Road Safety Data, Collection, Transfer and Analysis

Deliverable 6.3 Report on Small Scale Naturalistic Driving Pilot

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LIST OF ABBREVIATIONS

ASFINAG	Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft
CAN	Controller Area Network
DAS	Data Acquisition System
DaCoTA	Road Safety Data, Collection, Transfer and Analysis
EC	European Commission
ERSO	European Road Safety Observatory
EU	European Union
FOT	Field Operational Tests
g	gravitation acceleration (1g = 9,8 m/s^2)
GPS	Global Positioning System
HP	Horse power (1HP = 75kW)
Hz	Hertz (per second)
ID	Identification
IFSTTAR	Institut français des sciences et technologies des transports, de l'aménagement et des réseaux (French institute of sciences and technology for transport, development and networks)
KFV	Kuratorium für Verkehrssicherheit, Austria
km	Kilometer
ND	Naturalistic Driving
OBD	On Board Diagnosis
Or Yarok	A large road safety NGO , Israel
Prologue	Promoting real Live Observation for Gaining Understanding of road user behaviour in Europe
RED	Risk exposure data
RFID	Radio-frequency identification
SD	Standard deviation
SPI	Safety Performance Indicator
SWOV	Institute for Road Safety Research, the Netherlands
Technion	Israel Institute of Technology
TrackTec	An on-board recording device
TransCAD	A software program allowing handling GIS linked data
TTI	Test and Training International,
V max	Maximum vehicle speed
WP	Work package

EXECUTIVE SUMMARY

WP6 of DaCoTA, *Driver Behaviour Monitoring through Naturalistic Driving*, aims to develop an implementation plan for a large scale activity that uses Naturalistic Driving (ND) Observations to continuously monitor relevant road safety data within the framework of the European Road Safety Observatory. Compared to other Naturalistic Driving initiatives, the unique objective of Naturalistic Driving observation within ERSO is the continuity of data gathering, the scale (all European countries, representative for each country and comparable between countries) and the focus on safety performance indicators (SPI), alternative safety indicators and mobility.

This deliverable reports the outcome of the third task which was to test and refine the practical and technical feasibility of the method of data gathering by naturalistic driving. Two small scale studies were carried out, one in Austria and one in Israel. Previous work within WP6 has identified two target scenarios for the implementation of Naturalistic Driving (ND) studies within ERSO (Talbot, 2010):

Scenario 1 would be a basic data acquisition system (DAS) that comprises of a GPS logger and accelerometer. This is a relatively low cost system centred on the collection of vehicle speed, speeding and exposure data such as vehicle Km and time in traffic. A robust identification of the person who drives the car and algorithms of map matching to infer from GPS coordinates the road type and its legal speed limit are part of scenario 1. Topics of interest for Scenario 1 are: vehicle Km, person Km, number of trips, time in traffic, excessive speed, acceleration.

Scenario 2 would supplement the Scenario 1 DAS with additional sensors or capability e.g. connecting to CAN data, that would allow the collection of additional variables that are important in the monitoring of road safety but cannot be measured using the Scenario 1 DAS. E.g. headway, lane behaviour, signal use, lights use. Topics of interest for scenario 2 are: inappropriate speed, seatbelt use, headway, braking, safety systems, lane behaviour, signal use, light use.

The Austrian study aimed to collect data according to Scenario 1. 10 participants were recruited to take part in the study – 5 males and 5 females with an age range of 20 to 66 years old. The majority of participants were experienced drivers. An off-the-shelf DAS, the *pDrive lite* ®, was utilised to collect data on GPS position, acceleration (lateral, longitudinal and vertical), speed and date/time. The system also recorded video at the start of each trip in order to identify the driver. A cartographic database of Austria was required for Map matching. Data was available for road type but not speed limits. Questionnaires were used to gather driver and vehicle data at the beginning of the study and to assess participants experience of driving with the pDrive *pDrive lite* ® system half way through the study and at the end. All participants were asked to fill in a travel diary for 1 week during the data collection period to record additional information about their trips.

Data was collected on each vehicle for 4 months. During this time, all data except video were collected continuously. The *pDrive lite* ® records data at 100 Hz and this was reduced to 10Hz for analysis as such a high sampling rate is not necessary for Scenario 1 data collection. Data was manually transferred from the DAS to a SQL database approximately every 2 weeks. Map matching was then undertaken to identify the type of roads the participants used for each trip. A trip was defined as the time at which the ignition is switched on to the time at which the ignition is switched off. Comparisons between the DAS data and reported trips in the travel diary revealed that participants often reported fewer trips. One reason for this maybe that the definition of a trip as used in the Austrian study was not understood by the participants.

3.644 trips were recorded for the participants during the 4 month data collection period. Analyses were possible with regard to road type, driver gender, weekday, time of day and length and duration of journey as well speed and acceleration. Discussion of speed however were limited as the available map data for Austria does not included speed limit information and without a headway measure it is difficult to know whether the driver can choose their speed or are constrained by the vehicle in front. Thus the Austrian study demonstrated that it is possible to collect data according to Scenario 1.

The Israeli study aimed to collect data according to Scenario 2. 7 participants were recruited to take part in the study – 3 male and 4 female. All were experienced drivers. The DAS comprised of MobilEye, a system that measures headway and lane departure and TrackTec, a system which acts as a data logger and records vehicle speed, acceleration and vehicle position. Can-Bus data was collected for 1 vehicle and a system which records fuel consumption was fitted to 4 vehicles. These systems were off-the-shelf technology however the connections between them were developed for the study. GIS software was used to perform map matching.

Data was collected on each vehicle for 6 months. A mixture of continuous and event-based methods was used to record data. Headway, acceleration, speed and GPS were measured continuously at a sample rate of 30 seconds. Event-based measures were taken when a predefined event occurred for example when the lane departure and collision warning thresholds were met. As a result of the difficulties the Austrian study encountered with regard to trip definition, the Israeli study used a modified trip end definition whereby the trip was classed as ended once the engine had been off for 15 minutes.

3.459 trips were recorded for the participants during the 6 month data collection period. Analyses were possible with regard to road type, driver gender, weekday, time of day, length and duration of journey, speed and acceleration as well as headway and lane departure. Other Scenario 2 topics that rely on Can-Bus data were more problematic. Due to the difficulty in collecting Can-Bus data the Israeli study only collected this on 1 vehicle. Due to the age of the vehicle seat belt use data was not available. In addition headlight use data was not meaningful as the vehicle had been modified to automatically turn on the headlights when the engine was started.

Both studies demonstrated that it is possible to collect relevant data continuously over a period of time using relatively low cost and easy to install equipment. The different approaches used by the studies highlights the ways in which decisions made, with regard to sampling rate and trip definition in particular, can affect the data collected. Different sampling rates and different trip definitions do not have any impact on overall driven kilometres and differences in driven time would be negligible. However the trip definition does affect the number of trips recorded and results in different lengths and durations of single trips. This is important if conclusions are based on average trips. The trip definition must be carefully defined before a large scale study commences as any change following the start of data collection has large implications for database structure and handling. The sampling rate has little effect on average speed or maximum/minimum speeds as this is a relatively constant variable. However the sampling rate can have a big effect on the maximum accelerations recorded and too low a rate may lead to important events being missed. Depending on parameters of events that have to be monitored, the sampling rate has to be defined consistently for a large scale ND study. Therefore a compromise must be found between huge amounts of data and the gain/loss of events.

The Austrian and Israeli studies lead to the following practical recommendations when implementing a ND study:

- Besides a detailed planning and recruitment procedure, a ND study needs to be well structured and organised (support team). Continuous support allows errors/defects to be corrected as soon as possible (to prevent of data losses).
- Relatively cheap, off-the-shelf devices can be sufficient for a ND study. But it is essential to have a storage capacity that is big enough, as data can be lost when the storage device approaches its capacity. A buffer battery is very useful to guarantee a safe storage of the data.
- For a large scale activity it is recommended to stream data onto some form of solid state storage device, e.g. by transmitting the data automatically by UMTS and to store them on a server.
- Numerous secondary variables or indicators can be calculated from the raw data. The problem is more how to define them and how to operationalise them. Depending on what conclusions need to be drawn, more or less additional information may be needed.

DaCoTA WP6 T6.3 demonstrated the capability and usefulness of collecting very detailed data on exposure, travel speed and associated characteristics. It shows that it is possible to obtain a very detailed account of exposure and safety related behaviours which it is, so far, not possible to collect.

Collecting these variables on a representative sample of drivers in all EU countries by means of these naturalistic studies would add a very valuable aspect to the ERSO database and would enable many cross-country behaviour studies - eventually linking them to accident occurrence and safety.

1 INTRODUCTION

This is the second Deliverable of WP6 of the DaCoTA project. DaCoTA is a Collaborative Project under the Seventh Framework Programme, co-funded by the European Commission DG Mobility and Transport. The project officially began on January 1st 2010 and will continue to 31th of December 2012. The six technical Work packages of DaCoTA will work together to provide tools and methodologies to support road safety policy and further extend and enhance the European Road Safety Observatory (ERSO) developed within the SafetyNet project[1].

ERSO was created with the aim of being the primary focus on road safety data and knowledge. It also aims to support all aspects of road and vehicle safety policy development at European and national levels (ERSO 2010d). The observatory is now hosted by the EC Transport Road Safety Website (http://ec.europa.eu/transport/road_safety/index_en.htm)

WP6 of DaCoTA, *Driver Behaviour Monitoring through Naturalistic Driving*, aims to develop an implementation plan for a large scale activity that uses Naturalistic Driving (ND) Observations to continuously monitor relevant road safety data within the framework of the European Road Safety Observatory.

This report is one in a series of reports (Deliverables 6.1 – “Report on Naturalistic Driving observation within ERSO”, 6.2 – “Report on Study design”, 6.3 – “Report on Small Scale Naturalistic Driving Pilot” and 6.4 – “Report on Implementation plan for Large Scale Naturalistic Driving research within ERSO”). It reports the outcome of the third task which was to test and refine the practical and technical feasibility of the method of data gathering by naturalistic driving. This was achieved by performing the following activities:

1. designing the small scale pilots
2. developing/modifying the technological equipment
3. performing small scale studies
4. analysing speed and other indicators

This chapter covers the general goal of work package 6 and task 6.3 “realisation of small scale studies” as well as a general framework for the setup of the field trials. The small scale field trials are based on two different scenarios, proposed in DaCoTA 6.1 (Talbot, 2010).

Chapter 2 outlines the Austrian field trial including the methodology of recruitment of participants and installation of the technology used, data-collection and -storage, analysis and results and recommendations arising from the experiences in the Austrian field trial. The Israeli field trial is described in Chapter 3. It follows the structure of Chapter 2, describing the characteristics of the Israeli procedures.

Finally, in Chapter 4 all information presented in Chapter 2 and Chapter 3 is used to draw comparisons between methodological differences and to draw conclusions for further ND-studies, especially for the implementation of a large scale study. The information gathered in these small scale studies is relevant for further developments of large scale studies.

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[1] SafetyNet was an Integrated Project that was funded by the Sixth Framework Research Programme of the European Commission.

The deliverable concludes with a comparison of different approaches and recommendations for further ND-studies.

1.1 General Goal of WP6

Many EU countries collect road safety data, though methods of data gathering still lack uniformity. The Naturalistic Driving method greatly expands the possibilities of collecting and harmonizing data in real traffic. It offers opportunities for more, better and more efficient data collection compared to traditional ways of data collection, such as interviews, surveys, field experiments with small sample sizes, police records etc. Moreover, it allows for better comparability of data between countries as exactly the same data can be gathered for each country in the same way.

WP6 of DaCoTA, *Driver Behaviour Monitoring through Naturalistic Driving*, aims to develop an implementation plan to continuously monitor relevant road safety data. The methodology will describe the necessary framework to gather, record and analyse naturalistic driving behaviour.

This involves four tasks, each building upon each other and culminating in an implementation plan for naturalistic driving research within ERSO.

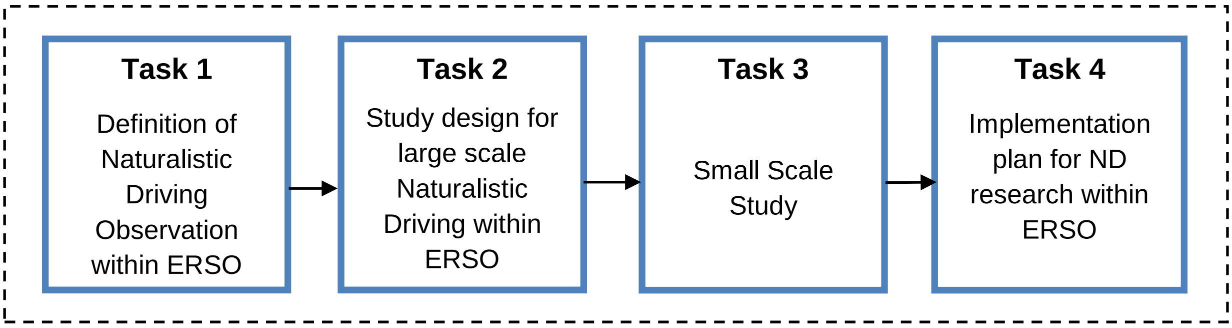

Figure 1: DaCoTA WP6 tasks

Naturalistic Driving observations will allow the building up of a database of drivers' behaviour, gathering normal and also critical situations and near-misses. Results can be used to calibrate other existing relevant data and therewith enable data that is currently observed to be harmonized.

