Deliverable D8.1: Methodology for Test and Pilots

Work package:	WP8 – Integration and Pilot Testing
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Status:	Final
Date:	31/01/2019
Version:	0.8
Classification:	Public

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Authorised date:31/01/2019

TransSec Project Profile

Grant Agreement number: 776355

Acronym:	TransSec.
Title:	Autonomous emergency maneuvering and movement monitoring for road transport security
URL:	www.transsec.eu
Start Date:	01/02/2018
Duration:	36 months

Partners

Partner	Country
Daimler AG	GERMANY
TeleConsult Austria GmbH	AUSTRIA
FUNDACION CENTRO DE TECNOLOGIAS DE INTERACCION VISUAL Y COMUNICACIONES VICOMTECH	SPAIN
WATERFORD INSTITUTE OF TECHNOLOGY	IRELAND
UNIVERSITAET STUTTGART	GERMANY

Document Control

This deliverable is the responsibility of the Work Package Leader. It is subject to internal review and formal authorisation procedures in line with ISO 9001 international quality standard procedures.

Version	Date	Author(s)	Change Details
0.1	01/12/2018	Martin Tolan	Table of Content.
0.2	10/12/2018	Martin Tolan / Nithin Padmaprabhu	Initial contributions.
0.3	20/01/2019	Martin Tolan / Nithin Padmaprabhu	Initial contributions.
0.4	24/01/2019	Ruisong Han	Internal reviewer
0.5	25/01/2019	Nithin Padmaprabhu	Changes and formatting
0.6	28/01/2019	Ruisong Han	Internal reviewer
0.7	28/01/2019	Nithin Padmaprabhu	Changes and formatting
0.8	28/01/2019	Ruisong Han	Final Version

Executive Summary

Objectives

The aim of this project is to improve road safety by the use of satellite navigation application technology as provided by Galileo and EGNOS features and services in combination with available NDS maps, vehicle on-board sensors and communication, precise positioning, road lane and off-road navigation, movement monitoring and autonomous emergency manoeuvring, providing new in-vehicle security functionalities. As part of TransSec project, the objective of WP8 is to take the TransSec solution and perform tests and an evaluation of the success of the solution in real-world environmental conditions so an assessment as to the overall success of the project can be determined.

The main aim of this document is to capture the testing methodology required for the entire duration of the TransSec project. This document is also intended to act as a reference during the various integration, functionality to check and testing phases that have been planned for the project. Thereby we have a consistent prototype to be used to contribute to the successful evaluation of the project.

This document will also include the testing and evaluation carried out with real pilots of the TransSec solution on various differing hardware testbeds. Medium-duty and heavy-duty trucks are used in a designated pilot site in Stuttgart.

The results of the pilot evaluations will be available after M12, M24 and finally M36.

Results

The high-level details required for the successful execution of multiple pilot programs for the testing and evaluation of the TransSec solution are captured in this document. Also included are the questionnaires that provide valuable feedback from each of those pilots as to the various aspects of the success of the project:

- Technical performances of each work package
- Reliability
- Cost effectiveness
- Availability

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2 Abbreviations and Acronyms

Abbreviation	Description
WP	Work Package
DTC	Development and Testing Centre
V2V	Vehicle to Vehicle
TCA	Tele Consult Austria
TSSG	Telecommunications Software and Systems Group
V2X	Vehicle to Everything
GNSS	Global Navigation Satellite System
EGNSS	European Global Navigation Satellite System
EGNOS	The European Geostationary Navigation Overlay Service

3 Introduction

3.1 Purpose of the Document

Deliverable D8.1 will provide the methods to evaluate and demonstrate the TransSec project. This includes the pilots, vehicles, and methodology used to test the TransSec solution. This testing will mainly concentrate on the overall functionality, accuracy, response, etc. A detailed report of the demos/testing will be provided whenever the demos are conducted during the project lifetime. The output of these testing/trials will be used for dissemination purposes to reach the larger and broader community.

