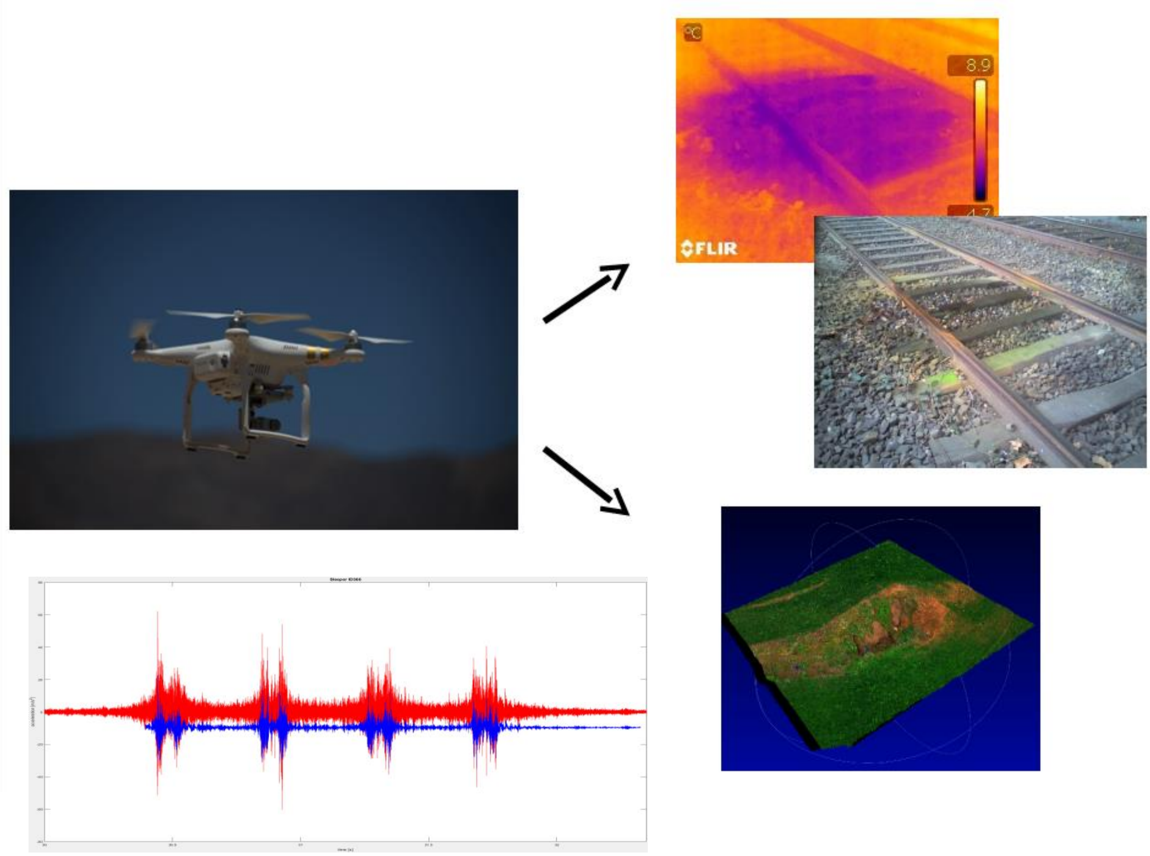


Figure 15: Examples of photogrammetric-, thermoinfrared- *and* vibration-results

The second measurement tool to be implemented in the test site is a drone with a thermoinfrared camera used for the thermoinfrared method. The system has been developed by Cerema. The objective of this study is to assess the characteristics of potential surface degradations / fissurations using and combining visible and thermalinfrared data.

Figure 16: Example of LC photogrammetric model (source: SNCF)

The Cerema team has worked for 10 years on the link between surface temperatures, subsurface processes (associated to water and airflow, evaporation) and surface properties (effect of porosity, thermal conductivity, topography and albedo), at different scales of time and space (Antoine and Lopez, 2018).
In particular, there is a high interest in understanding the link between the micro-topography and the temperature signal, using a thermal infrared camera. The observed surface temperatures may be highly influenced by the presence of topography, inducing temperature contrasts of several degrees Celsius and depending on the sky proportion α, as shown in Figure 17. As an example, during the afternoon, a fracture on a road will appear warmer because of its delayed cooling, compared to a relatively flat area. It is proposed to observe such temperature gradients during deformations on a diurnal cycle basin (to get the temperature evolution during the day). Such survey may be combined 1) with 3D visible models obtained by photogrammetry and 2) numerical modelling of conductive-radiative processes available in our lab (using Comsol Multiphysics) to fully understand the link between the surface temperatures and the fracturing.

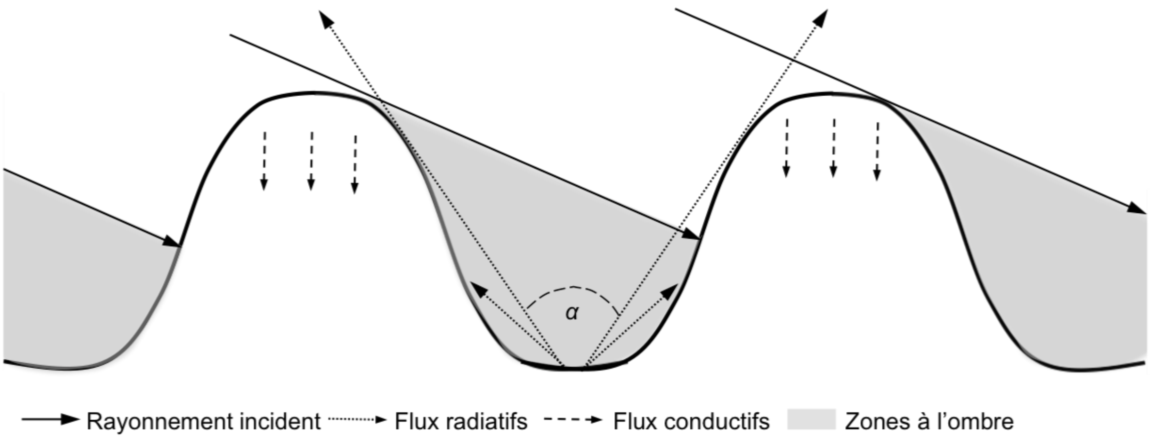


Figure 17: Influence of the topography on the radiation. The emitted energy seen by a thermal infrared camera highly depends on the sky proportion α.

The other measure to be implemented in the test site is the vibration method. The vibration measurement tool will be developed by NTNU. Wireless accelerometer sensors network will be mounted on the LC structural layers at different locations. The exact location for mounting the accelerometers will be decided based on the geometry of the LC and the sensitive area for the vibration sampling. During the passage of a road vehicle, the vibration level will be recorded.

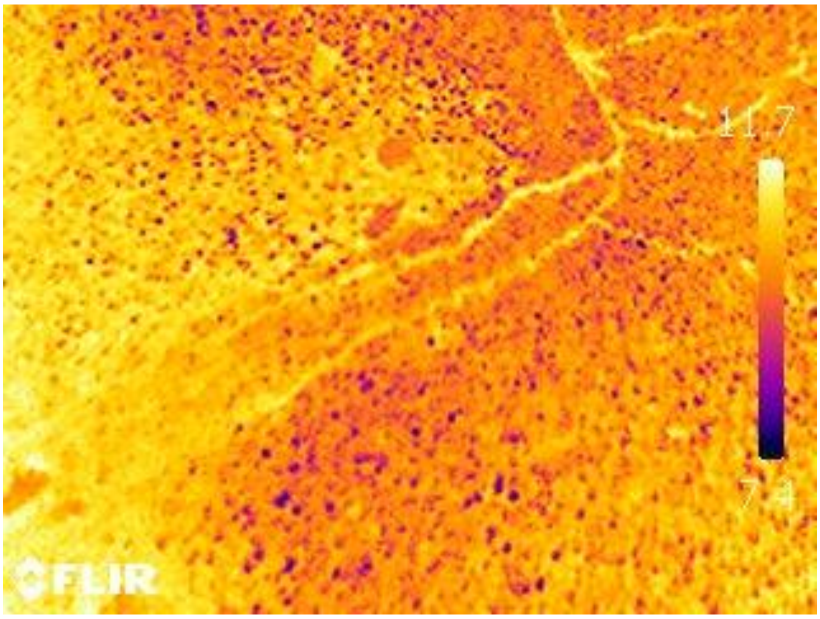


Figure 18: Thermal infrared observation of thin fractures on a road during afternoon in winter. Note the temperature contrast between the fractures and the surrounding medium

4.6. Guidelines to pilot implementation, operation and monitoring

4.6.1. Pilot implementation guidelines

The Cerema test site will be designed specifically for the SAFER-LC project to generate degradations on the LC surface.
Two entities will use the Cerema test site: the Cerema NC for photogrammetric and thermoinfrared measurements and the NTNU for accelerometer instrumentation on or in the road/rail structure.
The Cerema test site will be effective at the end of May 2018.

4.6.2. Operation and monitoring guidelines

The Cerema is responsible for testing and evaluating the experiment within the test site. Vibration recordings will be made at different moments at the 5th, 10th, 20th truck passages to compare the vibration trend with surface degradation.

4.7. Prerequisites and boundary conditions of test site use

The presence of a responsible person from Cerema is required to use the test site. The use of the different tools requires an authorization. The Cerema site is accessed through the reception. There is no need for a safety training as this test site is specifically prepared for the SAFER-LC project with

no interference from other road users. Only people from the consortium will be participating in the testing and no risky situations will be foreseen that have concerns on health and safety. The site is open from 8.00 to 12.00h and from 13.00 to 17.00h. The experimental structure is located on open ground, which may be subjected to weather conditions. The water content of the structure will not interfere with the photogrammetric measurement.
There is no issue that infringe the privacy and confidentiality topics in the tests to be carried out in this test site.

4.8. References

Chanut M-A., Kasperski K., Dubois L., Dauphin S. et Duranthon J-P (2017), Quantification des déplacements 3D par la méthode PlaS – application au glissement du Chambon (Isère), Revue Française de Géotechnique. Doi: 10,1051/geotech/2017009

Mézon C., Antoine R., Finizola A., Marsella A, Scifoni S., Normier A., Fauchard C., Ricci T.(2016), Airborne advanced photogrammetry and Lidar for DEM extraction over a complex terrain - a comparative study submitted to Annales of Geophysics.