This Work Package will specify how Naturalistic Driving observations can contribute to ERSO, complementarily to or instead of the data already available to investigate road safety in the framework of SafetyNet (microscopic accidents analysis, and databases for macroscopic accidents, risk exposure and safety performance indicators).

1.2 Objective of Task 6.3

The objective of the small scale Naturalistic Driving study was to test and refine the practical and technical feasibility of the method of data gathering as defined in task 6.1 (see D6.1, Talbot, 2010) and 6.2[2] (Milestone 6.2). Compared to other Naturalistic Driving initiatives, the unique objective of Naturalistic Driving observation within ERSO is the continuity of data gathering, the scale (all European countries,

[2] Task 6.2 is carried out parallel to Task 6.3. Deliverable 6.2 will be available after Deliverable 6.3. But parts of the task (i.e. Milestone 6.2) serve as input for Task 6.3

representative for each country and comparable between countries) and the focus on safety performance indicators (SPI), alternative safety indicators and mobility.

Whereas in PROLOGUE[3] the focus was more on safety related events (unsafe behaviour), in DaCoTA the focus is, in addition, on continuous sampling of driving behaviour under normal driving conditions, on a representative basis, both for safety and mobility purposes. Another major difference is that in PROLOGUE the focus is on research applications whereas in DaCoTA the focus is on tools for decision-making. One aspect which is addressed in DaCoTA is the management and maintenance of such a sample over time. Keeping ERSO in mind and considering a sample of 200-400 cars per country, properly sampled and continuously running, this is not a trivial task. The gathered information could be used over time. The information could be very useful in evaluating the effects on behaviour of various policies that might be introduced, changes in speed limits, daytime running light legislation, speed enforcement policies and the introduction of various safety devices or technologies.[4]

Regarding the SPIs of SafetyNet, the main focus of this study will be on the measures of speed, both on an absolute level and compared to the speed limit. Regarding exposure, the focus of the study will be to develop a full logbook of trip duration, trip length, trip timing, possibly trip location, and drivers' identification. Furthermore, it possibilities to stratify this for different road types or vehicle types should be explored. Data on crashes or near crashes is currently not collected directly. In this task it will be explored if certain manoeuvres could be defined that can be used as a proxy for near crashes, to be detected as extreme events (such as: very strong (negative) acceleration, extreme sharp manoeuvres and short headways).

There is no question about it that the extent of information on vehicle use (mobility) that can be collected through Naturalistic Driving technologies is on a different scale from what used to be the standard ways of collecting such data, either from representative samples of traffic counts or through travel surveys and vehicle distance travelled monitoring.

Results from mobility questionnaires include all modes, whereas results of Naturalistic Driving technologies include only information from vehicles included.

1.3 Realisation of small scale studies

In Task 6.3 two small scale studies were carried out, one in Austria and one in Israel. The studies were based on the Scenarios defined in task 6.1. Task 6.1 has identified two target scenarios for the implementation of Naturalistic Driving Studies (NDS) within ERSO (Talbot, 2010):

Scenario 1 would be a basic data acquisition system (DAS) that comprises of a GPS logger and accelerometer. This is a relatively low cost system centred on the collection of vehicle speed, speeding and exposure data. A robust identification of the person who drives the car and algorithms of map matching to infer from GPS coordinates the road type and its legal speed limit are part of scenario 1.

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[3] PROLOGUE, Field trial in Austria, Deliverable D3.3, November, 2010

[4] A document about the added values of the DaCoTA field trials compared to the PROLOGUE study is attached to this Deliverable (ANNEX).

DaCoTA WP6 recommends that the following topics should be investigated with a Scenario 1 DAS:

- Vehicle km
- Person km
- Number of trips
- Time in traffic
- Excessive speed
- Acceleration

Scenario 2 would supplement the Scenario 1 DAS with additional sensors or capability e.g. connecting to CAN data, that would allow the collection of additional variables that are important in the monitoring of road safety but cannot be measured using the Scenario 1 DAS.

The following topics would be of interest but require a Scenario 2 DAS:

- Inappropriate speed
- Seatbelt use
- Headway
- Braking
- Vehicle Technology: safety systems
- Lane behaviour
- Signal use
- Lights use

The Austrian small scale study was carried out as described in Scenario 1. For the Israeli small scale study Scenario 2 provided the basis.

Milestone 6.2 “Design of a small scale practical study” (Bonnard, 2010) provided task 6.3 with a set of elements necessary for designing and implementing the small scale study of the DaCoTA project. Thus, several aspects were developed:

- The target RED and SPI for the small scale study
- The technical solutions to collect data and estimate SPI and RED
- The sample selection
- The legal and ethical requirements
- The observation period
- The general technical issues to solve

Two major outcomes were expected:

1. From a technical point of view, the required technological equipment for observation, data handling and analysis was developed and used to collect data.

2. From a behavioural analysis point of view, the data collection provides a data set of naturalistic driving behaviour that will permit interesting analysis.

For the actual performance of the pilots, subcontractors TTI (Test and Training International, Austria) and Or Yarok (Israel) have been utilised.

2 THE AUSTRIAN FIELD TRIAL

2.1 Introduction

The Austrian field trials were based on **Scenario 1**. Thus, a basic DAS was used that comprises of a GPS logger and accelerometer.

Table 1 shows the variables collected by the DAS.

Data acquisition	
Variable	**Collection methods**
Start of journey	pDrive lite® (Sensor – ignition on linked with time stamp)
End of journey	pDrive lite® (Sensor – ignition off linked with time stamp)
Length of journey (km)	Derived from cumulative GPS distances
Duration of journey (time)	Derived from number of data lines recorded

Table 1: data acquisition

The data should be aggregated by driver and vehicle characteristics. Thus, the following variables have been collected and calculated in the Austrian small scale study (Tables according to D6.1).

Driver variables	
Variable	**Collection methods**
Age	questionnaire (+driver identification)
Gender	questionnaire (+ driver identification)
Purchasing of driving license	questionnaire (+ driver identification)

Table 2: driver variables

Vehicle variables	
Variable	**Collection methods**
Make	vehicle record (+ questionnaire)
Model	vehicle record (+ questionnaire)
Age	vehicle record (+ questionnaire)

Table 3: vehicle variables

Network variables	
Variable	**Collection methods**
Road type (urban area, outside urban area, motorways)	GPS + map matching
Road way geometry (curve radius)	GPS (20x/s)

Table 4: network variables

Other contextual variables	
Variable	**Collection methods**
Date and time of day	pDrive lite® records time
Length of journey (km)	pDrive lite® (data available) absolute time, time & way start per trip with 0 and ends at the end of the trip.)

Table 5: other contextual variables

Topic Variables	
Variable	**Collection methods**
Time driven (journey so far)	pDrive lite® (inferred from trip start/data logger time stamp)
Speed	pDrive lite® (GPS)
Acceleration (longitudinal: acceleration and deceleration, lateral)	pDrive lite® (accelerometer)

Table 6: topic variables

Exposure (eco-driving)	
Context variables	**Collection methods**
Vehicle distance travelled	Aggregated: Length of journey (km)
Person distance travelled	Driver ID plus Aggregate of: Length of journey (km)
Number of trips	Derived from Start and End of journey then aggregated (every trip will be stored in data file).
Time in traffic	Aggregate of: Duration of journey (start/end of journey)

Table 7: exposure variables

In order to achieve the objective, there was a need for continuous monitoring, to generate and maintain a sample over time. So, the DaCoTA small scale study provided full records of individual data sets.

Ten drivers/vehicles took part in the study for four months each.

General information
10 devices
From March 2011 to July 2011

Table 8: general information about the Austrian field trial

For driver identification, a short video was recorded at the start of each trip.

2.2 Methodology

This chapter gives a detailed description of the Austrian field trial, including recruitment of participants, technology used and installation of the equipment.

Particular attention is paid to any problems/difficulties (technical and operational) related to the objective of T6.3 (to test and refine the practical and technical feasibility of the method of data gathering as defined in task 6.1 and 6.2).

2.2.1 Participants and recruitment procedure

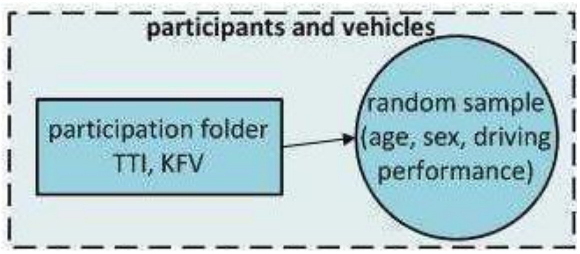

Figure 2: recruitment procedure

Milestone 6.2 suggested trying to obtain a homogeneous sample instead of a representative one. Thus, the ideal sample for the small scale study is a balanced group between males and females and a group homogeneous in terms of age. In terms of driving experience and driving patterns, it was decided to focus on experienced drivers and to focus on drivers who will use their cars nearly every day, who will drive in various driving contexts and who will drive at least 250km/month. This second criteria was established to collect enough driving hours during the small scale study.

The task for the researcher was to find ten subjects who were willing to participate in this field trial. Therefore, the research companies (KFV, TTI) asked in their respective circle of acquaintances for appropriate test drivers, i.e. individuals who possess a valid driving license and regularly drive their own car. The potential subjects were informed that they would receive a small allowance (100 €) for a 4-months-participation. If a person showed interest, he/she would provide his/her contact details to be forwarded to Test & Training International (TTI) in order to settle an appointment for the installation procedure.

Test subjects could be found quickly, and the goal of a balanced sample distribution (5 male, 5 female) between genders was reached (see Table 9).

Gender	Age	Issue date of driving licence	DAS installation	DAS removal
male	34	1996	18.03.2011	18.07.2011
male	36	1993	08.03.2011	08.07.2011
male	47	1982	28.03.2011	28.07.2011
male	65	1964	28.03.2011	28.07.2011
male	66	1965	09.03.2011	09.07.2011
female	20	2010	16.03.2011	16.07.2011
female	32	1997	16.03.2011	16.07.2011
female	42	1987	18.03.2011	18.07.2011
female	43	1986	09.03.2011	09.07.2011
female	43	1987	15.03.2011	15.07.2011

Table 9: participants' information

The requirement for a homogenous group in terms of age was not met appropriately. "Driving experience" has to be defined clearly when needed for further studies. As no other information was available, the issue date of driving licence was taken as equivalent to driving experience in the Austrian field trial.

Also the driven distance per month is not always easy to estimate. If a person uses the car for going to work every day, the driven kilometres can be estimated more easily than if a person uses the car mainly for private purpose and if chosen routes vary.

When subjects attended the installation of the DAS, they signed the participant´s acknowledgement and received the first half of the allowance (50 €). The second half was received after the data collection was finished and participants came again to TTI´s premises to have the system uninstalled.

Legal, ethical and privacy requirements

As Naturalistic Driving studies involve human participants and collect, store and analyse their behavioural data, the setup of a Naturalistic Driving Study entails a set of legal, ethical and privacy requirements that have to be observed by the researcher.

Following Milestone 6.2, the legal, ethical and privacy requirements related to Naturalistic Driving studies are listed according to the three following principles:

1) Informing participants on their rights and duties

2) Ensuring participants' safety and privacy

3) Conforming to European and National legislation

After all the requirements have been fulfilled and the subjects consented to participate, the device was installed.

Only specified garages were qualified to install the pDrive lite ®[5] device in the subjects' car. These garages were responsible for any difficulties arising for the pDrive lite ® device and had to guarantee the car's roadworthiness.

2.2.2 Technology used

This chapter covers the description of the technology and modifications (general as well as particular modifications for the DaCoTA objectives).

In Milestone 6.2 it was defined that Scenario 1 requires a DAS with a GPS, an accelerometer (minimum of longitudinal), data processor and means to store/download data, plus a means of identifying the driver ID (e.g. RFID tag/magnetic swipe card).

This needs to be an integrated system with the individual components synchronised so that a common time stamp can be used to link data. Additional requirements of the DAS are that it is robust – malfunctions and data loss have to be rare events – and that it is unobtrusive.

In a large scale activity, the maintenance requirements of a DAS have to be minimal as man-power resources are likely to be limited. Equipment needs to be unobtrusive so that the participants quickly forget about the presence of data logging equipment and behave in an as natural way as possible.

Thus, within the scope of the small scale study, the scenario should use a simple DAS with minimal requirements:

- GPS
- Accelerometer
- Cartographic database for Map Matching
- Driver identification

pDrive lite ®

The specified unit used within this study was an off-the-shelf Naturalistic Driving data collection system, i.e. pDrive lite system ® (see Figure 3). This system is a small black box which allows the capturing of vehicle and video data.

The data are stored on a memory card (up to 64 GByte) and can then be subsequently downloaded and analysed using comprehensive computer software, or simply archived to a hard drive or DVD.

The box is specifically designed for Naturalistic Driving studies as it was downsized from an original device which was made for driver training and feedback purposes. This device allows for a quick but unobtrusive installation in the car as only a few lead cables have to connect to the main unit.

In this study, video data was also collected in order to identify the driver.

Additionally, videos can also be triggered based on acceleration/braking values or GPS position. Such functionalities have been already used in ND research projects, such as in the EU-funded project PROLOGUE.[6]

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[5] http://www.pdrive-system.com
[6] Videos are not part of task 6.3.