3.2 Objectives

The main objectives of this WP are to test and evaluate the TransSec solution in real conditions with real pilots and to assess security and security satisfaction. Breaking down these objectives into measurable demonstrations, the aims of TransSec are:

- To validate the complete TransSec system in medium-duty truck Mercedes-Benz Atego;

- To validate the complete TransSec system in heavy-duty truck Mercedes-Benz Arocs;

- To implement demonstrations at the pilot sites in Stuttgart, and to validate the TransSec solution in terms of functionality, reliability, accuracy, and other technical performances.

3.3 Intended Audience

The dissemination level of D8.1 is public. This document is intended to be a reference for all partners involved in WP8 as well as for the reviewers. The procedures explained here can also be useful for User Experience practitioners.

4 Description of Pilot and Test Scenarios

The TransSec project will make a major effort in validating the developed solution with users and in real scenarios, since its acceptance (from the end users and security forces) is a key element for reducing the market entrance barriers of our new product or application. Two pilot testing campaigns are foreseen. Pilot tests will be conducted with a medium-duty (Mercedes-Benz Atego) and a high-duty (Mercedes-Benz Actros/Arocs) truck on public roads and off-road areas in Stuttgart and surrounding cities.

4.1 Infrastructure and Equipment

The infrastructure for the final demos will be provided by Daimler in Stuttgart, Germany. Currently, there are two testing sites in Wörth and Münsingen, to perform various test depending on the requirements of TransSec project. This test will be conducted under a controlled environment. In addition, Daimler will provide two different vehicles for the testing purpose.

4.1.1 Vehicles and Drivers

Daimler will provide two trucks for testing and demos. A medium-duty truck (Mercedes-Benz Atego) which is primarily used for distribution and on the city roads with weight restrictions. Moreover, a heavy-duty truck (Mercedes-Benz Actros/Arocs) which is used for long distance/dangerous goods transport and off-road construction traffic will be used.

Figure 1: Heavy-duty Truck (Actros/Arocs) and Medium-duty Truck (Atego)

Technical equipment and a workshop to build up test trucks are available inside the Mercedes-Benz plant in Stuttgart. For very dangerous driving manoeuvres, closed test areas with roads and off-road sections are available in the Mercedes-Benz truck testing centres in Wörth and Münsingen. All the locations are around Stuttgart.

Each truck will be staffed with a driver and an observer. The drivers will be experienced developers, Daimler test drivers and in majority external professional truck drivers. Except for shorter demos, the total driving duration per driver is one full day, but with enough resting time between each trip to guarantee that the local driving regulations can be followed. For each pilot test campaign, a questionnaire for drivers

and observers has been prepared and will be answered after the test trips. Additionally, vehicle data and data of security functions will be logged during trips. The pilot test campaigns are closed with questionnaire evaluation and log data analysis.

For the first pilot test campaign, 20 full days with 20 drivers will be used. The second and final pilot test campaign will last 30 full days with 30 drivers. Test drivers for the pilot test campaign will be external professional truck drivers. Observers will be from Daimler project team and optionally from other TransSec partners. To sum up, the two pilot test campaigns will encompass 50 full day test trips with 50 external professional truck drivers.

4.1.2 Test Track 1: Mercedes-Benz Truck Testing Centre in Wörth, Germany

Figure 2: Mercedes-Benz Truck Testing Centre in Wörth, Germany

Wörth is the Development and Testing Centre (DTC) which belongs to Mercedes-Benz. Most of the development work has been carried out here. This site has all the required infrastructure to test road connected networks, automated and electric driving tracks. It has numerous rough-road tracks and different roadway profiles that replicate the roads of this world. It is also possible to simulate some of the environmental conditions existing in South America, South Korea, Africa and of course even in Europe.

The Wörth testing site comprises of a break-in track with an inclination of up to 49%, offices, and service spaces, which can be an added benefit to TransSec project to conduct the various testing and integration of the work packages. Bench tests can also be performed in Wörth premises e.g. TransSec functionality testing and unit testing.