T. Lopez, R. Antoine , Y. Kerr, J. Darrozes, M. Rabinowicz, G. Ramillien, A.Cazenave and P.Genthon (2015). Subsurface hydrology in the Lake Chad basin from convection modelling and observations, Surveys in Geophysics, doi:10.1007/s10712-016-9363-5.

Antoine R., Lopez T (2017). Télédection dans l’infrarouge thermique, Manuel de mécanique des roches, Tome V : Thermomécanique des roches, pp. 157-202, ISBN 978-2-3567-465-7, Paris, Presse des Mines, Collection Sciences de la Terre et de l’Environnement, 2017.

PN number 21, line 405000 of Argentan to Granville (Normandy), PK 044+0698

PN number 85, line 379000 of Mezidon to Trouville-Deauville (Normandy), PK 031+0540

SETRA, Ministère des transports, direction des routes (1982), Transports exceptionnels – Définition des convois-types et règles pour la vérification des ouvrages d'art.

5. VTT TAMPERE

5.1. VTT Tampere at a glance

- **Test site location / address:** Niittyhaankatu 8 Tampere Finland
- **Accessibility:** Private Testsite
- **Test site contacts:** Ari Virtanen , ari.virtanen@vtt.fi
- **Company that owns Test site:** Technical Research Centre of Finland VTT Ltd

- **Introduction:** Research and development of the connected and automated vehicles in VTT is mainly located in Tampere. Nevertheless, testing of the vehicles themselves is not tied to a particular location in Finland. Equipment can easily be moved to any appropriate test location in Finland. The self-driving vehicles may however only be driven manually in Scandinavian countries; permission to drive automatically is only valid in Finland. It is not allowed to drive them anywhere else. In SAFER-LC the VTT test site containing the vehicles can be used to test and develop methods that reflect a way in which automated vehicles can cope with dangers especially at passive level crossings and to develop V2X-messages between rail and road environment.

Figure 19: VTT Research facilities at Tampere © Google Maps.

5.1. Technical description of the test site

Self-driving cars

Figure 20: VTT Self-driving and connected car research platforms Martti (left) and Marilyn 2.0 (right). © VTT

VTT runs two research platforms for connected and self-driving car development. “Martti” is built on a Volkswagen Touareg platform with the focus is to develop self-driving technologies for rural environments. “Marilyn” is built on a Citroen C4 platform with the focus on urban area automation. Both vehicles are equipped with lidars, radars and camera sensors for environment perception as well as GNSS, inertial and odometria for positioning. For connectivity, both vehicles have ITS-G5, LTE and pre-5G communication units on board. The software systems of the vehicles are open, therefore it is simple to add additional hardware and software for testing and research purposes.

Environment perception

Figure 21: Portable sensor rack for rapid prototyping and feasibility tests. © VTT

VTT has developed a portable sensor rack for testing the feasibility of various vehicle sensor configurations in various applications. It contains short and long range (24/77 GHz) radars, a thermal camera, a stereo camera and a LiDAR. The system also contains a rugged laptop, which communicates with the rack via Ethernet. The laptop is used for recording data from the sensor data. The rack is designed to be easily installable into various vehicles on the road and the rail. For example it has been used in tests at the front of the locomotive. It might as well be utilized in train detection tests. Additional sensors exist that are not installed to fixed installations. A second version of the rack is currently designed.

Mobile road side unit

Figure 22: Mobile road side unit. © VTT

Figure 22 shows mobile road side unit equipment, which can be installed within 20 minutes. This equipment can be used for testing road-side sensors and V-2-X technology. It contains computer units, a camera with VRU and car detection capability, a road state monitoring unit, software for gathering information from sensor units and ITS-G5, pre-5G base station and cellular communication units. It also contains a traffic light unit on board. In SAFER-LC it can be used to simulate a level crossing communication unit. There are additional ITS-G5 communication units (>10 pcs) which can be used for test installations.

Driver monitoring

Camera based driver-monitoring system for detection of visual and cognitive workload and driver intention analyses based on gaze angle are part of the vehicles. The technology is based on the combination of the vehicle dynamic parameters (speed variation, lane keeping, etc.) and facial features.

Figure 23: Driver monitoring system © VTT

C-ITS development and test simulator

A simulation environment contains accurate vehicle models and a real environment model of Tampere City area. The simulated area can be changed to any other area, for example to an area containing level crossings. The simulator can be used at hardware-in-the-loop simulations if necessary. The software itself runs in the Linux environment and therefore it not tied to the hardware seen in Image 6. In SAFER-LC, the simulator can be combined with self-driving car software and used for testing and demonstration of developed functionalities.

Figure 24: Simulation environment for ITS application testing and development. © VTT

Research network

VTT has extranet environment for research purposes. Different services and servers can be installed and executed in this network. It is separated from VTT corporate network and experimental services and back office applications can be installed and executed freely. In SAFER-LC it is intended to use of the research network to run the Junavaro simulator and for sharing data.

Junavaro database and simulator

The Junavaro database was collected during the Junavaro project (Öörni *et.al.* 2013). The Project equipped 70 passenger and freight trains with tracking devices and the database contains train traffic from southern Finland over one year period. The database size is approximately 24 GB. It can be used to generate realistic train traffic simulation for development purposes. A rail network database and level crossing database are available from Finnish Travel Agency as open data.

The simulator software was developed during the LeCross project funded by European Space Agency (Virtanen *et.al*, 2015). It utilizes algorithms developed in Junavaro. The Simulator provides information to rail section 142 between Hanko and Karjaa. The simulator provides possibilities to alter GPS accuracy and availability as well as communication system latencies. For the use in SAFER-LC it can be modified to provide arrival time estimations to simulations.

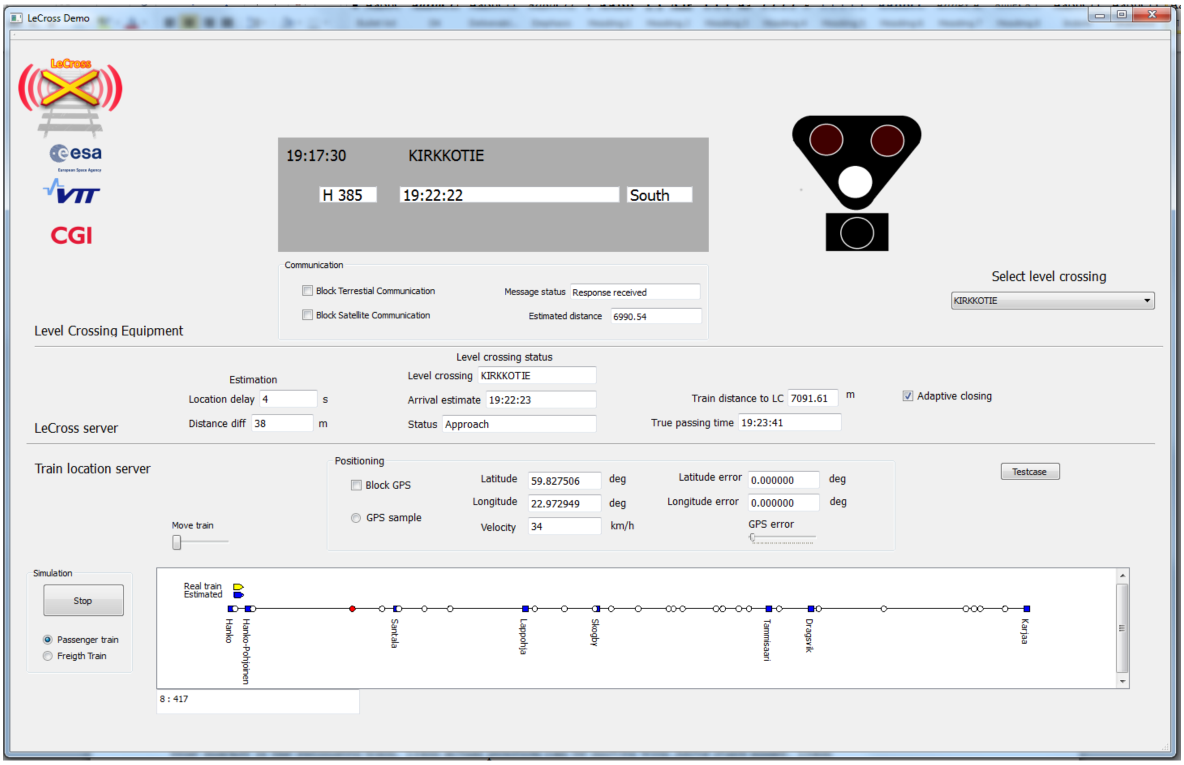


Figure 25: Simulator user interface

5.2. Safety measures that can be evaluated in test site

- It is possible to evaluate safety measures that are connected to the behaviour of the self-driving cars at level crossings.
- It is possible to evaluate safety measures that involve C-ITS (Cooperative, connected and automated mobility) messaging.
- Typical research questions are how certain C-ITS application should be implemented; what is the relevant content of the C-ITS message; what is the timing and location accuracy of C-

ITS message content; how far a train can be detected with environment perception sensors in passive level crossings.

- The Junavaro-project evaluated the concept of the in-vehicle mobile phone warning system.
- For SAFER-LC the test site can be used to development and testing C-ITS applications between rail and road environments.

5.3. Data and indicators that can be acquired

Data gathered are datasets from sensors and vehicle control systems as well logging data from communication messages. These have to be further analysed to evaluate system performance.

5.4. Description of tools that are used for data collection within the site (technical details)

- Tools are described in the technical chapter.
- VTT operate the tools.
- VTT can provide necessary interface documents. The technology used is DDS (data distribution service), therefore the operator needs to have some knowledge of the technology.

5.5. Guidelines to pilot implementation, operation and monitoring

5.5.1. Pilot implementation guidelines

- Tests should have a detailed plan that con be followed, implementations usually require an exchange of interface documents and testing if interfaces work as planned.
- VTT owns and runs all equipment. Tests at level crossings need to be discussed with the Finnish Traffic Agency.
- The majority of the test environment is ready to use. There are other projects using the environment, therefore some synchronisation is required.
- The Junavaro simulator is not yet modified for SAFER-LC.

5.5.2. Operation and monitoring guidelines

- VTT personnel operates self-driving cars and other equipment.
- All equipment can be used as single separate units.
- Data is stored to individual units and collected on an external hard disk.
- Data can be made available at the extranet to be downloaded by partners. Usually datasets are rather large.
- Automated vehicles must have a supervisor during the operation.