Figure 3: pDrive lite® front view

For Naturalistic Driving purposes, it must be ensured that drivers are not irritated by visible devices, reminding them that their driving behaviour is recorded. In order to avoid such effects, it is necessary to conceal the used technology as much as possible, i.e. installing recording technology in an unobtrusive way.

As the box is only 3,5 cm high, 14 cm wide and 15 cm deep, it can be easily installed under the passengers´ seat or in the trunk of the car, typically. The usage of hook and loop fasteners allowed for a stable installation on the vehicles´ floor carpet. At the same time the mounting material used ensured sufficient air circulation for equipment cooling.

On the rear of the unit there are a number of inputs (listed below):

1. 4 external camera inputs
2. GPS antenna
3. External sensor input (ECU/OBD)
4. Data port (RS 232)
5. Audio input (stereo)
6. Audio output (stereo)
7. Video output
8. Power connector

Beside the collection of GPS data, accelerometer data was also collected. The main **pDrive lite** ® **system** unit contains a 3-axis accelerometer that is used to measure the lateral, longitudinal and vertical acceleration of the vehicle. Accelerations measured are used for a number of different purposes in the **pDrive lite** ® **system**, namely:

- to measure directly how quickly the vehicle is being accelerated or how much braking is being used
- to measure how hard the vehicle is cornering
- to combine with the speed measurements from the GPS system to improve accuracy
- to combine with the positional measurements from the GPS system to improve accuracy

Powering and starting/stopping recordings

It is also a necessary requirement for ND equipment that subjects do not interfere with the equipment in order to start or finish the trip recordings. Therefore, the setup of the system was chosen to start up with ignition power: the trip recording starts when the driver turns the key towards the “ignition” position and the recording ends a couple of seconds after the vehicle key is removed from the lock. The system is backed up by an internal battery as it takes some seconds to finish the recording and save the files to the data storage cards.

Data collected with the pDrive lite ®

- GPS position
- Lateral acceleration
- Longitudinal acceleration
- Vertical acceleration
- Speed
- Date/Time

Sampling rate of collected data

Another important consideration for data collection is the sampling rate at which data from the GPS and accelerometer is recorded. The chosen sampling rate has implications for data storage and analysis. If the large scale study is limited to generating RED data and excessive speed SPI, as suggested by D6.1 and Milestone 6.2, then there is no need for a high sampling rate. According to Milestone 6.2 recording data once every ten seconds or even less frequently would be adequate. It is unlikely that a sampling rate of greater than once per second (1Hz) is required for Scenario 1 DAS.

With pDrive lite ® raw data is gathered with a rate of 100 values per second which represents 100 Hz. Within the DaCoTA small scale study, a reduction to 10Hz took place.

Additional data delivered from pDrive lite ® - Video-Data (e.g. for ID-Check)

By the use of a video, which starts 60 seconds after the trip, the driver can easily be identified. This approach ensures that only the data of selected test subjects is analysed and that any driver who is not taking part in the study is excluded. Therefore, a camera was mounted behind the rear mirror in the most unobtrusive way (Figure 4).

Figure 4: driver camera behind rear mirror

2.2.3 Installation specifications

Figure 5: preparation installation

For the small scale study, mechanics of TTI installed the device in ten cars. The installation duration varied between 15 minutes and one hour. Consequently it can be said that the installation of pDrive lite ® takes 25 minutes.

Due to problematic cable systems, the installation in one car had to be cancelled.

2.3 Data collection and procedure (progress)

This chapter deals with the collection of required data and the different types of data which were gathered within the procedure (technical data, data of subjects, questionnaires, travel diary and video). An overview of the process of data collection is given in Figure 6.

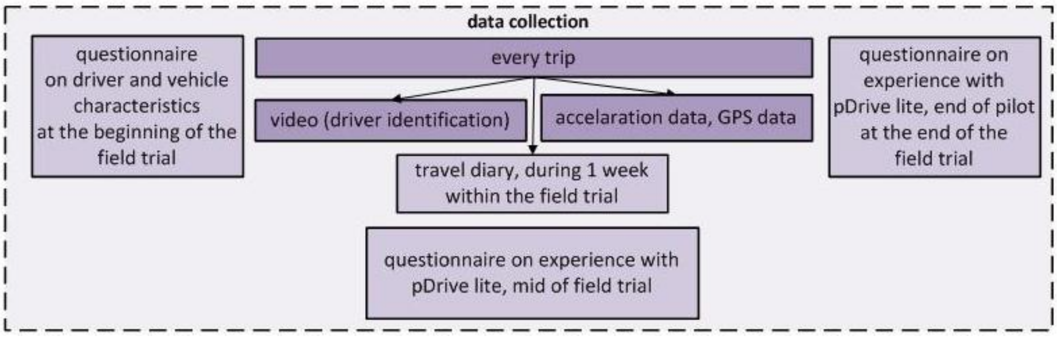

Figure 6: process of data collection

2.3.1 Questionnaire data

Questionnaire about driver and vehicle characteristics

When people were interested in taking part in the study, they were asked about their driver and vehicle characteristics. Detailed data were recorded when people attended the installation.

Questionnaire about experiences with pDrive lite ®

A questionnaire was administered once during and once after the small scale study. The aim was to have a certain quality management as well as a control of the device's practicability.

The following topics were considered in the questionnaires:

- Awareness of the pDrive lite ® device presence in the vehicle
- Influence of the pDrive lite ® device on the road behaviour
- Difficulties during the testing phase concerning the pDrive lite ® device

All drivers completed the questionnaires.

2.3.2 Data from DAS

A trip starts by starting the engine, henceforth the data is going to be recorded.

During every trip a RUN File emerges which contains the continuous binary data from the different sensors.

2.3.3 Travel diary

During the small scale study, every participant was asked to fill in a travel diary for one week, which should provide information of every trip, e.g. the driven kilometre, the number of trips as well as possible correlation of subjects' information and collected technical data.

The diary was delivered online and the participants were asked to answer the following questions:

- Did you drive your car yesterday?
- How many trips did you start? / How many trips have you started?
- At what time did you start your first trip?
- At what time did you end your first trip?
- What was the purpose of this trip?
  - Way to work – way back home
  - Shopping
  - Leisure time
  - Way to school/university – way back home
  - Driving for fun
  - Other
- To which category does the road belong? / On which road category did you drive?
  - Urban road
  - Interurban road
  - Both
- How did you feel while driving?
  - I was in a good mood (positive).
  - I felt neutral.
  - I was in a bad mood (negative).
- How many passengers were in the car?
- Who was your co-driver? (statement on co-driver)
- Did any special incidents happen while you were driving?
- Pass a comment on the first trip.

It was also possible to fill out a text box where the subject could comment on the first trip.

Contextual data (e.g. drivers' mood, amount of passengers and purpose of trip) could support interpretations of the data (correlation of subjects' information and collected technical data). For example: Novice male driver travels at high speed if friends (of the same age) are in the car.

Not every subject was motivated to keep such a travel diary but nine of the ten kept one and this led to a 90% rate. However a misunderstanding concerning the definition of a trip arose. A trip in the Austrian field trial is defined from the time when starting the engine to the time when turning off the engine. Some participants defined one trip as the time from leaving home to arriving back home.

2.3.4 Video

After engine start and one minute of driving, a trigger was activated to run the driver identification by video. The video lasts for one minute. To read the video a special video player is needed (e.g. specific software required).

Additionally, special events were defined, at which point video data from two cameras are recorded. These are saved in extra directories on the memory card with a copy of the data from the run file synchronized to the video stream. The video records were not used within task 6.3. A separated working group of WP6 deals with the analysis of the DaCoTA videos.[7]

2.4 Data storage

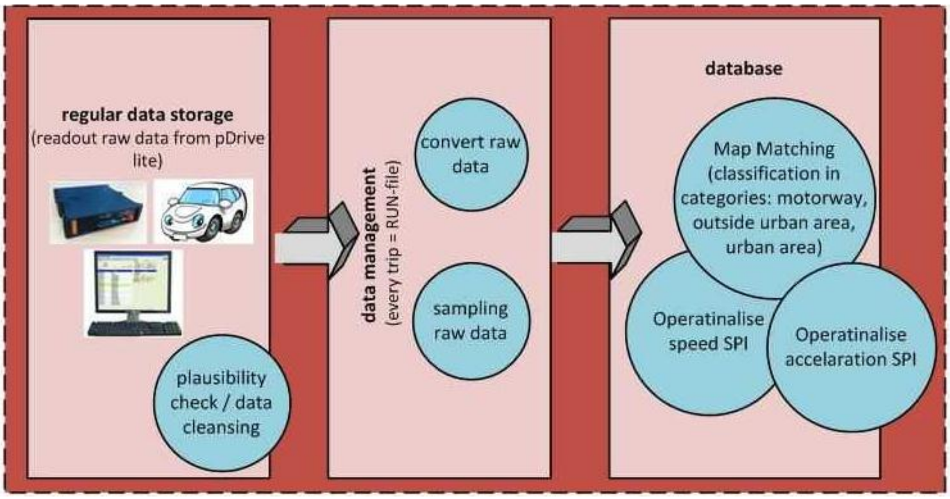

Figure 7: data storage

Collecting data over a long period has two strong constraints: the volume of the data that have to be stored on computers and the time taken by computers to analyse the data in order to produce relevant SPIs.

The first aspect implies that data are regularly transferred from the vehicles to a data warehouse for later analysis. This transfer can be performed manually, with operators copying the files from the acquisition systems to the data warehouse or automatically through a wireless network in real time. The data retrieval strategy has to be carefully studied as each solution presents pros and cons in terms of technical implementation, process and cost. Practical implementation can be a mixture of both, manually and automatically transfer, depending on the amount of data.

The second aspect implies that powerful computers must be used to analyse the data from the data warehouse. The structure of the database has to be designed to ease both the retrieval and the processing of data and the algorithms have to be optimised in order to cope with the continuous arrival of data.

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[7] Morris, A. et al (TSRC), Analysis of Driver Behaviours in the Austrian Naturalistic Driving Field Study as Determined from Video Data (Working Title)

In the Austrian field trial the data were manually transferred from the pDrive lite ® from every car to the data warehouse. The time-interval of data storage (transfer of data from the pDrive lite ® to the data warehouse) depended on the amount of trips from every driver. In the DaCoTA research the data were stored about every two weeks. Which data storage device is used depends on the number of driven km,. In this trial the volume was 4 GByte for ordinary drivers and 16 GByte for extra ordinary drivers.

Note: Due to the damage of internal pins of the memory card – a careful handling is required. To avoid data losses the exchange should be made by an expert.

2.5 Data processing

During every trip two types of data were recorded, in particular raw data (GPS and acceleration) and video.

Before importing into the database the following tasks had to be executed:

- Control every raw data file
- Make video analysis for driver identification
- Mapping the participants' trips on a map as well as denoting trip starts and ends

2.5.1 Data cleansing and plausibility check

Because of GPS inaccuracy in tunnels or garages the plausibility of those data has to be checked. To receive a correct determination of the position, 3 - 4 GPS signals are necessary. The device determines an accuracy of the position, depending on the number of visible satellites. A limit of ten meters accuracy was set up. Values above this ten meter limit will be ignored by an automatic system.

In some cases the acceleration sensor did not provide correct data. Thus, the acceleration values were not considered in the analysis.

Extreme values in the data recording (e.g. if the car drives in a road hole, this can lead to extreme acceleration values) were filtered by an algorithm.

2.5.2 Importing data to the SQL server

Every file has to be opened manually or automatically. The data were prepared manually and afterwards imported in a SQL database.

For easier data processing, a data reduction takes place. Raw data were gathered with a rate of 100 Hz. Those data were reduced to 10Hz, averaging or integrating 10 records.

After that, map-matching of the GPS-data from the device took place on the SQL-Server, using an Austrian street map, which allows a categorisation into motorways, urban and interurban roads.

2.5.3 Enhancement of raw data

Map matching

The Map Matching method adjusts the road coordinates with the evaluated position of the vehicle.

In the Austrian field trial the following three vector layers were used:

- ASFINAG layer for motorways and clearways
- urban roads
- interurban roads

The study provides a 95% accuracy concerning the determination of the subjects' position. Because of uncertain vague information an approximate speed value was estimated for the municipal roads.

Speed

The following limitations complicate conclusions about speed, speeding and excessive speed:

1. By the time of the DaCoTA small scale Naturalistic Driving study, for KFV there were no maps available that include legal speed limits.

2. There is no data about time-headway. Hence, it cannot be determined whether the driver has a free choice of speed at a certain spot.

For analysis, trip episodes were chosen, which are relevant for speeding information. Those are sequences with a constant speed for at least ten seconds. Constant is defined as a maximum range in the episode of 3 km/h; episodes are not overlapping.

Acceleration

The pDrive lite ® records acceleration continuously. For the analysis, three conditions are defined as starting points:

- Absolute lateral acceleration over 0.25 g (which is equivalent to 2.45 m/s²)
- Longitudinal acceleration over 0.25 g and
- Longitudinal acceleration lower than -0.25 g (i.e. breaking with more than 2.45 m/s²)

Episodes are defined in the data stream around these events:

- After the event point the data stream is examined until the condition is not fulfilled for more than one second. Then the last data point which fulfils the condition is selected as the episode end.
- A constant time interval of two seconds was added before the event to the episode (see Figure 8).