4.1.3 Test Track 2: Mercedes-Benz Truck Testing Center in Münsingen, Germany

Figure 3: Mercedes-Benz Truck Testing Center in Münsingen, Germany

The Münsingen testing centre is a challenging track near Stuttgart, focused on testing the New Actros. The testing site contains a total of 10 miles of different testing surfaces such as high-speed straights, new rough-road tracks, a crosswind simulator, steep inclines, and a banked curve. Additionally, Daimler included new off-road sections and "whisper asphalt" surface to isolate and test car noise in this site.

The testing track offers a succession of tight bends, dips, crests, sharp climbs and steep descents, as well as sections which forces drivers to make simulated sudden lane changes and cross sections of a broken or uneven road surface. This will be used to test the various functions of TransSec project.

4.2 Public Route Testing

A route we could recommend would be to test this TransSec system in the inner city of Stuttgart and around Stuttgart. There will be two phases for public testing: the first set of public testing will be outside the Stuttgart city area, and another testing will be inside the Stuttgart city. Outside the city includes the road conditions like some of the major roads, national highways, motorways, freeways, bypass, and Expressway. Inside the city, the testing area will be concentrating on more pedestrian congested areas like smaller roads, city markets, near shopping centres, pedestrian crossing, etc. The public testing will allow us to test the complete working prototype and capture the logs in a real environment. As mentioned earlier, all trials will involve observers inside the cabs of trucks.

5 Testing Strategy

The testing plan is scheduled into three development cycles or phases, which are bench testing *[Unit tests (Alpha), Integration tests (Beta)]*, end-to-end systems tests *(Functionality Testing),* and scenario-based testing.

5.1 Bench Tests

It includes two types of bench testing which include unit tests (Alpha) and integration testing (Beta), where each work packages is tested independently and dependently to each other.

5.1.1 Unit Tests (Alpha)

Unit tests will be used to test each functionality in all the work packages. This will occur in the different project timelines. Each work package has demos during the 36-month project duration. All the demos mentioned in the project deliverables will be achieved by testing in the laboratory or in a controlled scenario. At the end of the first project year, there are several demos to be performed in work packages WP2, WP6, WP8. All these demos are to be submitted in the form of video recordings and a companion report. The year one demos will include the videos of the following functionality in following work packages:

- WP 2.2 (TCA) - Galileo Positioning System for Trucks
- WP 2.3 (TCA) - Authentication of GNSS Signals and Spoofing Detection
- WP 6.4 (TSSG) - Implementation of risk communication to vehicle (V2V)
- WP 8.2 (DAIMLER AG)- Test and demo precise vehicle positioning

5.1.2 Integration Tests (Beta)

Integration tests focusses on the integration of the work packages and the bench testing for complete functionality after the integration. Final TransSec product will have all the work packages working together and producing the expected output. The Beta tests will be performed just before the TransSec product is installed onto the trucks. So, integration of all the work done is integrated and tested in a controlled environment.

This testing will concentrate on testing the functions of each work package after the integration of all the work packages has been finished. The integration includes the work carried out in work packages 2-7 such as sensor data fusion, vehicle positioning, generating map data and localization, traffic scene analysis, V2X communications and autonomous emergency manoeuvres.