5.6. Prerequisites and boundary conditions of test site use

VTT self-driving cars test permission and insurance allows automated driving only in Finland. Manually vehicles can be driven only in Scandinavian countries. Tests at level crossings need to be discussed with Finnish Traffic Agency.

5.7. Use of VTT Tampere test site in SAFER-LC

In SAFER-LC, Tampere test site is expected to be used in the development of C-ITS messaging and behaviour of the autonomous vehicles at passive level crossings. Development is done by using the Junavaro simulator and C-ITS development simulator using the hardware-in-the-loop method for the ITS-G5 modems. After the development in a simulation, developed algorithms can be tested in real vehicles. For safety reasons, real trains are not used in tests. The development refers to WP2 low-cost methods development.

5.8. References

Virtanen, Ari; Kostiainen, Juho; Simola, Nina; Iqbal, Omar. 2015. Improving level crossing safety with satellite technology. 22nd World Congress and Exhibition on Intelligent Transport Systems and Services, ITS World Congress, 5 - 9 October 2015, Bordeaux France, ERTICO; EU

Öörni, Risto; Virtanen, Ari; Hietikko, Marita; Kauvo, Kimmo. 2013. Development of an in-vehicle warning system for railway level crossings. In: Research highlights in safety and security. Veikko Rouhiainen (ed.). VTT, ss. 94 - 95 http://www.vtt.fi/inf/pdf/researchhighlights/2013/R10.pdf

6. AIM MOBILE TRAFFIC ACQUISITION (DLR)

6.1. AIM Mobile Traffic Acquisition at a glance

- **Test site location / address:** The exact location where the sensor poles will be placed is to be determined. It could be a level crossing probably close to Braunschweig.
- **Accessibility:** The level crossing can be in public space. Furthermore a private ground of a company having railway tracks would be possible.
- **Test site contacts:**, Kay Gimm, kay.gimm@dlr.de, Jan Grippenkoven, jan.grippenkoven@dlr.de
- **Company that owns Test site:** DLR owns the detection system (German Aerospace Centre e.V., Braunschweig). The owner of the ground where the system will be placed is to be determined.

The AIM Mobile Traffic Acquisition system is part of the test field AIM (Application Platform for Intelligent Mobility). It consists of semi-mobile sensor poles as instruments for detection and assessment of traffic participants' behavior.

6.2. Technical description of the test site

The following paragraphs will describe the sensory set-up and give an overview about the primary output of the facilities. The installation consists of the pole itself holding a sensor head and different antennas and a weather-proof cabinet, containing the different processing computers as well as several electric and electronic devices. Every pole installation is based on a transportable concrete foundation. The field of vision of the associated sensors can be fused to get a better performance and a wider field of detection. The poles have a remote access due to an LTE-connection. Furthermore the system has a V-2-X-ability.

Figure 26: Mobile sensor poles at railway station and level crossing

Figure 26 shows different sensor poles used in measurements at different locations. On the left a sensor pole is used in front of the main station in Braunschweig to analyse the cooperative behavior of different traffic participants (pedestrians, bicyclists, busses, trams) at a shared traffic space. In the right part of the picture a pole is shown that was used to analyse the behavior of road traffic participants at an active level crossing with light signals. All poles are equipped with stereo-camera systems and an active infrared lighting system for artificial scene illumination, in order to be able to sense traffic as well during day- as nighttime.

The sensor data are fused and processed to represent the main output of the system, which are trajectories of the detected traffic participants. These trajectories hold information about the classification and dimensions of the object as well as its location, velocity and other dynamic state variables. The trajectories are tracked and stored with a rate of 25Hz. They are automatically stored in a database for offline analysis purposes with the respective scene videos for manual assessment and validation.

6.3. Safety measures that can be evaluated in test site

With the AIM Traffic Acquisition Platform motorized as well as non-motorized road users are detected, tracked and classified as e.g. cars, trucks, railways and pedestrians and cyclists. The related video and numerical trajectory data is analysed for research purposes.
It is possible to evaluate safety measures based on specific measurement connected to the behaviour identified traffic participants in a long-term evaluation. The behaviour before the implementation of a given safety measure can be compared with the behaviour after the implementation based on a large dataset of observations.
Typical research questions cover ways to improve and understand traffic in various areas. The behaviour of the traffic participants can be analysed to identify typical and atypical events. Furthermore, safety critical events can be identified semi-automatically by specific triggers. One example for them are surrogate safety measures like Post Encroachment Time (PET) The identification of behavioral patterns in shared traffic areas that lead to risky situations are particularly interesting in order to be able to predict and antagonize them.

6.4. Data and indicators that can be acquired

The system detects traffic participants. The output consists of augmented scene videos that show the tracked objects. Furthermore, numerical trajectory data can be used for analysis purposes. With a rate of 25Hz position, speed, acceleration, object size and heading are derived.
According to the virtual image of the traffic flow it is possible to calculate surrogate safety measures or aggregated information like traffic volume. The amount of occurrence of specific events for e.g. red light crossing can be derived before and after a specific measure has been implemented.

6.5. Description of tools that are used for data collection within the site (technical details)

The sensor head consists of stereo cameras and an infrared flashlight to be able to use the system at night. In addition, an outdoor control cabinet is required with process computers and electronics inside. DLR-staff is operating the system regarding transportation, calibration, data collection and data analysis. Third parties might assist regarding transportation. The system itself boots up in order to automatically collect data. The analysis of the data needs competences in e.g. Matlab or Python as well as the software itself.

6.6. Guidelines to pilot implementation, operation and monitoring

6.6.1. Pilot implementation guidelines

The AIM Mobile Traffic Acquisition Platform has to be placed closed to a spot of interest where traffic can be observed. A connection for power supply is needed. A current generator depending on gasoline is one option for short runtimes of days. A connection to the local grid is preferred. Then the system is calibrated and is able to run 24 hours a day, seven days a week for several weeks without additional activities for necessary. For management and monitoring purposes the LTE-connection can be used.

There are several necessary steps that have to be taken before the system is ready to use:

- The location at which the system is supposed to be placed has to be defined.
- The measures that are to be analysed have to be implemented at the dedicated level crossing where the AIM Mobile Traffic Acquisition System will be placed. The system will collect data of the passing traffic.
- The owner of the ground or the local municipality has to grant the possibility to implement the measures and to deploy the detecting infrastructure at this place.
- Privacy issues have to be clarified with the municipality responsible for the area surrounding the level crossing.
- The power supply of the system has to be guaranteed.
- A concept for detection of relevant parts of the hotspot by sensors has to be created. The system has to be transported to the chosen level crossing. There it has to be set-up, connected to energy supply and calibrated. Then the data collection can start. After several weeks the hard drive capacity comes to a limit. As a matter of this hard drives would have to be changed if the duration of measurement exceeds a certain period of time.

6.6.2. Operation and monitoring guidelines

DLR is responsible for testing and evaluations within the test site. The Traffic Acquisition Platform consists of up to three sensor poles. Depending on the needed sensor coverage demands they could be connected if a cable network connection is available. One single pole is sufficient for the use in the context of the level crossing.

There are hard drives installed in the control cabinet of the sensor pole that allows storage of the data. These hard drives have to be physically transported to the DLR Institute of Transportation Systems in Braunschweig and transferred into a backend database.

Depending on the size of data it can be transferred via a file hoster or exchange of an external hard drive at a physical project meeting.

There is a management and monitoring system which is controlling the system based on "*icinga*". This system gives an overview of the correct functionality of all modules and servers. It can be accessed via a remote connection if mobile communications are available.

6.7. Prerequisites and boundary conditions of test site use

The system is used in public spaces and uses video data. No person related information like faces or number places are stored. Augmented scene videos that visualize the tracked traffic participants

are stored in low quality that does not allow the perception of person related aspects. If the system is placed somewhere it has to be accepted by the owner of the ground or the local municipality.
The system is designed to work 24 hours a day, 7 days a week. The infrared flash allows operations also during bad weather conditions and at night times. However, tracking quality might decrease to a certain acceptable extent during certain conditions.

6.8. Use of AIM Mobile Traffic Acquisition in SAFER-LC

Within SAFER-LC the acquisition platform can be especially useful to analyse additional safety measures that makes use of infrastructural manipulations in the road traffic environment. The platform is useful for measures that target road traffic participants. It cannot be used to analyse the behaviour of train drivers. The AIM Mobile Traffic Acquisition system will be used to detect traffic at a railway crossing and to analyse the traffic behaviour in order to evaluate measures that can be implemented at a level crossing in WP4.

6.9. References

Grippenkoven, J., Gimm, K., Stamer, M., Naumann, A., & Schnieder, L. (2015). Untersuchung des Fehlverhaltens von Verkehrsteilnehmern an einem Bahnübergang mit Blinklichtsicherung. *Signal & Draht*, 23-27.

Schnieder, L., Grippenkoven, J., Lemmer, K., Wang, W., and Lackhove, C. (2013). Aufbau eines Forschungsbahnübergangs im Rahmen der Anwendungsplattform Intelligente Mobilität, *Signal & Draht*, 25-28.

Schnieder, L., Grippenkoven, J., Lemmer, K., Wang, W., & Lackhove, C. (2014). Untersuchung des Verkehrsablaufs am Forschungsbahnübergang. *Eisenbahntechnische Rundschau*, 58-62.

Schnieder, L., Grippenkoven, J., Wang, W., & Lackhove, C. (2015). Untersuchung beobachtbaren Verhaltens von Straßenverkehrsteilnehmern am Forschungsbahnübergang Braunschweig-Bienrode. *16. Symposium Automatisierungssysteme, Assistenzsysteme und eingebettete Systeme für Transportmittel*. Braunschweig.

7. THESSALONIKI LIVING LAB

7.1. Thessaloniki at a glance

- **Test site location / address:** Thessaloniki, Greece
- **Accessibility:** The test site in Thessaloniki is public. It is composed of 30 level crossings in the surroundings of Thessaloniki.
- **Test site contacts:** Josep Maria Salanova (CERTH) & Alexandros Dalkalitsis (TRAINOSE)
- **Company that owns Test site:** there is no test site as such, but the LCs are managed by OSE & GAIOSE & TRAINOSE

The city

Thessaloniki is the second largest city in Greece, currently accommodating 1.006.730 citizens in its greater area. Situated in Northern Greece, Thessaloniki covers a total of 1.455,68 km^2 with an average density of 665,2 inhabitants per km^2. Due to its geographical location, Thessaloniki plays an important social, financial, and commercial role in the national and greater Balkan region, also due to the development of a transportation hub within the city's limits. According to the General Secretariat, the total number of vehicles in the city exceeds 777.544, including private cars, heavy vehicles and motorcycles.