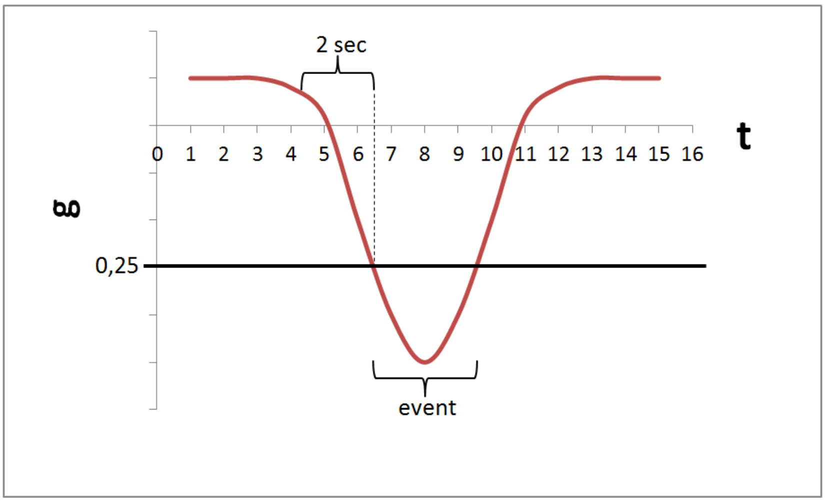


Figure 8: time episode for analysing events

2.6 Results

This chapter shows the results regarding the measured variables and further calculated variables as well as results from the surveys and the travel diary.

The aim of Task 6.3 was not to analyse the road user behaviour in detail, nevertheless DaCoTA faces a general analysis of road user behaviour like the chosen speed or general braking behaviour.

Results are not all-embracing, but more showing examples of what can be done with the data. Thus, data are not interpreted.

2.6.1 Results of the quality management questionnaire

In the first survey (during the field trial), all participants stated to be *aware of the DAS* "on and off". In the final questioning still nine participants say so, however, one person declared that he/she was aware of the DAS "always". This awareness cannot be based on specific situations. Participants specify several situations, from stepping into the car, starting, up to driving.

Sometimes it is friends that make the drivers aware of the system by asking about e.g. the camera on the front shield, cables or the GPS-receiver.

Participants also stated some specific situations, mainly at the beginning of the field trial, which advised the driver to the DAS existence. Namely, the situations were:

- Critical driving situations (in these situations some drivers would like to use the DAS for evidence)
- Cameras dangling from the shield, when they were not fixed well

Troubles (e.g. dangling cameras) arose for four participants, only at the beginning. No problems were reported after the field trial.

According to participant's self-assessment, *driving behaviour* was not changed by the DAS. Only at the beginning, one participant describes minor changes. One participant fastened their seatbelt at the start of a trip and not – like before – after driving a while.

Two participants would like to get some *feedback* from the system to be able to adapt driving behaviour.

2.6.2 Travel diary

For one week, every participant was asked to fill in a travel diary, which should provide information of every trip. Nearly half of the trips were driven to and from work (see Table 10)

Trip purpose	Number of trips	in %
To and from work	47	33
Shopping and private errands	39	27
Leisure (meeting friends, dining etc.)	39	27
Other	19	13
Total	**144**	**100**

Table 10: trip purpose

Vehicle nr.	Days recorded	Trip purpose				Trips total
		To and from work	Shopping and private errands	Leisure (meeting friends, dining etc.)	Other	
1	7	4	4	0	0	**8**
2	7	6	6	2	0	**14**
3	7	1	13	6	0	**20**
4	7	7	4	3	3	**17**
5	7	7	4	14	10	**35**
6	2	0	0	4	0	**4**
7	7	14	6	5	5	**30**
8	4	0	2	1	1	**4**
10	7	8	0	4	0	**12**

Table 11: trip purpose by participants

Trips by pDrive lite ®	Self-reported trips							total
	1	2	3	4	5	6	7	
1	3							3
2		6						6
3		3	1	1				5
4		1	2	1	1			5
5		1	2	1	2			6
6			1		1	0		2
7		1	1		1	1	1	5
8			1	1		1	1	4
9			1					1
11				1				1
14	1							1
15				1				1
	4	12	9	6	5	2	2	40

Table 12: self-reported trips

Note: in the cells the number of days is given. In total, reports of 40 days were collected by means of the travel diary.

Table 12 shows that in total, on 40 days at least one trip was stated in the travel diary. On 14 days (35%), the number of trips stated in the travel diary concurs with the number of trips recorded by pDrive lite ®. On two days (5%) more trips were stated in the travel diary than recorded by pDrive lite ®. This may be due to rejected trips because of the plausibility check. It is unlikely, that those deviations occurred due to a defect of the DAS, as other trips were recorded on that day.

24 times the participants stated fewer trips than pDrive lite ® recorded. This implies that it is very difficult to get objective information by distributing a travel diary. In one case, the participant made 15 trips per day. It can be assumed that the participant summarized the single trips. This leads to the conclusion, that the definition of trips may not always be clear to the participants.

2.6.3 Data Analysis RUN file

The analysis of the RUN file data is based on the variables of task 6.1 and task 6.2.

Results are un-weighted by gender, hour, day etc. Weighting is not yet meaningful, because the sample data are not meant for an analysis. Further results are illustrating the capabilities of the data and the applicability of the proposed algorithms to calculate indicators in SPI and RED.

Vehicle variables

In Table 13 one can see vehicle data of participants' cars.

Car type	Initial registration	Motor size	V max	Weight	HP	Fuel type
Mazda 323	1991	1324	164	1050	73,44	petrol
Audi A3	1998	1896	194	1240	110,16	diesel
VW Passat	1998	1896	196	1367	110,16	diesel
VW Passat	1998	2771	230	1511	193,12	petrol
Mercedes M	2002	2685	183	2125	163,2	diesel
Opel Astra	2005	1364	178	1155	89,76	petrol
Kia Ceed 1,6 CRDi	2007	1582	172	1342	89,76	diesel
VW Golf Plus	2008	1896	183	1434	104,72	diesel
Mercedes E	2008	2987	244	1770	224,4	diesel
Peugeot 308	2009	1397	178	1351	95,2	petrol

Table 13: vehicle variables

Number of trips

In total, 4.551 trips were recorded by the pDrive lite ®. After data cleansing 4.030 (88,6%) trips were observed in order to filter only trips of participants.

Not only participants drove the cars that were part of the Austrian field trials. Thus, an ID-Check assured that only trips of the target person (who signed the contract) were taken into account.

The target person has to be identified by video-check. If a video shows another driver or if the person is not positively identifiable, trip data were excluded from the analysis. Table 14 shows, how many trips have been driven by the participants and how many trips had to be excluded from further analysis.

Vehicle nr.	Trips of participant		Trips of other person		Total
1	241	97,6%	6	2,4%	247
2	284	89,6%	33	10,4%	317
3	831	95,8%	36	4,2%	867
4	312	77,2%	92	22,8%	404
5	466	94,7%	26	5,3%	492
6	323	79,4%	84	20,6%	407
7	475	98,8%	6	1,2%	481
8	161	62,4%	97	37,6%	258
9	205	97,2%	6	2,8%	211
10	346	100,0%	0	0,0%	346
Total	**3.644**	90,4%	**791**	**9,6%**	**4.030**

Table 14: trips by vehicle and participant

Further analysis contains 3.644 trips, which could be definitely assigned to the participants. That is in this study, person or driver kilometres are defined similar to vehicle kilometres, because only trips of participants – who signed the contract – are included in the analysis.

Passengers were not taken into account in this study. Thus, person and vehicle kilometres do not comply with general definitions.

Date and time

Figure 9 presents the number of trips by day of the week. 711 trips (19,5%) were made on Fridays, most likely for leisure and various non-work purposes. This refers to males and females. In general, male participants made more trips than females.

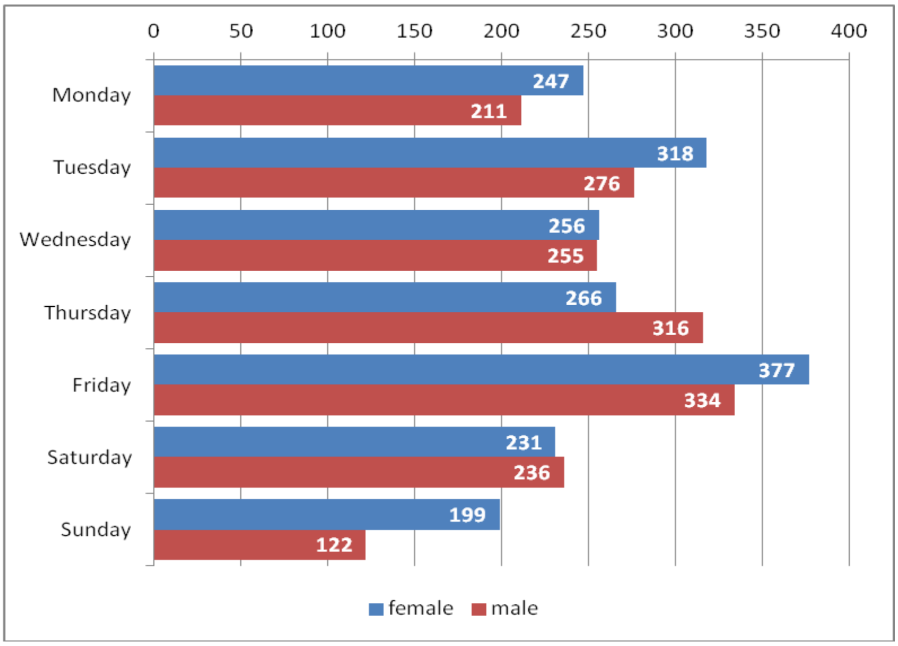


Figure 9: trips by weekday and gender

Table 15 indicates that most trips are made in the morning and in the afternoon. The female participants show their peak in the afternoon, whereas the male participants made most trips in the morning.

Time (hour)	**Gender**		**Total**
	female	**male**	
0	17	5	22
1	3	2	5
2	0	1	1
3	6	6	12
4	70	12	82
5	89	24	113
6	113	172	285
7	79	99	178
8	103	109	212
9	83	128	211
10	107	107	214
11	154	126	280
12	142	127	269
13	151	124	275
14	133	163	296
15	173	155	328
16	128	119	247
17	114	91	205
18	85	83	168
19	39	38	77
20	37	31	68
21	21	18	39
22	22	8	30
23	25	2	27
Total	**1.894**	**1.750**	**3.644**

Table 15: trips by hour of day and gender

Table 16 shows another presentation of the results in Table 15. Here it becomes clearer that the afternoon peak is the time period with the highest number of trips (26%).

Time (hour)	Per cent	Time category	Per cent
0	0,6%	0-4 am Night	1%
1	0,1%		
2	0,0%		
3	0,3%		
4	2,3%	4-6 am Early Morning	5%
5	3,1%		
6	7,8%	6 - 9 am Peak Morning	19%
7	4,9%		
8	5,8%		
9	5,8%	9 am - 12 noon Day	19%
10	5,9%		
11	7,7%		
12	7,4%	12 noon - 3pm	23%
13	7,5%		
14	8,1%		
15	9,0%	3 - 7 pm Peak Afternoon	26%
16	6,8%		
17	5,6%		
18	4,6%		
19	2,1%	7 pm - 0 Early Night	7%
20	1,9%		
21	1,1%		
22	0,8%		
23	0,7%		
Total	**100%**		

Table 16: trips by hour of day in categories

Length and duration

One requirement for participating in the field trial was to drive at least 250km/month. Thus, in the four months long field trial, each participant should drive at least 1.000km. Table 17 shows, that 69.663 kilometre of trips were covered during this period in total, whereas a high variance between participants can be observed.

Vehicle nr.	Number of trips	Distance driven
1	241	4216
2	284	4961
3	831	16042
4	312	8749
5	466	9800
6	323	6192
7	475	4491
8	161	1625
9	205	7093
10	346	6493
Total	**3.644**	**69.663**

Table 17: person-trips and person-km

The majority of trips are quite short (less than 5 km, see Table 18). This is, on the one hand as a result of the definition of a trip in the Austrian trial (A trip starts by starting the engine). Hence, if the driver stops e.g. for refuelling or for drawing money and therefore turns off the engine, the continuation of the journey will count as another trip.). On the other hand, participants live in or near the main city Vienna, so the distances travelled to work or supermarkets are rather short. That also emerges, when the trip duration is taken into account. Just under a quarter of trips lasted less than five minutes (see Table 19).

Trip length	Number of Trips	Per cent
Less than 5 km	1518	42%
5-10 km	435	12%
10-20 km	601	17%
20-30 km	341	9%
30-50 km	425	12%
50 km and more	297	8%
Total	**3.617**	**100%**

Table 18: trip distance

Some trips cannot be assigned to the length classes above. This is because of missing GPS-signals, so in less than 1% of trips this information is missing. Time is recorded by the pDrive lite ®, so the duration can be recorded for each trip.

Trip duration	Number of trips	Per cent
Less than 5 min	836	23%
5-10 min	724	20%
10-20 min	762	21%
20-30 min	516	14%
30-50 min	575	16%
50 min and more	231	6%
Total	**3.644**	**100%**

Table 19: trip duration

Trip duration and trip length can also be observed for each participant (see Figure 10).