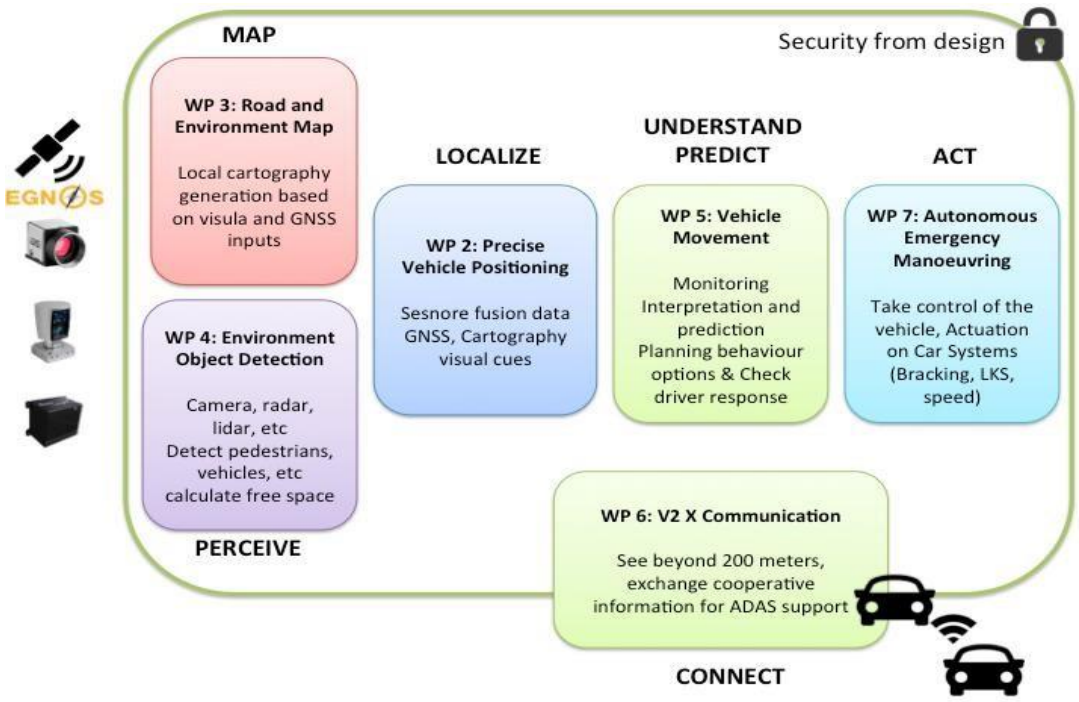

Figure 4: Integration of Work Packages

Below are the mentioned test cases we will be testing once the integration of all the work packages is completed, but they are not limited and can be changed during the course of the project lifetime:

- Precise positioning of the vehicle and protection measures against sensor manipulation and malicious attacks
- Generating map data and localization information to align the cartography with the scene.
- Sensing of the environment for detecting dynamic and static elements of the scene
- Traffic scene analysis and prediction for dynamic manoeuvre and path planning. It considers largely the notion of risk and risk perception.
- Connectivity between the vehicles as well as the infrastructure into play by defining and testing v2x interfaces.
- Non-defeatable basic and combined autonomous emergency manoeuvres to prevent intentional crashes.

5.1.3 End-To-End Systems Tests (Functionality Testing)

Final Prototype deployment: Once the final TransSec working product is developed, it will be installed in the trucks for testing various technical functionalities existing in the product. This will be the final step of the testing to be conducted in this project. There will be logs created in each work packages to analyse the outcome of the testing. Based on the logged data, we will analyse the performance of the TransSec product. Testing will be conducted on the public roads of Stuttgart as above-mentioned testing sites.

In this context, TransSec will develop and integrate the following elements in the final product, but not limited to: *(Might change during the project lifetime to improve the product quality):*

- Accuracy and integrity of the positioning using EGNSS components and services in a multi-system multifrequency environment.
- GNSS signal authentication and sensor data fusion for realising a resilient navigation system.
- Road and environment element tracking.
- Communicate risk to other vehicles and to infrastructure (V2X) beyond 200 meter-range achieved by cooperative solutions (V2X).
- Local dynamic maps generation.
- Precise and robust positioning based on visual cues, dynamic map and EGNSS fused with dissimilar sensor data.
- Scene evolution calculation. Interpretation of the scene elements and the prediction of each element dynamics.
- Handover functionality and emergency manoeuvre activation
- Scene continuous monitoring and analysis, by means of outside sensing (EGNSS, cameras, vehicle data, etc.). Beyond 360° sensing: understanding and correlating scene.
- Classification and Selection of current situational hypotheses and prediction of future scene development.
- Estimation of the predicted risk and utility of the selected situations.
- Planning of risk-minimizing behaviour options.
- Selection and Evaluation of the most appropriate behaviour.