Thessaloniki became a living lab for mobility and freight services, where various ITS and C-ITS services were tested during the last years through various projects (COMPASS4D, COGISTICS, C-MOBILE). A local ecosystem has been established during the execution of the named projects, where private and public stakeholders collaborate. This infrastructure and eco-system will be activated for the execution of the SAFER-LC pilot.

From railway view Thessaloniki is one of the most important railway hubs in Hellenic region. The route Athens – Thessaloniki connects the two biggest cities of Greece. From view of passenger transportation Athens – Thessaloniki is the most busiest and important line in Greek region. From view of freight transportation Thessaloniki is the main hub that connects Pireaus with Eidomeni and Balkan area. Port of Thessaloniki is one of the main clients of Greek railway and the second biggest in Greek region.

The rail infrastructure and operator in Thessaloniki

Inside Thessaloniki railway hub TRAINOSE, the main railway operator in Greek area, operates regional, freight and suburban trains. Main lines connect Thessaloniki with Athens, Alexandroupoli, Florina, Larisa and Eidomeni. The railway network in Thessaloniki center is complicated because it connects the main railway passenger station, freight centers, depot sites and train factories. All level crossings in center of Thessaloniki are automatic with user side protection.

The pilot for SAFER-LC

Since most of the LCs in Thessaloniki have no barriers, the pilot implementation to be executed in the framework of the SAFER-LC project aims at increase safety at LCs by providing alerts to drivers in the surroundings of the LCs about trains approaching the LC. This implementation will be one of the first in Europe testing multimodal cooperative services.

More in detail, in Thessaloniki a solution based on mobile communications will be developed and tested at 30 level crossings (Figure 27) in the surroundings of Thessaloniki (from the total of 58 of the tables above) by a fleet of up to 1.000 taxi vehicles from the TaxiWay taxi association and 25-30 trains. (These are the maximum numbers, the final number of taxis and trains will depend on the routes they follow and the areas they circulate during the pilot operation).

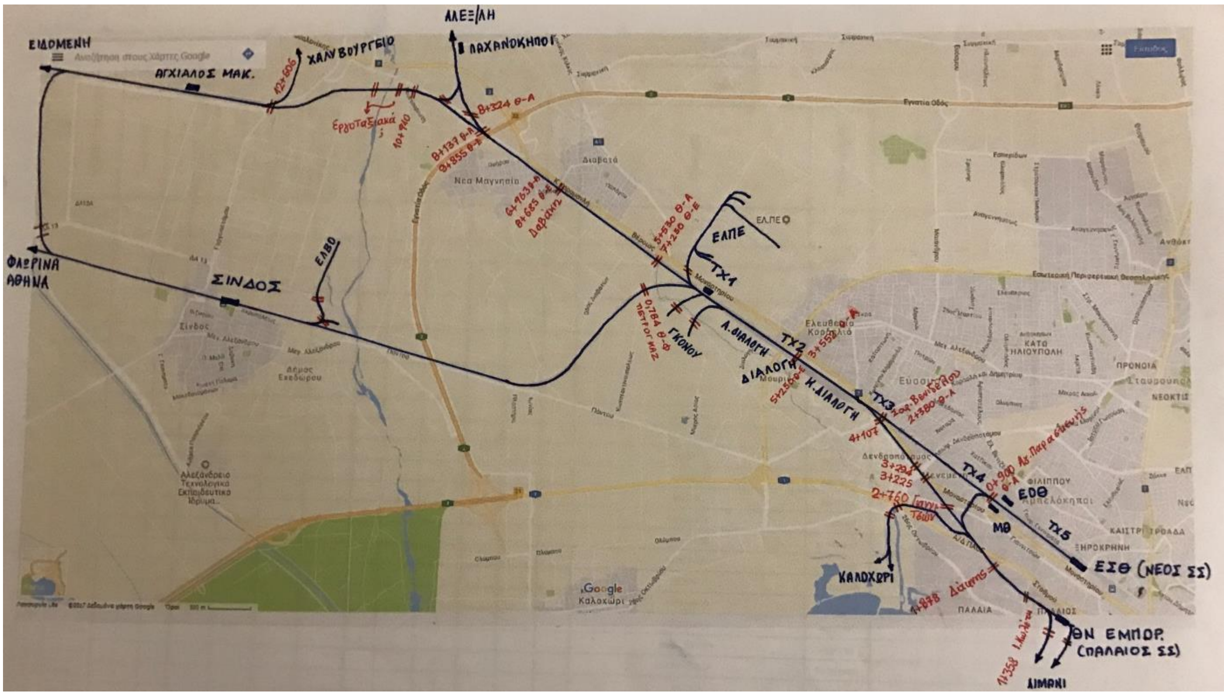


Figure 27: Level crossings in Thessaloniki.

7.2. Technical description of the test site

The warning system based on mobile communication will detect that a train is approaching an LC and will send an alert to the taxis nearby about the risky situation. The trains will be equipped with Galileo-enabled devices in order to be monitored in real time. The taxis are already equipped and monitored for dispatching purposes. The warning system will be provided through a dedicated pop-up window generated by the dispatching and navigation application already used by the taxis.

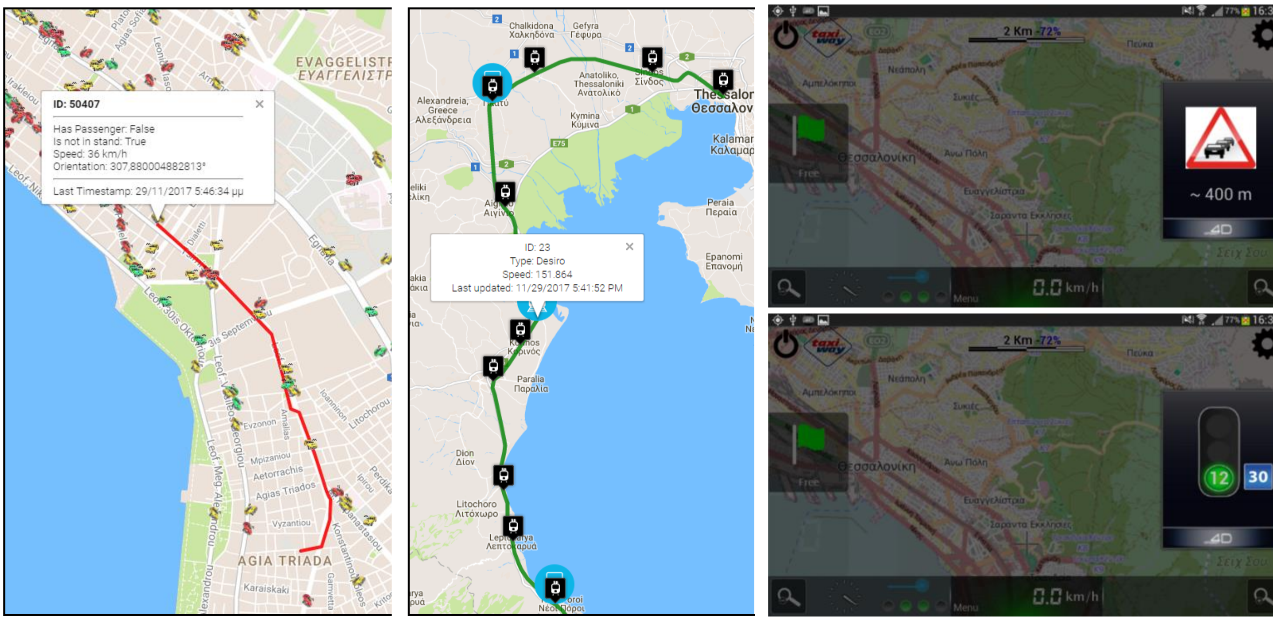


Figure 28: Trains and taxis monitoring in Thessaloniki (left). Pop-up alert for taxis implemented during the COPASS4D project (right).

The major elements of the warning system for level crossings within the living lab in Thessaloniki are the following:

- Location tracking devices and monitoring system: all taxis and some trains are already equipped with location devices and monitored by Taxiway and TRAINOSE respectively. TRAINOSE will equip more trains with location tracking devices in the framework of the SAFER-LC project.
- Detection system: CERTH already receives the locations of the taxis in real-time as part of its collaboration with the Taxiway association (Figure 28 left). The trains are already monitored by TRAINOSE in real time and in the framework of the SAFER-LC project the locations of the trains will be also accessible to CERTH. CERTH will develop a detection system based on geoposition where the taxis circulating in the surroundings of a LC will be informed of approaching trains in a three-level alert system (200, 500 and 1000 meters).
- Alert system / HMI device: The taxis are already equipped with smart devices connected to the dispatching centre of Taxiway. CERTH will develop a new pop-up based application that will run in the background of the smart device. It will alert the drivers as it was done in the COMPASS4D[1] project, where traffic light status and road hazard warning were provided to the drivers (Figure 28 right).
- In addition, the DLR naturalistic driving study (NDS) platform will be installed in up to five taxis in order to collect data for analysing the drivers' reaction to the safety service in the context of the approach to level crossings. The NDS platform consists of a set of four miniature cameras that will be installed in the taxis. It will monitor as well the environment

[1] http://ertico.com/projects/compass4d/

as the driver’s behaviours and facial expressions. In addition to the cameras, a GPS sensor is implementer in the NDS system to detect driving parameters such as speed, acceleration and position of the taxis. Cameras and GPS are connected via cables to a data storage box that stores all data on SD cards. The GPS position in the combined data file can be used to extract exactly the data sequences that are recorded during the passage of the level crossing.

The smart detection system will be based in map matching the locations of all the vehicles to a set of pre-defined polygons. If there is a match (a train and a taxi in the same polygon group) an alert will be generated.