Whereas the average trip duration of participant 8 is more than 15 minutes at an average distance of around 10 km (what accounts for many urban trips), participant 4 and 9 drove longer distances in a comparatively short time.

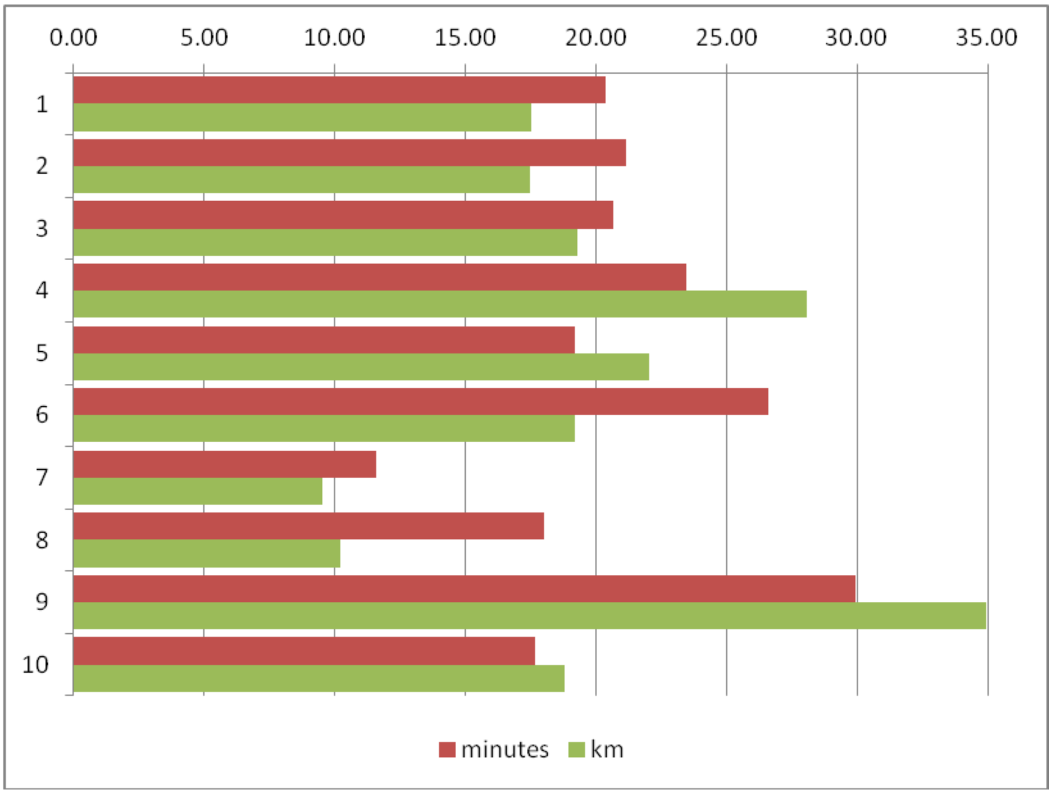


Figure 10: average trip duration/trip length by participants

Regarding the distribution among weekdays, more trips were driven on Fridays than on other days. Also more short trips (less than 5 km) were driven on Fridays. Not surprisingly, more long trips (more than 50 km) could be observed on weekends (Table 20).

	Number of trips						
Trip length	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
Less than 5 km	174	240	198	224	314	225	143
Between 5-10 km	58	76	52	76	70	71	32
Between 10-20 km	80	95	103	111	129	56	27
Between 20-30 km	42	71	56	53	63	23	33
Between 30-50 km	75	76	62	73	65	34	40
More than 50 km	28	34	40	45	48	56	46
Total	**457**	**592**	**511**	**582**	**689**	**465**	**321**

Table 20: trip distance by weekday

Road type distribution

Table 21 shows how much time the participants spent on average on different road types. E.g. participant no. 9 drove 205 trips. On average, per trip he/she spent 12 minutes on motorways. Taking into account only those trips where he/she drove on motorways at least for a short time, one can see that the average duration of time spent on the motorway is more than 31 minutes.

Veh. nr.	No. of trips	Motorway			Interurban			Urban area		
		mean all	mean (if motor-way)	max	mean all	mean (if inter-urban)	max	mean all	mean (if urban)	max
1	241	4,8	10,6	44,5	1,3	2,2	7,5	13,9	14,0	66,7
2	284	5,3	10,2	193,0	0,8	1,3	8,0	14,8	14,8	46,5
3	831	3,5	9,2	95,2	2,7	3,8	19,7	10,2	11,3	84,2
4	312	7,2	11,9	111,8	2,2	3,2	9,7	13,4	13,9	64,7
5	466	9,9	24,3	134,7	0,7	1,4	9,0	7,2	7,5	41,3
6	323	7,6	18,1	137,3	0,5	1,4	5,5	17,5	17,7	170,3
7	475	1,0	3,5	69,8	1,7	4,1	10,0	8,8	8,9	50,5
8	161	3,6	9,2	116,2	0,2	0,6	4,7	12,5	14,1	167,7
9	205	12,1	31,7	277,8	1,1	1,4	12,2	16,2	16,4	95,7
10	346	5,5	18,7	103,5	1,7	4,5	10,8	9,5	9,6	40,0
Total	**3.644**	**5,6**	**13,9**	**277,8**	**1,5**	**2,8**	**19,7**	**11,5**	**12,0**	**170,3**

Table 21: trip duration (minutes) by participant and road type

Note: “all“ means, that all trips driven by the person where taken into account. The column on the right (e.g. “if motorway”) shows the results, if only those trips are taken into account, that were driven at least party on this type of road. “Max” is the longest duration ever driven on the type of road during the trial-period.

The longest time spent on motorways during the trial was 277 minutes. The average time spent on interurban roads is less than 3 minutes, whereas the participants spent a lot of their driven time in the urban area (12 minutes on average). The results reflect the area of the trial (mainly Vienna), where people either drive on urban roads or use the urban motorway, or leave the city on motorways to drive to the next urban area.

Speed

Table 22 shows the average driven speed on different road types. As mentioned in section 2.5.3, no maps including legal speed limits were available at the time of the study in hand. Thus, only general speed limits for each road type can be taken into account. The general speed limits are:

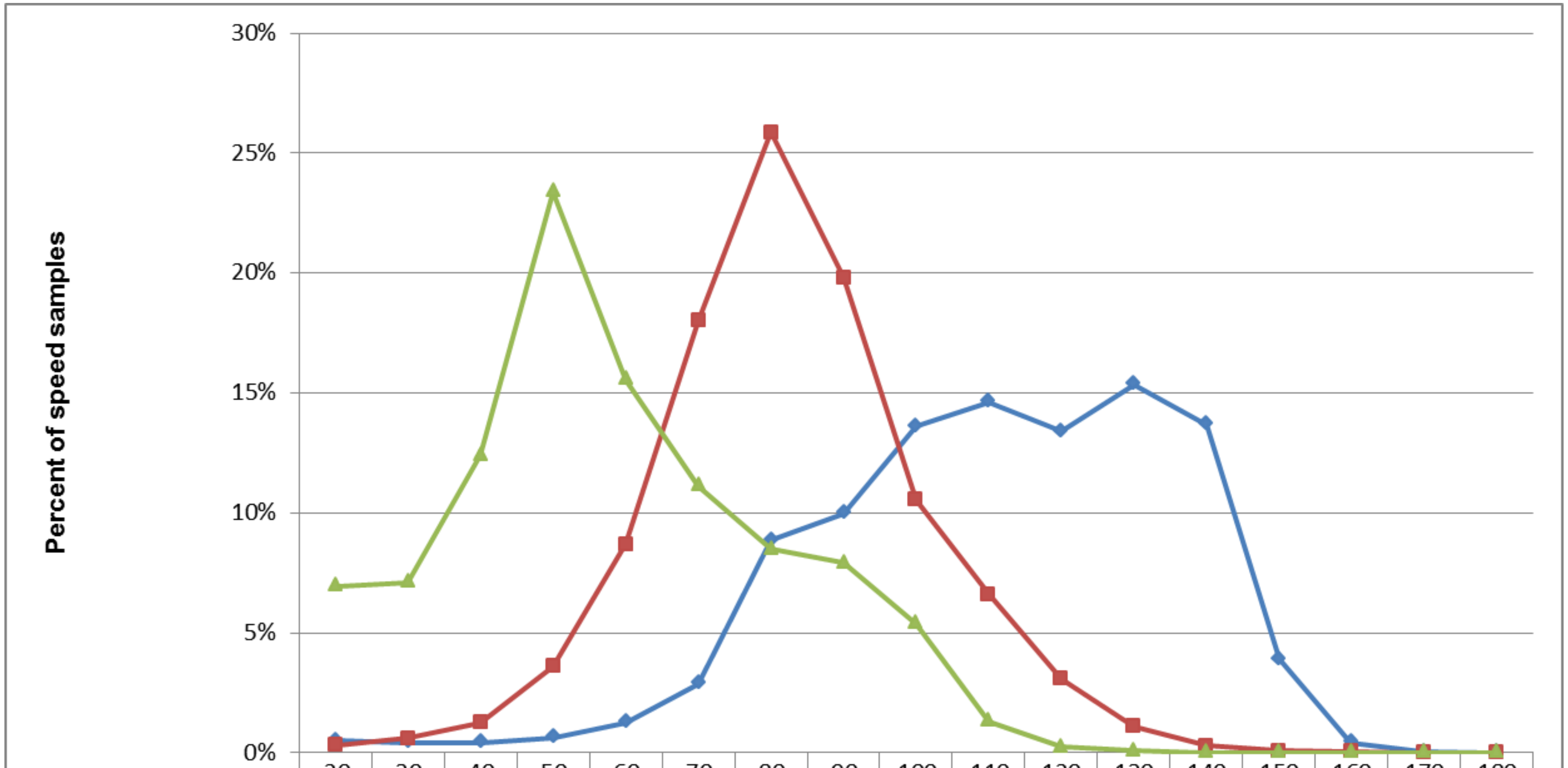
- 130 km/h on motorways
- 100 km/h on interurban roads
- 50 km/h on urban roads (legal speed limits sometimes allow 70 km/h on urban roads)

Thus, Table 22 shows in general, how fast participants of the Austrian field trial drove. But no conclusions can be drawn about speeding.

		Female	Male	Total
Motorway	Mean	109,7	112,4	**111,1**
	SD	23,1	25,3	24,2
	Max.	166,3	180,9	180,9
Interurban	Mean	84,8	81,6	**82,5**
	SD	21,4	16,9	18,4
	Max.	148,6	161,5	161,5
Urban	Mean	51,2	62,4	**58,3**
	SD	20,4	22,3	22,3
	Max.	127,3	149,6	149,6

Table 22: speed by road type and gender

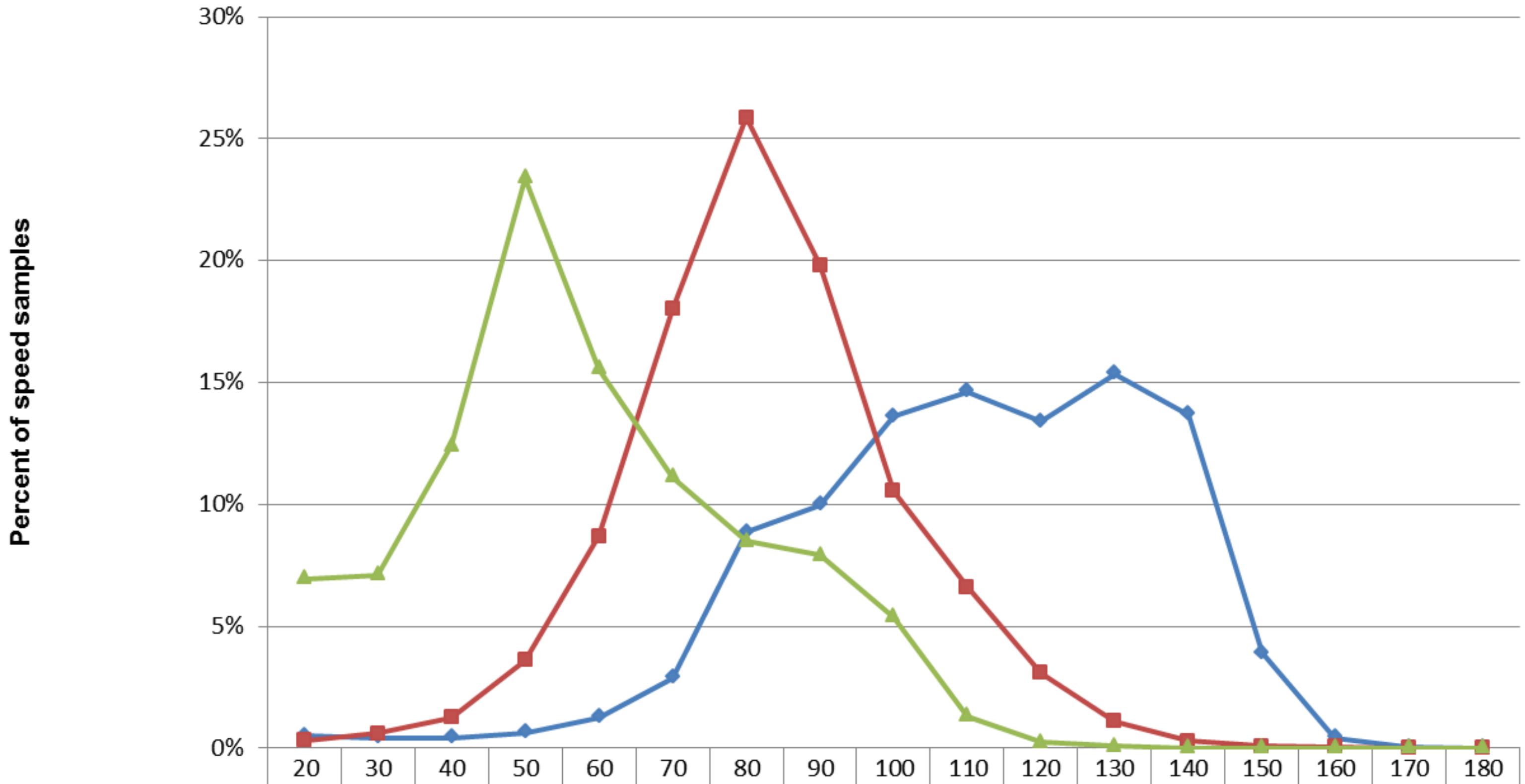
Figure 11 and Figure 12 show the distribution of speed measurements on different road types. Notice, that speed measurements in this case are single measurements that were recorded ten times a second (10Hz), if they fulfil the requirements defined in chapter 2.5.3 (constant speed for at least ten seconds, ranging maximum 3 km/h). Consequently, it is unsurprising that more speed measurements exist for motorways than for other road types.