5.1.4 Scenario-based Testing

A scenario-based approach can be adopted as a methodology to support the testing and validation phase of the trials. There are 14 use cases and scenarios considered in TransSec project. Table 1 and Table 2 provide all the 14 use cases and their priority levels with respect to risk communication (WP6). For now, use cases which will be used at the end of year 3 have not been finalised. For each of the work packages, each use case presents its own set of challengs. The testing routes will identify key areas / pedestrian crossings on the routes. Particular focus will be paid at pedestrian and people gathering areas as follows, and where possible the following scenarios will be enacted to further trial the system accuracy and responsiveness.

The components of the TransSec project will continuously be monitoring the vehicle via the various sensors installed. These include (but are not limited to) high-accuracy positioning sensors (e.g. GNSS), cameras and radar. Fusion of all of the inputs provides the analysis software with enough information to overlay the results onto maps where the overall attack risk for the vehicle will be evaluated.

For example, in the event of misusing the trucks, essential information should be transferred by one or more of the communications methods and the vehicles should be brought under control immediately. Thus, the sensing and communicating systems of trucks should be operational from engine start. When operational, if the control system judges that the truck has become a threat to the other road users, the

mechanical systems of the trucks should be taken under control. Controlling the mechanical systems of the trucks is the final stage of the mitigation actions.

No	Name	Pedestrian Density	Threat Level		V2X Scenario Typicality	Prioritised Level	Mainly Applicable
			Direct	Indirect			
1	Pedestrian Shopping Zone	High	High		High	High	V2P & V2I
2	Shopping Street	High	High		High	High	V2P & V2V
3	Market Place	High	High		High	High	V2P & V2I
4	Tourist Promenade	High	High		High	High	V2P & V2I
5	City Canyon				High	High	V2V & V2I & V2P. Consider obstacles affecting communication quality, and the routing algorithms.
6	Tunnel				High	High	V2V & V2I. V2V & V2I become main communication method in this case, and the reliability we provide is very important.
7	Cyber Attack			High			It is not a prioritized use case, but WP6 will conduct research on privacy.
8	City Road Crossing	High				Low	
9	Bus Station	High		High		Low	
10	Rail Vehicle Crossing			High		Medium	V2I. What if the attack target is a high-speed bullet train with lots of passengers?
11	One-Way Road					Low	
12	Motorway Service Area					Low	
13	Dangerous Goods Transport			High		Medium	Reduce communication delay in V2V, to give other cars enough reaction time.
14	Security Zone					Low	

Table 1: Priority Levels of Use Cases

Prioritised use cases		Medium priority use cases
1,2,3,4	5,6	10,13
For 1-4, they are typical use cases for WP6 and the interaction between pedestrians, cars	Unique use cases that are different from 1-4.	We have listed these two use cases since they may lead to some indirect threat to the public safety. We may have to consider the particular needs in these cases.

and infrastructure is complex.		

Table 2: Priority Levels Indicator

5.2 Analysis of the Testing

For the purpose of analysing the test results, the data of all tests will be logged for each work package and analysed during later stages. Also, testing will be recorded from inside/outside of the truck to ensure that the trials/incidents taking places are captured. The footage will then be analysed and categorised, i.e. false, missed detection, correct detection etc. coupled with the driver feedback forms provided to the TransSec project and these results will be documented in the final report.

5.2.1 Data Collection and Analysis (Observations Basis)

The following Observational Data collection methods will be adopted for the trial testing and system validation. Active Daimler or project partner will be the validation supervisor, taking notes, observations internally within the cab during the trials.

- Observing and recording the TransSec system behaviour, and its response to the emergency manoeuvring and movement monitoring.
- Observing and recording, the systems alerts and logs aides in the vehicle cab and comparing it to the scenario.
- Another camera will be used to record/validate the vehicle under test, on the route and monitor the scenarios from an external point of view outside of the vehicle and report and document the findings.
- Also, any additional feedback comments from drivers or other TransSec project participants will be recorded in detail during the testing process.

The aim is to effectively record and assess system performance such as the number of detection rates during the trial.

5.2.2 Data Collection and Analysis (Logged Data)

As there are many functionalities in the TransSec project, there will be backend logs generated during the test process. This logged data contains some of the technical information about the GNSS signal authentication and sensor data, maps, risk communications, and precise/robust positioning data, etc. The collected data from the testing will be analysed for the calculations like accuracy and performance metrics.