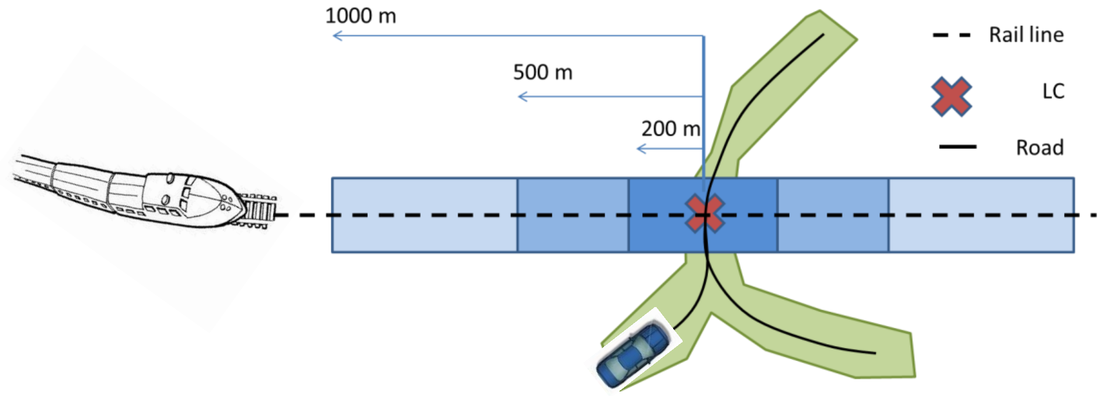


Figure 29: Rail and road polygons for the alert system in Thessaloniki (theoretical representation).

The alert will inform the driver about the approaching train and the expected time of arrival (ETA) to the LC, which is calculated using the speed of the train and the distance to the LC. Three advices will be generated, when the distance between the train and the LC are 1.000, 500 and 200 meters, providing the ETA as estimated using the speed of the train (Figure 29).

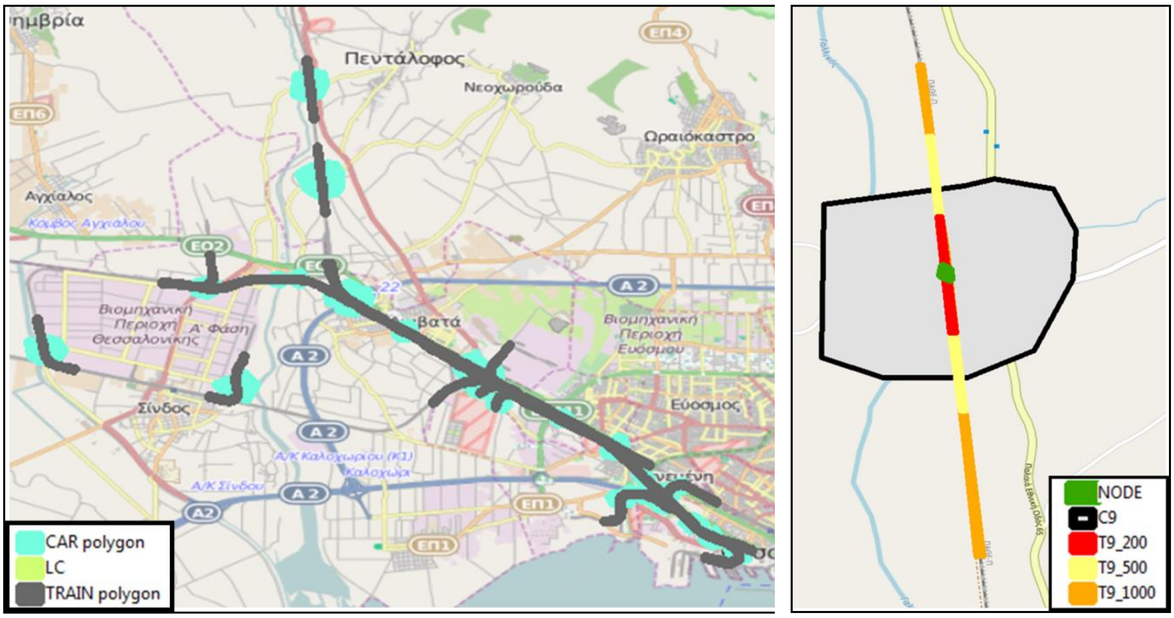


Figure 30: Polygons of the alert system implemented in Thessaloniki.

With regards to the rail infrastructure, all Thessaloniki network is electrified. In terms of rolling stock infrastructure in Thessaloniki TRAINOSE operates the following vehicles. ADTRANZ 220 and SIEMENS 120 operate in the main route of Greece which is Athens Thessaloniki. SIEMENS DESIRO operates in Thessaloniki suburban.

- ADTRANZ is the main locomotive of route Athens - Alexandroupoli. Athens Domokos is almost the half of the route Athens Thessaloniki which is the main route of Greek region. OSE bought ADTRANZ fleet in 1995 from Germany. ADTRANZ belongs to group of DIESEL locomotives and this happens because the route Athens Alexandroupoli is not electrified. It has 2853 horsepower and it can achieve a maximum speed of 160 km/h. Most of the times ADTRANZ work in pair with second ADTRANZ locomotive. It operates only for passenger trains.

Figure 31: Adtranz locomotive

- SIEMENS 120 is the main locomotive of Athens Thessaloniki. The out shape looks like ADTRANZ but unfortunately SIEMENS 120 is an electrified locomotive. When Athens

Domokos is going to be electrified SIEMENS 120 fleet will replace the ADTRANZ one. SIEMENS 120 costs almost the one third of a diesel locomotive in fuels and maintenance. Furthermore, SIEMENS 120 has 6796 horsepower and can operate the same amount of tones that two ADTRANZ can operate.

Figure 32: Siemens 120 locomotive

- SIEMENS DESIRO is an electrified car-train. It operates in Kiato - Athens airport and in Thessaloniki - Larisa suburban. OSE bought SIEMENS DESIRO in 2005 and they have 3000 horsepower. It can achieve a maximum speed of 160 km/h and it is one of the newest trains OSE has.

Figure 33: Siemens Desiro locomotive

In Thessaloniki area there are 3 main railway paths. The first path is the Alexandroupoli route, the second one the Eidomeni and the third one the Florina route.

- The Thessaloniki – Eidomeni route is one of the most important freight lines in region. It connects the Hellenic region with Skopje and European Union. According infrastructure manager 4 LC's from 26 are unprotected.

Thessaloniki – Eidomeni line

Num.	Km position	Type	Position
1	1+356	Automatic user side protection and warning and rail side protection	I Koleti
2	1+878	Automatic user side protection and warning and rail side protection	Dafnis

3	2+760	Automatic user side protection and warning and rail side protection	Giannison
4	3+225	Automatic user side protection and warning and rail side protection	Menemeni
5	3+294	Automatic user side protection and warning and rail side protection	Menemeni
6	4+107	Automatic user side protection and warning and rail side protection	Kordelio
7	5+250	Automatic user side protection and warning and rail side protection	Kordelio
8	7+250	Automatic user side protection and warning and rail side protection	Nea Ionia
9	5+685	Automatic user side protection and warning and rail side protection	Nea Ionia
10	9+855	Automatic user side protection and warning and rail side protection	Nea Ionia
11	10+910	Automatic user side protection and warning and rail side protection	Nea Ionia
12	12+606	Automatic user side protection and warning and rail side protection	Sindos
13	19+508	Automatic user side protection and warning and rail side protection	Agios Athanasios
14	20+239	Automatic user side protection and warning and rail side protection	Agios Athanasios
15	23+115	Automatic user side protection and warning and rail side protection	Gefira
16	35+765	Automatic user side protection and warning and rail side protection	Kastanas
17	38+412	Automatic user side protection and warning and rail side protection	Akropotamos
18	43+879	Automatic user side protection and warning and rail side protection	Aspros
19	54+130	Automatic user side protection and warning and rail side protection	Polikastro
20	57+275	Automatic user side protection and warning and rail side protection	Polikastro
21	57+565	Automatic user side protection and warning and rail side protection	Polikastro
22	58+010	Automatic user side protection and warning and rail side protection	Polikastro
23	60+496	Passive level crossing	Axioupoli
24	73+580	Passive level crossing	Eidomeni
25	74+950	Passive level crossing	Plagia
26	77+172	Passive level crossing	Eidomeni

- One secondary line is the Thessaloniki – Alexandroupoli. From strategic view this line connects the Thessaloniki with North Europe and Turkey. According infrastructure manager 3 from 21 LC's are unprotected.

Thessaloniki – Alexandroupoli line

Num.	Km position	Type	Position
1	0+900	Automatic user side protection and warning and rail side protection	Agia Paraskeui
2	2+380	Automatic user side protection and warning and rail side protection	Kordelio
3	3+552	Automatic user side protection and warning and rail side protection	Kordelio
4	5+530	Automatic user side protection and warning and rail side protection	Nea Ionia
5	5+983	Automatic user side protection and warning and rail side protection	Nea Ionia
6	8+137	Automatic user side protection and warning and rail side protection	Nea Ionia
7	8+324	Automatic user side protection and warning and rail side protection	Nea Ionia
8	11+037	Automatic user side protection and warning and rail side protection	Nea Ionia
9	13+225	Automatic user side protection and warning and rail side protection	Mesaio
10	14+650	Automatic user side protection and warning and rail side protection	Mesaio
11	24+058	Automatic user side protection and warning and rail side protection	Mesaio
12	27+800	Passive level crossing	Gallikos
13	29+167	Automatic user side protection and warning and rail side protection	Gallikos
14	32+822	Passive level crossing	Kampani
15	35+793	Automatic user side protection and warning and rail side protection	Pedino
16	40+850	Automatic user side protection and warning and rail side protection	Kristona
17	43+534	Automatic user side protection and warning and rail side protection	Kristona
18	47+400	Passive level crossing	Megali Vrisi
19	52+980	Automatic user side protection and warning and rail side protection	Stauroxori
20	58+822	Automatic user side protection and warning and rail side protection	Xerso
21	60+731	Automatic user side protection and warning and rail side protection	Xerso

- One very important passenger line is the Thessaloniki – Florina line. This line connects Athens to Thessaloniki. These two cities are the biggest in Hellenic region. According the infrastructure manager all of the LC's in this part of the line are fully automatic and they are protected.