	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
Motorway	1%	0%	0%	1%	1%	3%	9%	10%	14%	15%	13%	15%	14%	4%	0%	0%	0%
Interurban roads	0%	1%	1%	4%	9%	18%	26%	20%	11%	7%	3%	1%	0%	0%	0%	0%	0%
Urban roads	7%	7%	12%	23%	16%	11%	9%	8%	5%	1%	0%	0%	0%	0%	0%	0%	0%

Speed observed

Figure 11: distribution of speed by road type



	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
Motorway	1%	0%	0%	1%	1%	3%	9%	10%	14%	15%	13%	15%	14%	4%	0%	0%	0%
Interurban roads	0%	1%	1%	4%	9%	18%	26%	20%	11%	7%	3%	1%	0%	0%	0%	0%	0%
Urban roads	7%	7%	12%	23%	16%	11%	9%	8%	5%	1%	0%	0%	0%	0%	0%	0%	0%

Speed observed

Figure 12: speed by road type and gender

Table 23 shows the percentile speed distribution given in Figure 12 by road type. Especially on urban roads it is obvious that the participants travelled faster than the general speed limits. But it has to be pointed out that on some Austrian urban roads it is possible to drive up to 70 km/h. However, at least more than 20% of speed measures on urban roads were too high and also on motorways.

	Percentile						Median
	50	**60**	**70**	**80**	**85**	**90**	
Motorway	113,5	119,3	127,7	133,9	137,0	140,5	113,5
Interurban	81,9	85,6	90,2	96,5	101,2	106,5	81,9
Urban	55,0	60,6	68,6	78,3	84,8	91,5	55,0

Table 23: speed percentiles by road type

The results above focus on speed in terms of free chosen speed. The Austrian trial is based on Scenario 1, thus, no device for measuring headway was available. So we tried to find an indicator of free choice of speed (as described above).

Another indicator may be the time, i.e. it can be assumed that in rush hours drivers are not able to choose their speed freely, whereas this is possible the rest of the day.

Table 24 shows the distribution of average speed by time. This includes all speed measurements above 5km/h recorded by the pDrive lite ®.

No significant difference can be observed between mean speed during the defined rush hours and speed during the rest of the day. Most likely, differences occur on urban roads, but are negligible. Besides it has to be stated, that about two third of trips drop out of the analysis, when taking only speed data of rush hours into account.

hour of day	Mean speed			Number of trips			Standard deviation		
	motorway	interurban roads	urban roads	motorway	interurban roads	urban roads	motorway	interurban roads	urban roads
0	81,8	61,4	32,6	3	4	12	5,8	10,5	7,4
1	76,2		33,6	1		7	.		13,1
2	109,8	89,7	36,7	1	1	2	.	.	6,4
3	107,7	86,8	42,1	8	8	15	22,5	23,5	19,7
4	84,6	82,4	45,8	53	72	85	21,7	15,3	9,0
5	85,2	73,0	37,1	55	67	125	28,4	17,9	12,0
6	101,6	62,3	42,4	152	213	302	28,6	22,5	12,2
7	89,8	62,2	37,3	64	99	197	24,9	17,4	12,7
8	93,3	63,1	39,0	90	111	216	23,0	17,1	13,3
9	85,3	62,5	38,4	93	120	230	28,1	17,8	12,2
10	95,6	65,8	40,3	99	126	217	22,7	20,9	13,6
11	84,6	69,1	38,3	114	147	291	26,8	16,8	12,4
12	90,8	66,1	40,2	135	163	285	25,7	17,4	12,4
13	88,5	65,7	39,9	130	162	287	25,7	17,2	12,1
14	91,0	65,3	38,0	130	176	304	28,8	17,8	13,2
15	89,8	62,4	37,4	135	189	339	28,7	19,0	12,2
16	85,8	63,3	37,3	88	131	258	30,0	19,0	11,2
17	94,2	63,3	39,0	88	119	208	24,3	17,8	10,4
18	92,4	64,7	37,7	53	94	173	22,1	17,9	11,4
19	77,6	67,7	37,6	37	47	87	26,4	13,0	9,7
20	88,3	66,0	37,8	27	41	75	24,8	13,0	10,5
21	75,6	67,8	39,6	14	16	41	32,5	14,0	10,5
22	89,2	63,2	36,2	10	13	32	21,2	17,7	7,6
23	79,0	72,7	38,1	9	6	26	39,1	20,6	9,2

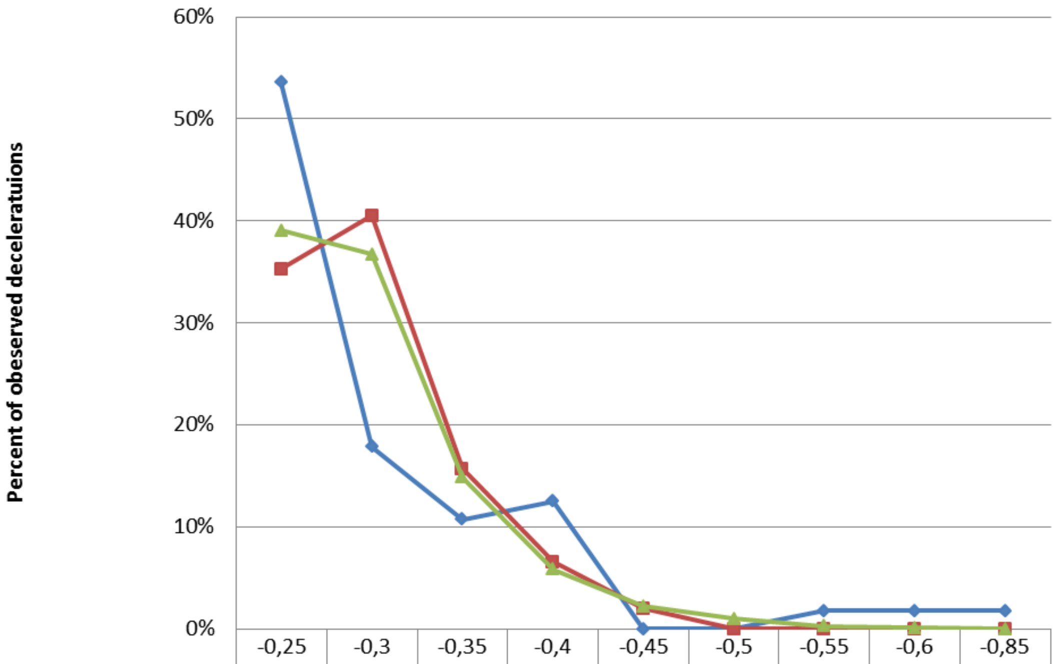
hour of day	Mean Speed			Number of trips			Standard deviation		
	motorway	interurban roads	urban roads	motorway	interurban roads	urban roads	motorway	interurban roads	urban roads
Total	**90,3**	**65,4**	**38,9**	**1589**	**2125**	**3814**	**26,9**	**18,7**	**12,2**
Total rush hours	**89,1**	**63,5**	**38,1**	**513**	**721**	**1369**	**26,2**	**17,6**	**11,8**
Total not in rush hours	**90,9**	**66,5**	**39,4**	**1076**	**1404**	**2445**	**27,3**	**19,2**	**12,4**

Table 24: average speed by hour of day (including all speed measurements >5km/h)

Longitudinal acceleration events

Section 2.5.3 defines two conditions for the analysis of longitudinal acceleration data (>0,25g, <-0,25g). An event starts if the condition is fulfilled and ends when the condition is not fulfilled for more than one second. Furthermore, 20 seconds before the event are added to the episode for further analysis (e.g. speed before event).

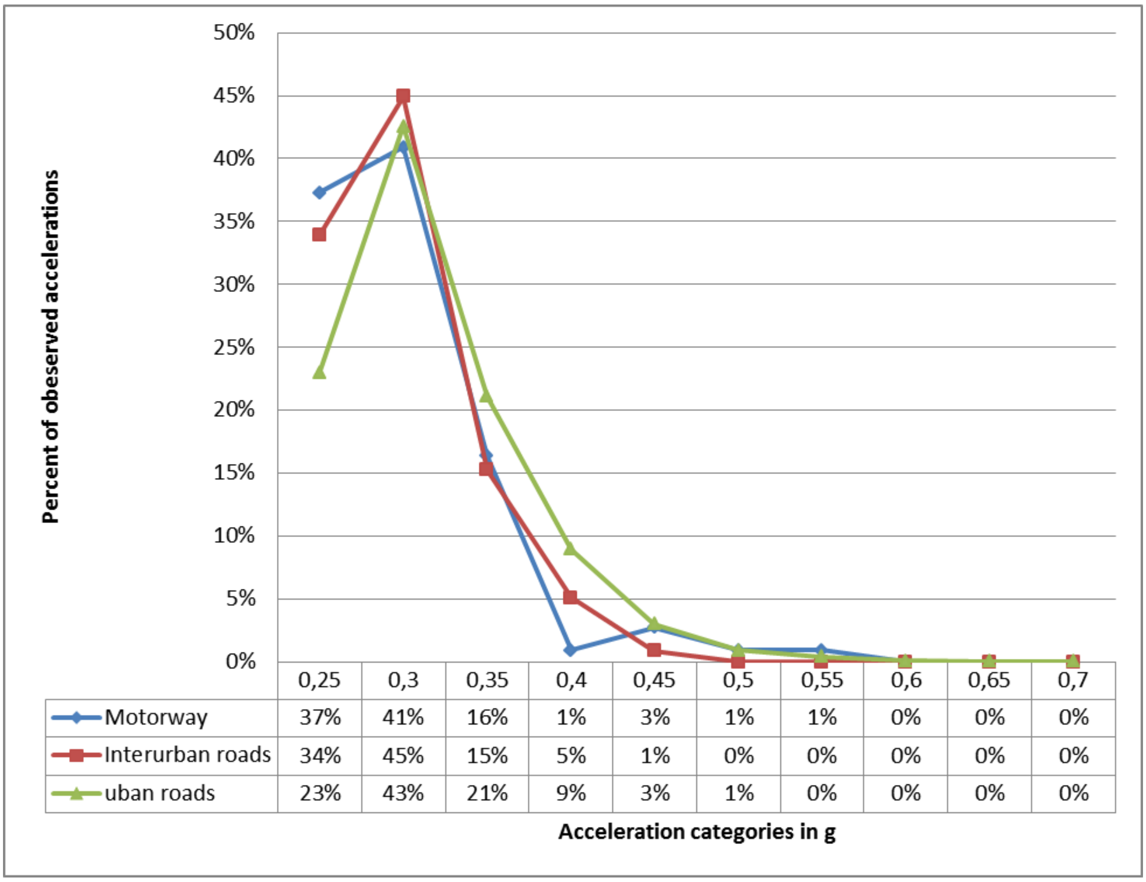
Figure 13 and Figure 14 show the frequency of acceleration events (braking and accelerating) by different road types, given the maximum acceleration measure of the event.