6 Survey

Survey questions to the drivers and observers are listed in this section. These questionnaires are based on the assumption that there will be user interface endpoints provided inside the cab. User interface endpoints may be visual/audio or manual indicators.

For safety reasons, the primary function of the drivers in the pilot is driving, instead of doing further recording work. On the other hand, the function of the observers who accompany the drivers are observing all the TransSec related information and assisting drivers to receive commands or notification information.

The questions used in the following survey serve as the base templates for making TransSec questionnaires. Questions will be refined in the future to make them easier to understand for the respondents and more scientific for analysers to get comprehensive results.

The results of these surveys will be used to help to judge the pilot results and performance and to improve the functionality of the TransSec solution.

6.1 Driver Survey

These questionnaires are based on the behaviour of the driver and the information about the vehicle he uses on the day.

- Name, vehicle number, Driving experience,
- What time was the vehicle was out on its daily routine? (Day or Night time)
- Did you drive around the pedestrian crowded area?
- How long did you drive the vehicle?
- What type of vehicle did you drive?
- Where did you more drive? Urban or rural area? (highway, ring road, regional, local road)
- Did the truck begin to halt when the suspicious activity was found?
- In public roads, was there any intentional maneuverer performed to check some of the functionality?
- Amount of driving in familiar areas? (always, often, sometimes, seldom, never)
- To what extent do you think that the test scenarios (use cases) in TransSec can simulate your daily work scenarios?
- Do you think the TransSec trucks are more secure on avoiding truck attacking than others?
- Did you avoid any collision with the help of the system fitted to the truck?
- What are your views on the overall system? Please explain any positive/negative comments in as much detail as possible

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6.2 Observer Survey

These questionnaires will be more concentrated on comparing the functionalities of the work packages and real-time experience.

- What was the climate conditions on the testing day? (temperature, humidity, rain)
- Were there any false detections?
- How frequently did the system generate a false alert?
- Are there any modifications to the system that you would recommend to enhance its performance?
- When using a TransSec system and driving in a wrong lane (e.g. bus lane, opposite direction, etc.) did you receive any response from the system?
- (WP2) If a TransSec navigation system is available, compared to the commercial products that you have used, how would you evaluate the accuracy of positioning?
- (WP3&4) If a TransSec navigation system is available, compared to the commercial products that you have used, is there more information like the surrounding pedestrian and traffic signs provided by it?
- (WP5) Is there any driving situation that is dangerous for other road users but ignored by the monitoring systems?
- (WP6, at the V2X receiving end) Can you clearly know the occurrence of an accident and gain relevant information about it through the V2X communication module?
- (WP7) To what extent do you think that the truck manoeuvred in time to avoid an accident?
- (Privacy) How concerned would you be about your privacy when driving a TransSec vehicle? (Very concerned; Moderately; Slightly; Not at all.)
- Approximately how many alerts did you receive today?
- Did you avoid any collision with the help of the system fitted to the truck?
- Did all the features worked as expected?
- What are your views on the system overall, please explain any positive/negative comments in as much detail as possible

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7 Conclusions

This report provides the high-level information about the testing pilots (infrastructures), testing methods, types of testing conducted during the TransSec project. It includes two types of bench testing concentrating on independent and dependent to work packages. Also, it provides the information about end-to-end systems tests (Functionality Testing) and scenario-based tests, where the complete TransSec product will be tested in a controlled area and a public area around the Stuttgart city. Information about the two testing pilots in Stuttgart which have different driving conditions is provided in this report.

The report also covers the methods of data collection during all the trials like manual observation and data logs. Manual observations include the video and survey questions asked for drivers and observers. Data collection is the prerequisite for correctly analysing the pilot results and deciding the further research and development directions.

This report serves as a start point in identifying the requirements and details of the pilot test. In this report, we have not included the information about the equipment and software details used. However, in-depth details of the equipment and software to be used in each stage of the testing will be provided by the respective work package demos *(refer to demo reports).*