Thessaloniki – Florina line

Num.	Km position	Type	Position
1	0+264	Automatic user side protection and warning and rail side protection	Petrogaz
2	14+066	Automatic user side protection and warning and rail side protection	Sindos
3	36+012	Automatic user side protection and warning and rail side protection	Platy
4	35+510	Automatic user side protection and warning and rail side protection	Platy
5	40+175	Automatic user side protection and warning and rail side protection	Platy
6	43+379	Automatic user side protection and warning and rail side protection	Platy
7	44+250	Automatic user side protection and warning and rail side protection	Ethniki
8	47+145	Automatic user side protection and warning and rail side protection	Vrysaki
9	48+040	Automatic user side protection and warning and rail side protection	Loutros
10	58+380	Automatic user side protection and warning and rail side protection	Kouloura
11	82+608	Automatic user side protection and warning and rail side protection	Mesi

7.3. Safety measures that can be evaluated in test site

The Thessaloniki living lab has been used for testing various cooperative ITS applications for road transport in the framework of the COMPASS4D and COGISTICS[2] projects as well as in the ongoing C-MOBILE[3] project. The ones related to safety are the following:

- Road hazard warning (COMPASS4D). This service was developed and tested along the Peripheral Ring Road, informing drivers about congestion ahead. It will be updated and tested in the C-MOBILE project.

[2] http://cogistics.eu/

[3] http://c-mobile-project.eu/

- Road works, emergency vehicle and signal violation warnings as well as warning system for pedestrians (C-MOBILE). These services will be developed and tested in the C-MOBILE project.

The research questions/hypotheses that will be tested in Thessaloniki in the framework of the SAFER-LC project are the following:

- The alerts will increase the attentiveness of the taxi drivers when crossing the LCs.
- The drivers will speed up/accelerate when approaching to the LC depending on the distance/expected time of arrival.

In order to assess the safety measures and answer to the above questions / analyse the hypotheses, no specific preparations are needed, only for the tests using the DLR equipment. The safety measures are tested under real-life conditions during the normal operation of both the trains and taxi services.

With regards to the scenarios described in D1.3, smart detection and communication system for information sharing will be evaluated in Thessaloniki. In addition, based on the data acquired with the NDS systems, it can be evaluated how the taxi drivers interact with the level crossing alerting application that will be tested. The video data will allow getting an impression of the effect of the application on the driver attention and driving behaviour during the level crossing passages[4].

7.4. Data and indicators that can be acquired

In Thessaloniki living lab, location data with regard to taxis- and train traffic will be acquired. The raw data that can be acquired in the test site is Floating Vehicle Data of the taxis and trains participating in the project. This data is composed of location (GPS coordinates), timestamp, orientation, vehicle id and speed at a 1Hz interval. This raw data allows CERTH to reproduce all the situations around the LCs and calculate indicators such as:

- Driving behaviour based on trajectories of the taxis when approaching a LC (speed, stops, rerouting…)
- Risk indicators such as time gap between the passage of a taxi and a train at the same LC (→ the smaller the time gap, the higher the risk)
- The camera data of the NDS system have to be annotated in order to result in data connected to the visual attention of taxi drivers while passing a level crossing. In addition to that, it can be used to extract the time / duration of certain related activities of drivers as a dependent variable (e.g. activities during the use of the warning system)

In addition, data about the warning system performance itself will be collected in order to calculate:

- False alarm (train not coming)
- Wrong alerts (taxi not heading to the LC)

The raw data is being already collected from January 2018 in order to estimate the indicators for the base line and compare them to the ones obtained from the period where the service was operational.

[4] Video data that involve persons (taxis drivers) will only be recorded with their permission. Participants can always refuse the use of their data. Video data will exclusively be used by partners of CERTH and the SAFER-LC project. Data will not be accessible to third parties. Raw video data will be deleted after the analysis.

7.5. Description of tools that are used for data collection within the site

All the data is generated by the respective fleet management equipment (tablets in the taxis and GPS receivers in the trains) and collected by CERTH. No special training for using the application is needed, since it will work automatically and launch pop-up alert windows. The data is anonymised in order to respect the privacy of the drivers and can be only processed by staff of CERTH, following the ethical framework/guidelines defined in WP8. More specifically:

- Taxiway provides the GPS locations of their fleets to CERTH-HIT. All vehicles are already equipped.
- TRAINOSE is going to provide GPS data for the operated fleet. Some of the GPS devices have already been installed in SIEMENS DESIRO trains. SIEMENS DESIRO is part of the suburban railway of Thessaloniki. These devices are connected in main battery of the train and they work under 12V voltage. Moreover, a specification of EN50155 can be used so to be compatible with the main rolling stock. In addition to the suburban, regional and freight trains are operating in the Thessaloniki region. These are ADTRANZ, SIEMENS 120 and MLW500 which operating regional passenger and freight routes. TRAINOSE will install GPS devices in this part of the fleet and will provide data for Thessaloniki pilot.
- Video data are only collected and analysed with the explicit consent of the taxi drivers that participate in the Thessaloniki living lab. No passengers will be recorded.

7.6. Guidelines to pilot implementation, operation and monitoring

7.6.1. Pilot implementation guidelines

Initially, a study of the trajectories generated by the taxis will be executed in order to define the most "visited" LC as well as the taxis that pass the most through them. This will allow to emphasize in the selected LCs and vehicles during the pilot, as well as to select the vehicles where the DLR platform will be installed. The same analysis will be done with the trains in order to equip the ones passing by these LCs.

CERTH is the leader of both the test site and the living lab in Thessaloniki, which facilitates significantly the implementation and testing activities. In addition, the two key stakeholders involved are TRAINOSE which operates the trains and is a partner in the project and the Taxiway association which manages the fleet of taxis, and has a long-term collaboration agreement with CERTH.

Most components of the test side will be ready by the end of 2017. The only missing component is to increase the number of connected trains and connect CERTH to the TRAINOSE system in order to receive the location of the trains in real time. During the second quarter of 2018 all the components will be developed and integrated and more trains will be equipped, aiming to deliver the detection system in the third quarter of 2018.

7.6.2. Operation and monitoring guidelines

The operation of the test site will be done without additional effort since it is based in the normal circulation of trains and taxis, which is their usual business. CERTH will monitor the execution of the pilot in order to be sure that the system works and validate the data collected. In addition, fine tuning

of the warning system is possible based on the early feedback of the drivers during the first weeks of the test interval.
The data is generated by the trains and the taxis and sent to CERTH, which collects it. The datasets will be formatted accordingly and sent to the partners responsible for analysing it. Details about the data and the tools for data collection were provided in t.4 and 7.5 respectively.

7.7. Prerequisites and boundary conditions of test site use

The only boundary condition is related to the privacy of the taxi drivers, which is solved by setting anonymous driver and vehicle identities (replacing the driver and vehicle identities related to real drivers and vehicle owners) which are updated every 24 hours, not allowing to track back who was driving at every time and location. Concerning the participating in a study using NDS data, the participation only happens voluntarily and requires a written consent of the drivers that are willing to participate. In addition, all data management and handling processes at CERTH are in accordance to GDPR (Regulation (EU) 2016/679) from March 2018.

7.8. Use of Thessaloniki test site in SAFER-LC

The Thessaloniki test site will be used as a proof-of-concept of the use of cooperative technologies and protocols in the rail sector for the provision of multimodal safety services.

7.9. References

The test site has been and is being used in various projects and studies:

- EOX (http://www.mobithess.gr/): provision of info-mobility services
- COMPASS4D (http://www.compass4d.eu/): testing of cooperative services for passenger transport
- COGISTICS (http://cogistics.eu/): testing of cooperative services for freight transport
- C-mobile (http://c-mobile-project.eu/): provision of advanced cooperative services for passenger transport
- Big Data Europe (https://www.big-data-europe.eu/): use of big data tools for the provision of traffic status prediction

A list with publications from the above projects is provided below:

Scientific journals

- E. Mitsakis, I. Stamos, J.M. Salanova Grau, E. Chrysohoou, G. Aifadopoulou (2013) Urban Mobility Indicators for Thessaloniki, Journal of Traffic and Logistics Engineering (JTLE) (ISSN: 2301-3680), Vol. 1 No. 2, June 2013. pp. 148 – 152. [DOI:10.12720/jtle.1.2.148-152]
- Mitsakis E., Salanova J. M., Chrysohoou E., Aifadopoulou G. (2015). A robust method for real time estimation of travel times for dense urban road networks using point-to-point detectors. Transport 30(3) 2015, pp. 264-272. Special Issue on Smart and Sustainable Transport. [DOI:10.3846/16484142.2015.1078845]
- Salanova J. M., Rusich A., Mitsakis E., Ukovish W., Pia-Fanti M., Aifadopoulou G., Nolich M., Scala E., Papadopoulos C. (2016). Evaluation framework in Cooperative Intelligent Transport

Systems (C-ITS) for freight transport: the case of the CO-GISTICS speed advice service. International Journal of Advanced Logistics (DOI: 10.1080/2287108X.2016.1144373).
- Stamos I., Mitsakis E., Salanova Grau J.M. (2016), Modeling Effects of Precipitation on Vehicle Speed: Floating-Car Data Approach, Transportation Research Record, Journal of the Transportation Research Board, No. 2551, pp. 1-12.
- Mitsakis E., Salanova Grau J.M., Iordanopoulos P., Mintsis E. (2016). Frameworks and Methods for ITS Evaluation. Evaluation of Intelligent Road Transportation Systems: Methods and Results. IET Digital Library. [ISBN: 978-1-78561-172-8]
- Salanova J. M., Maciejewski M., Bischoff J., Estrada M., Tzenos P., Stamos I. (2017). Use of probe data generated by taxis. Big Data for regional science. Routledge Advances in Regional Economics, Science and Policy. Taylor & Francis Group. [ISBN 1138282189, 9781138282186]

8. INTADER TEST SITES

8.1. Test Sites at a glance

In SAFER-LC, INTADER is planning to perform tests in Aydın (122+230 km), Seyhan – Adana (360+250 km), Seyhan – Adana (365 + 731 km), Tarsus – Adana (28 + 180 km) and Niğde (55 +185 km). All test sites have a video system that is supposed to be used to identify the user group's behaviour, especially the behaviour of vulnerable road users (children, elderly, disabled persons etc.). The video systems used belong to Turkish State Railways (TCDD). INTADER will not establish new video systems unless the obtained data from test sites is not sufficient. During the test periods, a month of data from each video system will be obtained because of the restricted storage capacity of the video systems.
To compare the effectiveness of applied non-technological measures in the test sites, data will be recorded continuously over a long period of time. When enough baseline data are recorded for a valid analysis, measures can be implemented and tested and compared to the baseline. Based on the repeated data acquisition before and after the implementation, results of the effectiveness of safety measures can be derived. Additionally, according to a "Confidentially Agreement" (Non-Disclosure Agreement), data obtained from the sites will not be disclosed to third parties unless TCDD will provide an official permission. To provide confidentially of user groups', INTADER and TCDD will take precautions such as not opening users' specific characteristics (face, the licence plate of cars etc.) or providing images are not including these specific characteristics.