	-0,25	-0,3	-0,35	-0,4	-0,45	-0,5	-0,55	-0,6	-0,85
Motorway	54%	18%	11%	13%	0%	0%	2%	2%	2%
Interurban roads	35%	41%	16%	7%	2%	0%	0%	0%	0%
uban roads	39%	37%	15%	6%	2%	1%	0%	0%	0%

deceleration categories in g

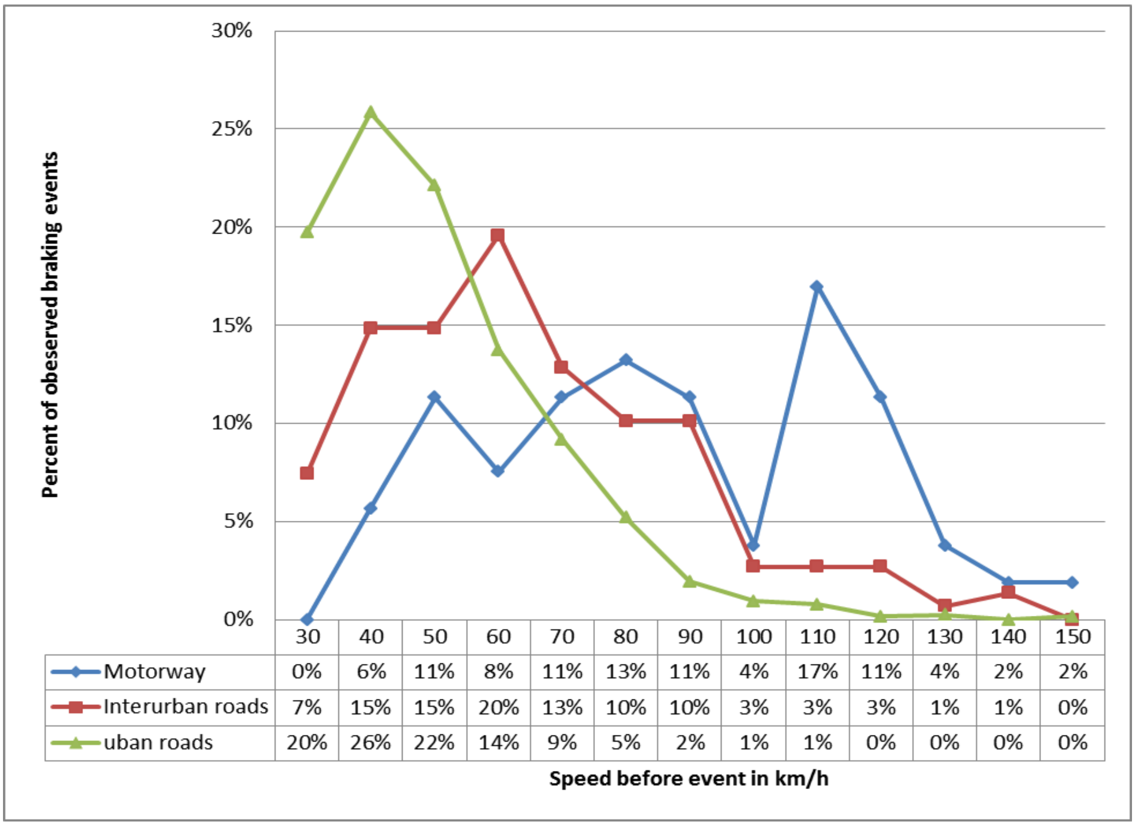
Figure 13: longitudinal acceleration events (braking)



	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7
Motorway	37%	41%	16%	1%	3%	1%	1%	0%	0%	0%
Interurban roads	34%	45%	15%	5%	1%	0%	0%	0%	0%	0%
uban roads	23%	43%	21%	9%	3%	1%	0%	0%	0%	0%

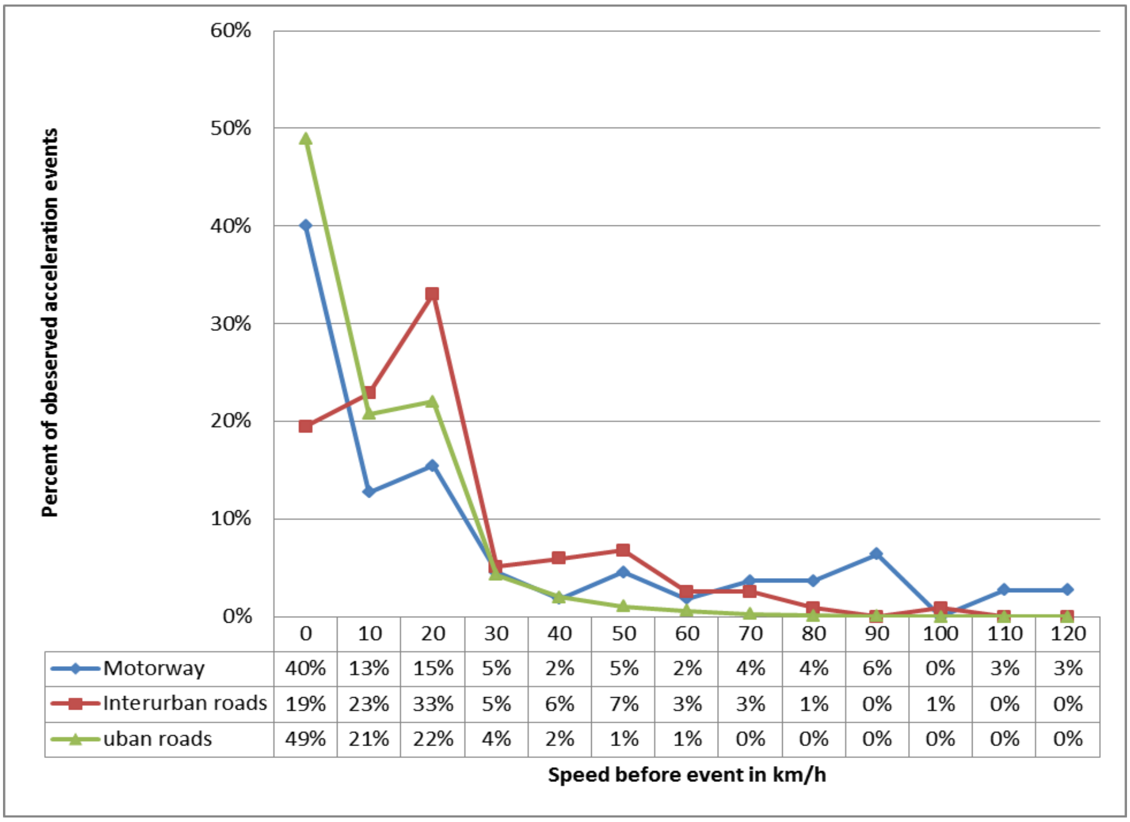
Figure 14: longitudinal acceleration events (accelerating)

Figure 15and Figure 16 show the distribution of episodes with g-values below -0,25g and g-values above 0,25g, depending on the speed before the event. On motorways, most episodes were observed when the speed before the event was about 120 km/h. On urban roads, the main part of heavy-braking episodes (<-0,25g) were recorded when participants drove about 40 km/h.



	30	40	50	60	70	80	90	100	110	120	130	140	150
Motorway	0%	6%	11%	8%	11%	13%	11%	4%	17%	11%	4%	2%	2%
Interurban roads	7%	15%	15%	20%	13%	10%	10%	3%	3%	3%	1%	1%	0%
uban roads	20%	26%	22%	14%	9%	5%	2%	1%	1%	0%	0%	0%	0%

Figure 15: longitudinal acceleration depending on speed before event (braking)



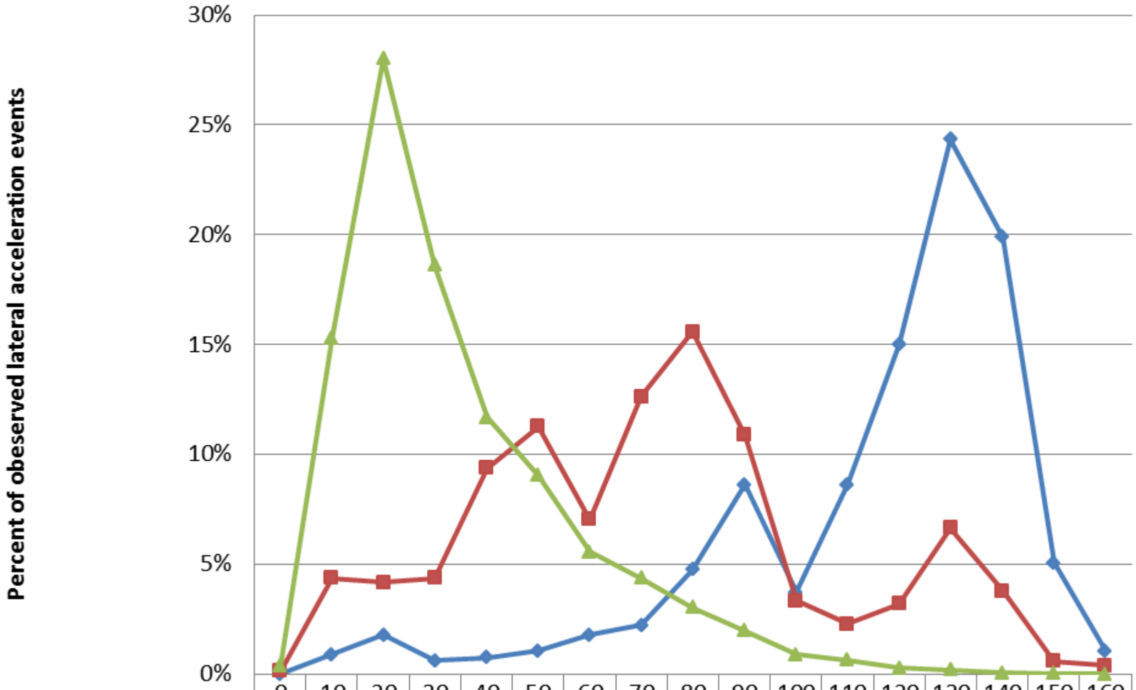
	0	10	20	30	40	50	60	70	80	90	100	110	120
Motorway	40%	13%	15%	5%	2%	5%	2%	4%	4%	6%	0%	3%	3%
Interurban roads	19%	23%	33%	5%	6%	7%	3%	3%	1%	0%	1%	0%	0%
uban roads	49%	21%	22%	4%	2%	1%	1%	0%	0%	0%	0%	0%	0%

Figure 16: longitudinal acceleration depending on speed before event (accelerating)

Lateral acceleration events

Lateral acceleration data above 0,25g are taken into account in the analysis, without discriminating between right and left.

Figure 17 shows the distribution of episodes with g-values above 0,25 g depending on the speed before the event. The distributions are different for each road type. On motorways, there is an accumulation of episodes at a speed level above 100 km/h. On interurban roads, multiple peaks can be observed, whereas on urban roads the accumulation can be observed at speed levels about 10 km/h to 30 km/h.



	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
Motorway	0%	1%	2%	1%	1%	1%	2%	2%	5%	9%	4%	9%	15%	24%	20%	5%	1%
Interurban roads	0%	4%	4%	4%	9%	11%	7%	13%	16%	11%	3%	2%	3%	7%	4%	1%	0%
uban roads	0%	15%	28%	19%	12%	9%	6%	4%	3%	2%	1%	1%	0%	0%	0%	0%	0%

Speed before event in km/h

Figure 17: lateral acceleration on urban roads depending on speed before event

2.7 Lessons learned & recommendations

2.7.1 Technology

It is essential to have a storage capacity that is big enough, as data can be lost when the storage device approaches its capacity. A buffer battery is very useful to guarantee a safe storage of the data. Thus, after the ignition is turned off the pDrive lite ® device can store the last recording of the trip in a safe way.

For retrieving the data from the vehicle, Milestone 6.2 outlines a number of solutions. For a large scale activity it is not recommendable to retrieve data by removing and copying data onto a central storage facility or plug a device into the car to upload data. In the small scale study of DaCoTA the data storage could be easily done. For a large scale study it is recommendable to stream data onto some form of solid state storage device, e.g. by transmitting the data automatically by UMTS and to store them on a server.

An alternative is to use the postal system to retrieve data. This method was used by an Australian FOT. They used Flash cards that were sent to participants who replaced them and sent the used cards back to the researchers (Regan et al, 2006). Another option is to use a form of wireless technology, for example Bluetooth or GPRS. This technology allows the automatic uploading of data, either when the vehicle is in close proximity with a receiver ‘hub’ or as data packets through the phone network.

In the Austrian trial, installation was not possible in one car. The easiest way to connect a DAS is to plug it to the cigarette lighter by a socket in form of a Y-plug. This is not always feasible, because the power supply is not defined consistently. That is to say, that the DAS used in the Austrian trial (pDrive lite ®) depends on the power supply. If the car, hence the power supply, is started, the pDrive is activated. An increasing number of cars are equipped with cigarette lighters that are provided with energy continuously. Thus, the DAS would be activated continuously and thereby cause the car battery to go flat.

To avoid this problem, another option is to connect the DAS to the power cable in the central distributor. In this case, the installation takes longer and is also more costly. The installation by a certificated garage can help avoiding problems with warranty.

2.7.2 Implementation

Besides a detailed planning and recruitment procedure, a ND study needs to be well structured and organised (support team). Due to continuous support errors/defects which occur, be it in the DAS or in the data storage, will be corrected as soon as possible (to prevent of data losses). In the Austrian field trial it happened, that due to sensitivity of the pDrive lite ® interface, a memory card’s pin was damaged. This shows the importance of regular inspections.

Another thing is that participants do not know if there is still enough space or if the storage is full. Thus, if data are not transferred automatically, a systematic check is essential. An option is to choose storage devices so big that enough data for e.g. half a year can be stored. But then, if the DAS is broken, also the storage device can be damaged. Then, data from half a year are lost.

The ideal solution would be a real-time data transfer. Then plausibility can be checked automatically and problems appear as they occur and so can be solved.

2.7.3 Data processing

In the Austrian trial a relational database was used to convert raw data from the pDrive lite ® into a structured mode for data analysis. It has to be kept in mind that the design of the database is essential for a large scale study.