Detailed Information about Aydın (122 +230 km) Test Site

- **Test site location / address:** Aydın, Turkey
- **Accessibility:** This test side is in the city centre and the most crowded crossing which is close to the hospital, commerce centre, residences and school.
- **Test site contacts:** Hasret Sahin, Canan Korkmaz
- **Company that owns Test site:** This test side is the LC on TCDD network
- **If not part of Test site:** N/A

Brief Information about Aydın (122 + 230 km) Test Site
The population of the Aydin city is 260 thousand people within the metropolitan municipality. The geographical position of the railway and station separates the city in the middle. There are schools, hospital, shopping centre and stadium really close to the Aydin Station. The State Hospital is also near the station zone and people from close towns are travelling to the city for treatments in the hospital.

The test site was chosen since especially vulnerable groups of persons use the level crossing, including children. Due to the location close to a school and a hospital, level crossing safety systems that are supposed to protect children, elderly or disabled persons could be tested at this site.

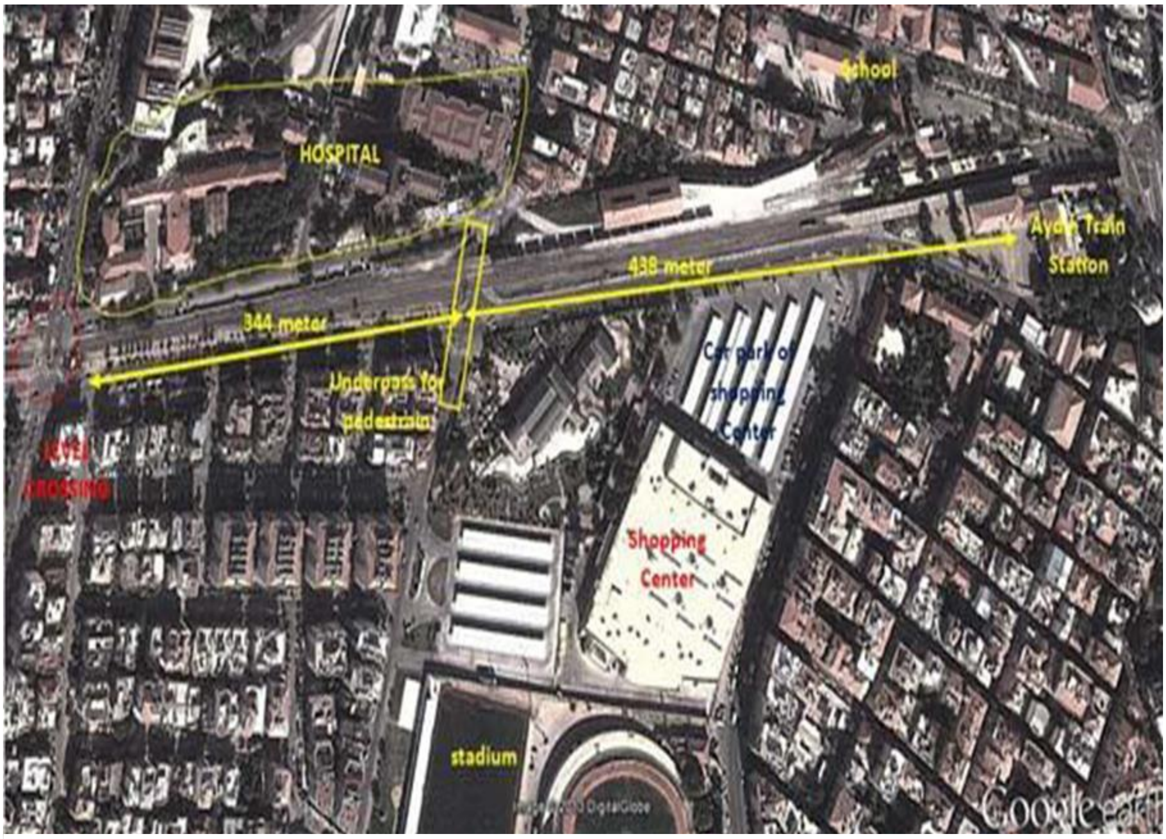


Figure 34: Aerial view of the Aydın test site

Figure 35: Aydın test site

<u>Detailed Information about Seyhan – Adana (360 +205 km) Test Site</u>

- **Test site location / address:** Seyhan, Adana Turkey
- **Accessibility:** The test site is open to public use and it is located in Adana**.**
- **Test site contacts:** Hasret Sahin, Canan Korkmaz
- **Company that owns Test site:** This test side is the LC on TCDD network
- **If not part of Test site:** N/A

<u>Brief Information about Seyhan – Adana (360 + 205 km) Test Site</u>

The population of the Adana city is 1,737 million, within the structure of the metropolitan municipality. Seyhan is an area in Adana. The population of Seyhan is 797,563. 49,89% of the population is female and 50,11 of it is male. 32,81% of the population is between the age 0-18 and it has a significant refugee rate as 8,84% of the total. The education level of Seyhan is low. 8,62%of the population graduated from university and 0,64% has master/ postgraduate degree.

The geographical position of the railway in Seyhan separates the district to an industrial zone and a residential zone. The LC is the shortest connection between industrial zone and residential zone. Considering the site location, this test site has also video system likewise in Aydın implemented in test site. However, the user group using this level crossing is different. The region has a high population of Syrian refugees. This special group of vulnerable LC-users is one of the main reasons to choose this location as a test site. The second reason is that the being a bridge between industrial and residential zone. In other words, workers in the industrial zone use this LC system. The accident risk is supposed to be higher than at Aydın site. Using the video camera system, it is possible to identify behaviour of users before and after the implementation of potential measures, so that their effectiveness can be measured. Depending on the data gathered from the test site, some physical measures could be taken. However, this will be decided in the later stages of the project.

Figure 36: Video Camera System in Seyhan-Adana (360 +205 km) test site

![SAFER-LC logo]

Figure 37: Level Crossing System in in Seyhan-Adana (360 +205 km) test site

<u>Detailed Information about Seyhan – Adana (365 + 731 km) Test Site</u>

- **Test site location / address:** Seyhan, Adana Turkey
- **Accessibility:** The test site is open to public use and it is located in Adana**.**
- **Test site contacts:** Hasret Sahin, Canan Korkmaz
- **Company that owns Test site:** This test side is the LC on TCDD network
- **If not part of Test site:** N/A

<u>Brief Information about Seyhan – Adana (365 + 731 km) Test Site</u>

The test location separates the industrial zone from the residential zone. The city has a very high refugee population. This test location is closely located to the Seyhan – Adana (360 +205 km) test location. However, there is a big bazaar area near to this test site location. At specific days in the week, many people visit this bazaar and have to cross the LC. The users' behaviour can be analysed

Figure 38: Seyhan- Adana (365 +731 km) test site

by the data from video system which is already established at the LC. According to our knowledge, typical groups of persons using the LC are female and male customers or sellers that are visiting or working at the bazaar. Additionally, a school is located close to the school. Therefore the behaviour of children at an LC will be observable in order to derive ideas about how safety measures could be designed for this specific group.

Figure 39: Side view of Seyhan- Adana (365 +731 km) test site

Figure 40: Level Crossing Systems Seyhan- Adana (365 +731 km) test site

Detailed Information about Tarsus – Adana (28 + 180 km) Test Site

- **Test site location / address:** Tarsus, Adana Turkey
- **Accessibility:** The test site is open to public use and it is located in Adana**.**
- **Test site contacts:** Hasret Sahin, Canan Korkmaz
- **Company that owns Test site:** This test side is the LC on TCDD network
- **If not part of Test site:** N/A

Brief Information about Tarsus – Adana (28+ 180 km) Test Site

Similar to the previous test location, this LC is located between the industrial zone and the residential zone of the city. The test location is close to Mersin, which is one of the most crowded cities in Mediterranean Region. This test location was chosen because it is located close to a nearby school, a hospital and a residential area. The site has a video system that enables the analysis of the behaviour of specific vulnerable user groups that cross the LC in this location. According to our knowledge, residents and children are using the line. A further user group are refugees living in regions close to the test site.

Figure 41: Side view of Tarsus - Adana (28 +180 km) test site

Figure 43: Level Crossing System Tarsus - Adana (28 +180 km) test site

Figure 42: Video System in Tarsus - Adana (28 +180 km) test site

<u>**Detailed Information about Niğde (Aydın 55 + 185 km) Test Site**</u>

- **Test site location / address:** Niğde, Turkey
- **Accessibility:** The test site is open to public use and it is located in Adana**.**
- **Test site contacts:** Hasret Sahin, Canan Korkmaz
- **Company that owns Test site:** This test side is the LC on TCDD network
- **If not part of Test site:** N/A

<u>Brief Information about Niğde (28+ 180 km) Test Site</u>

The population of the Niğde city is 216 thousand within the structure of the metropolitan municipality. 50,16% of the population is female and 49,98% of it is male. 32,89% of the population ranges between the age 0-18 and it has a significant refugee rate of 0,33% of the total population. The education level of Niğde is not quite high. 8,95% of the population graduated from university and 0,96% has a master/ postgraduate degree.

The geographical location of the city is close to Kayseri and Konya. The city culture and structure are different compared to cities like Adana that are located in the Mediterranean region. The city is more isolated compared to Adana, where the majority of people travel for trading. In case of Niğde, farming is the most important factor in the commercial sector of the city. Based this contrast to Adana, Niğde was chosen as a test site. Although the refugee rate in Niğde is not as high as in other test locations, it is a transition point of the refugee movement because of the geographic location of city.

The city is an important junction point of railways and highways. In terms of the railway, the city is located on the railway line which connects West Anatolia and cities located in southern part of Turkey. In addition, the railway line is also linking Syria and Iraq. Therefore, the majority of refugees coming from Syria use this line to pass through the inner cities in Anatolia. Hence, the LC could potentially be higher compared to other test locations.

The LC in this test location separates an industrial zone from a residential area. After collecting video data at the LC, user groups can be identified in detail. However, it is projected that refugees that cross the LC will be the most relevant user group at this LC.

Figure 44: Aerial view of Niğde (28+ 180 km) test site

Figure 45: Level crossing system in Niğde (28+ 180 km) test site

8.2. Technical description of the test sites

The selected test sites in Turkey are equipped with video systems and LC barrier protections. The specification of the LCs in the test sites in Turkey are provided in Table 1.

Table 1: Technical description of test sites

	Aydın (122 +230 km)	Seyhan – Adana (360 +205 km)	Seyhan – Adana (365 + 731 km)	Tarsus – Adana (28 + 180 km)	Niğde (Aydın 55 + 185 km)
Type of LCs	Manual user-side warning and protection	Automatic user side protection and warning	Manual user-side warning and protection	Automatic user-side protection and warning	Manual user-side warning and protection
Type of Road Surface	Stone pavement	Stone pavement	Composite	Asphalt	Composite
Video Camera Systems	Yes	Yes	Yes	Yes	Yes
Sight Distance from Road	N/A	2000 m	750 m	200 m.	N/A

***N/A means the information taken from TCDD or other sources are not clear. During site visits, these parameters will be clarified by LC system operators.*

<u>For all test sites:</u>
Non-technological measures to enhance safety are planned to be implemented at a test site in a later stage in the project. Details will be planned after an initial collection and analysis of the data obtained in the test sites. Currently, available data from TCDD are not sufficient to decide which measures should be implemented to enhance safety or what kind of technologies will be implemented in the test site other than video systems and existing measures. The implementation of technological measures is not in the scope of the test site.
Video camera systems are already implemented in each test site. The video systems enable gathering huge amounts of the data from the sites and to identify the risky behaviours at LCs. By using a video system, obtained data can be compared for different kinds of users (motorised, cyclists, pedestrians etc.). Additionally, the data can be used for evaluating the effect of the new safety measures and their effects on the site. The effectiveness and efficiency of new non-technological measures can be compared, based on data in obtained in a baseline period and an experimental period.

8.3. Safety measures that can be evaluated in test site

The current safety measure that is implemented at all of the test sites in Turkey are half barrier LC systems. As stated before, tests locations were chosen considering the populations of certain users' and vulnerable groups in the areas, like children, refugees or elderly.
The number of violations, the number of accidents, the severity and number of physical injuries reported to hospitals or pecuniary punishments (fines) are few examples for key performance indicators that might be considered during the tests. After the definition of basic key performance indicators, new non-technological measures will be evaluated.

8.4. Data and indicators that can be acquired

The raw data can be acquired from video systems located in the test sites. Data of each specific user group will be examined. The data consist of visual records of the days and accidents (if happened more recently), a timestamp, the location, the orientation of vehicles in the scenery, if possible vehicle an id and the speed of vehicles. After analysing raw data, detailed indicators will be determined. In the current stage, depending on statistics, the non-technological measures are defined in Figure 47. Depending on raw data taken from video systems and interview with LC operators and machinists, the causes of accidents or injuries can be examined properly and then other specific non-technological measurements except demonstrated in Figure 47 can be applied.

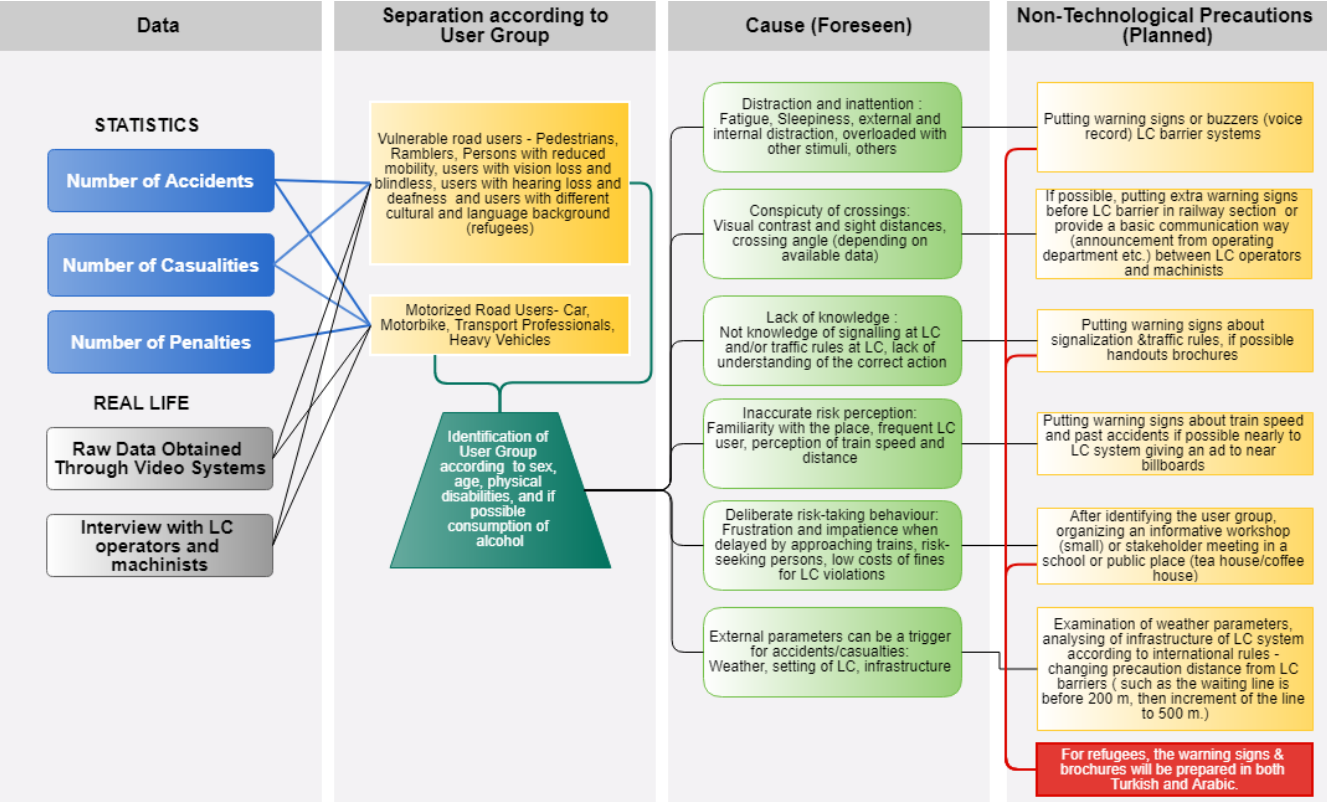


Figure 47

8.5. Description of tools that are used for data collection within the site (technical details)

All the data is gathered from existing video systems. Most of the cameras located on the test sides have multifunctional specifications such as storing large data from the sites, voice communication (some of them), web access, alarming systems etc. Therefore, raw data probably will include several parameters. The video systems can provide up to 3 megapixels resolution and obtain 60 frames per second. The minimum resolution obtained from video system resolution is 4CIF/4SIF (704 × 576).

During the test period, a monthly dataset from each video system will have to be drawn from the storage because of the restricted storage capacity. According to a “Confidentially Agreement” (Non-Disclosure Agreement), data obtained from the sites will not be opened unless TCDD provides an official permission. To provide confidentially of user groups’, INTADER and TCDD will take precautions such as not opening users’ specific characteristics (face, the licence plate of cars etc.) or providing images are not including these specific characteristics.
A special training is not required during the implementation phase. The data will be filtered and resolved to provide users’ confidentiality. During the tests, barrier usage and guideline manuals (if exists) will be collected from operators. Guidelines to pilot implementation, operation and monitoring

8.5.1. Pilot implementation guidelines

For all test sites in Turkey, concrete measures that will be tested will be defined in a later stage of the project. Based on KPIs explained in Section 6.4, the raw data taken from test sites will be evaluated. Analysis of raw data will be opened to TCDD for a detailed evaluation. TCDD and INTADER are responsible to decide at a later stage whether additional measures at the level crossings will be accepted for experimentation or not.
The stakeholders for these tests are TCDD and the local inhabitants of the regions surrounding the level crossings. As stated earlier, the cameras were already set up at the LCs, and they are fully operational. Therefore, the test sites are ready to be used. However, all detailed specifications for implementations of additional measures will be done at a later phase in the project.

8.5.2. Operation and monitoring guidelines

INTADER will be responsible for collecting raw data, testing and evaluations within the test site. Only TCDD operators and experts will be allowed to fetch the data from camera systems and insert it in the TCDD database. The video systems in the test sites can collect data for one month. This period could be rather short to identify the risks of actual accidents. Each single month the INTADER / TCDD team will visit the site and collect raw data from the video systems because of the limited storage capacity. Embedding an external storage capacity might be an option. TCDD permission is required. This issue will resolve after a meeting with TCDD scheduled planned in April 2018. Most of the equipment on the LC belongs to TCDD, therefore TCDD cares about maintenance works.

8.5.3. Prerequisites and boundary conditions of test site use

To implement new measures and to conduct tests on the sites, TCDD approval and official permission are required. The tests regions are closed to other countries’ borders. At the current moment, special military mobilization can be seen from time to time. Because of the high number of problems arising from a high refugee population, several unexpected accidents, events, or reactions from the public might occur and be detected. Some of the test sites are inside of the city, therefore, safety issues are of high relevance. Another boundary condition is related to weather conditions in Turkey. The test sites are located in regions that have a warm and humid climate, especially in summer. The hot and humid environment might damage certain equipment or the video systems.

8.5.4. Use of Turkey test site in SAFER-LC

The five test sites are chosen considering specific risks due to certain user groups and their location. Although LC barrier systems are already in use at the test sites, the real effectiveness of these barriers with regard to the inhabitants will be investigated. The output of the test will be useful when it comes to understanding what a certain user group needs in terms of extra precautions and measures that can enhance safety.

9. CONCLUSIONS

This deliverable contains an overview of a variety of test sites that can be used to examine the effects of measures aiming to enhance safety of level crossings. The guidelines are meant to serve as a basis to decide on a test site, where a given safety measure will be piloted and evaluated. While safety measures on a very conceptual level can be implemented in a simulation environment, more mature measures might be tested under real traffic- or close to real traffic circumstances. In order to qualify and/or quantify the effects of piloted safety measures in an appropriate way, key performance indicators will be defined in a separate parallel deliverable (D4.2). These the key performance indicators provide support in choosing the most appropriate indicators to be collected in each of the test sites for the evaluation of each piloted safety measure.

While this deliverable 4.1 serves as an impression to decide "*where*" to test certain measures, the parallel deliverable 4.2 offers insights into "*how*" to test them. The safety measures that will be tested in the test sites described in this document will be developed and defined within the SAFER-LC work packages 2 and 3.