In the realised study the trips of ten participants were recorded for a four months period. The table of measurements contains 65 million datasets. Hence, in a large scale study with thousands of cars recorded for a year or longer, a change of table structure would entail a rearrangement of the database which could take weeks. Thus, it is of importance to accurately define the structure of the database in a large scale study.

As shown in Chapter 2.6 numerous secondary variables or indicators can be calculated from the raw data. The problem is more: how to define them and how to operationalise them. For example “speed” has to be clearly defined; which conditions need to be filtered out for a consistent indicator. So the average speed may be different from the mean of all measurements.

Depending on what conclusions need to be drawn, more or less additional information may be needed. That information is not always available. An example regarding the Austrian trial concerns speed. We do not know, if the speed is freely chosen or if the driver drives in a convoy. Furthermore, information about legal speed limits is missing.

Summing up, lots of data analysis is possible within an available set. An exception is map-matching. Map-matching can be done afterwards and therefore applied to previous records. Contrary, information about headway cannot be added afterwards.

It has to be stated that Austrian map material was used in this trial. In a large scale study it is important to have the countries’ map material. The map material essentially defines what can be analysed. The map material used consists of two components: the categorisation of roads and polygonal lines. The categories “urban” and “motorway” are well defined; whereas roads not assignable to those two categories are problematic, e.g. interurban roads can pass through cities. By applying particular rules, 95% of trips could be assigned to the road categories. 5% contain coordinates not accurate enough and/or coordinates not fitting to the maps.

It is possible that if accurate maps are not yet available at the time of ND-driving, that map data are collected simultaneously or afterwards. It is even possible that maps are created based on the locations where the ND-vehicles drive.

2.8 Summary of the Austrian trial

This field trial has demonstrated the potential of a small scale ND study, using a simple DAS defined in D6.1 as scenario 1 - DAS. Aim of the study was to show the capabilities as well as possible problems. Thus, it was not intended to draw representative conclusions about driver behaviour.

The study demonstrated the feasibility of collecting detailed data on exposure, speed and associated characteristics. A full and continuous log book was provided for the ten participants involved in the field trial. Data on trip duration and -length, speed and acceleration as well as road types were collected continuously at 10 Hz intervals.

The variables recorded, as pre-defined by the other parts of WP6, included exposure related variables, speed related variables and other safety related variables. By means of continuously recorded raw data like GPS and acceleration, it was possible to calculate such variables.

In total, 3.644 trips have been monitored in a four months period. Details of those trips were analysed and are described in the report. Analysis comprises of results regarding road type, driver gender, weekday, time, length and duration and also various cross-tabulations.

Within these trips 116.417 episodes of ‘constant speed’ were recognised. These episodes include speed and acceleration events.

The travel diary served as a cross check concerning the participant’s trips. Misunderstandings regarding the travel diary led to the conclusion, that there are several different understandings of “trip”. So, other definitions of trips than that used in the analysis within the Austrian field trial will be introduced in the Israeli field trial (see Chapter 3). The implications of definitions of trip will be discussed in Chapter 4.

The study demonstrated that it is possible to obtain a very detailed description of exposure and safety related behaviour. Collecting these variables on a representative sample of drivers in all EU countries by means of ND would add a very valuable aspect to the ERSO database.

3 THE ISRAELI FIELD TRIAL

3.1 Introduction

In this section we introduce the Israeli experience and results of generating an inventory of relevant variables to monitor *road* safety through a small scale naturalistic driving observation trial.

In Deliverable 6.1 it was decided to focus on data with potential use for a European data base. Thus, a focus on exposure and speed was mentioned, stemming from earlier work carried out in the SafetyNet project. For such data a continuous log of travel is required, a feature which did not exist, for example, in the PROLOGUE trials. Another aspect of continuous monitoring, useful for an EU database, is the requirement regarding the equipment. This should be relatively simple to install and reasonably priced. Hence, a relatively large statistical sample at limited costs is possible.

This led to the use of in-vehicle data recorders in the current experiment, both in Austria and in Israel. The current field trial conducted in Israel provides a complete record of exposure and speed profile of the participants in addition to a record of other variables. The trial is based on a specific group, most of them are OR YAROK employees. This is unlike the PROLOGUE trials, in which most of the trials focused on young drivers[8]. However, it should be clear that the current small scale study does not represent a random sample of drivers, nor was this the intention.

3.2 Methodology

3.2.1 Participants

Seven vehicles and their drivers participated in the trial (see Table 25). Due to technical problems, the data of the eighth participant was not included. Six drivers are Or Yarok (a safety NGO) employees and one driver is an ITS Israel employee. Three were male drivers and four were female drivers. All these drivers drive vehicles provided to them by their organizations as part of their compensation plan.

They all have at least 15 years of driving experience and drive at least 1.5 hours a day on average. Most of the drivers drive on both urban and interurban roads. The vehicles are used for both work and other purposes. It should be noted that Or Yarok is a road safety organisation, and as such all employees are highly aware of safe driving practices. Thus, the sample in this trial is clearly biased and non-representative of normal driving in the general driver population.

All participants agreed to take part in the trial. No incentive was offered since Or Yarok vehicles are monitored on a regular basis (as part of the fleet safety policy).

[8] PROLOGUE, Field trial in Israel, Deliverable D3.2, December, 2010

Organization	Car type
Or Yarok	Ford (2x)
Or Yarok	Hyundai (2x)
Or Yarok	Volkswagen
Or Yarok	Toyota
ITS Israel	Peugeot

Table 25: list of vehicles

3.2.2 Technology used

The following systems and associated software were used for data collection:

1. MobilEye[9] - a system that measures distances and headways to the vehicle in front and measures lane departures. In its normal configuration it provides real-time warnings to the drivers, but does not log any information. We have created a mechanism to log this data using the TrackTec system.

   MobilEye detection is based on a smart camera located on the front windshield inside the vehicle. It functions as a “third eye” on the road, utilizing Mobileye’s vehicle, lane, and speed sign detection technologies to measure the distance to vehicles, lane markings, and speed signs. More details on the product and it’s method of operation can be found on the product’s website[10].

Figure 18: visual display of MobilEye

2. Can-Bus – a message-based protocol, designed specifically for automotive applications, existing in all modern cars. The system logs information items from the vehicle systems, for example: door open/close, mileage, engine switch, phone speaker.

3. TrackTec[11] – this system was originally designed for fleet management, and is used as a data logger, which records and transmits information. The system retrieves data from the car central computer using the Can-Bus and from MobilEye. The connection to the MobilEye system was developed especially for this project. The system also records vehicle speed, acceleration and deceleration and vehicle position.

[9] http://www.mobileye.com/
[10] http://www.mobileye.com/site-map/
[11] http://www.track-tec.com/fleetsl/Contact.aspx

Figure 19: TrackTec recording device

4. A system that records fuel consumption. It is based on electronic billing system used by the vehicles at gas stations.
5. TransCAD[12] – a GIS (geographic information system) software to undertake map matching of the GPS records and to display and analyse the results.

In selecting the above mentioned technologies a number of considerations played a part. First, the technologies should be relatively cheap and easy to install. Second, it was decided that the instrumentation should be connected to the vehicle Can-bus in order to extract additional information directly from the vehicle systems. In this context, a major consideration was to investigate how easy or difficult it would be to extract such information. Third, the Israeli trials did not include video recordings, which are part of the Austrian trials.[13] These data are more expensive to collect and analyse, and so may not be appropriate for the large-scale long-term implementation needs of ERSO.

3.2.3 Installation specifications

The technology used for this project was originally installed in eight vehicles. Due to technical problems, only data from seven vehicles were collected. The installation was done by authorized technicians, and took between two and three hours for each vehicle. The implication for further ND studies is that in selecting vehicle sample size, a safety margin should be built-in to allow for vehicles not being available for a variety of reasons.

It must be said that the total period of installation took much longer than it was planned. This was due to people not arriving for installation when required and turn-over of qualified technicians. Initially the experiment was supposed to start in January 2011, with two months for installation. In practice, the installation took twice as long, with all kinds of problems and the data flow started in February 2011. The study ran for six months, collecting more data than planned.

3.2.4 Geographical location

The participants were not restricted in their driving within the state of Israel. The Or Yarok organization is located in Hod HaSharon and ITS-Israel is in Herzelia, both in the Central part of Israel, near Tel Aviv. The participants all live in the same general area and so most trips took place in central Israel. However, some trips took place in other parts of the country. GPS measurement locations uploaded on a GIS map by using TransCAD software are presented in Figure 20.

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[12] http://www.caliper.com/tcovu.htm
[13] Video analysis was used for driver identification.

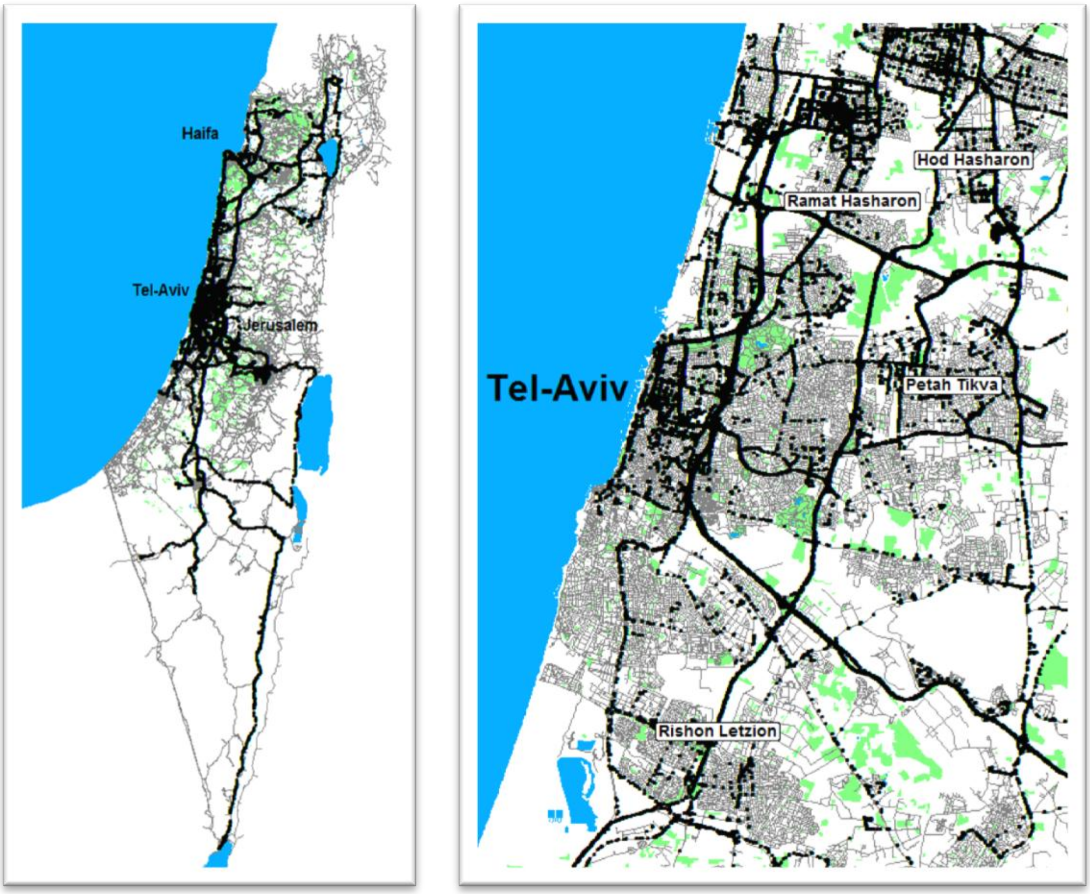

Figure 20: distribution of trips location (right: map of Israel, left: Central Israel)

3.3 Data Collection

3.3.1 Time-Based and Event-Based Data

The data were collected from the devices in the seven vehicles over a period of six months, from February 2011 to July 2011. Two measurement types were collected:

- Time-based measurements were collected every 30 seconds. These included headway measurements, acceleration, speeds, and GPS location. These measurements were sampled every 30 second in order to obtain a continuous record of these variables. In addition any time an event occurred, as described below, this was recorded as well. The sampling rate was decided on as a compromise between amounts of data to store, without discarding the possibility to obtain a continuous record of driving for each trip.

- Event-based measurements were collected whenever one of the following events occurred: Cut off Warning, Headway warning, Night and Dusk Indication, Lane Departure Warning, Forward Collision Warning, Light warning. The information collected at the time of the events also contains the speed, acceleration and GPS location, as in the time-based measurements. The definition of the events are presented in the following table:

Cut-Off Warning	The MobilEye Cut-Off Warning alerts the driver when a third vehicle enters between his vehicle and the vehicle in front
Headway Warning	The MobilEye Headway Monitoring and Warning monitors the driving distance to the vehicle in front (headway) and alerts the driver when the headway is less than a pre-defined threshold
Night and Dusk Indicator	The MobilEye Night and Dusk Indicator operate when the MobilEye camera collects a light level less than a pre-defined threshold. It usually occurs towards sunset time
Lane Departure Warning	The MobilEye provides a Lane Departure Warning (LDW) to alert drivers when they are about to swerve unintentionally outside of the lane they are driving in. It does not record intended lane changes, where the driver uses his indicator.
Forward Collision Warning	The Forward Collision Warning (FCW) alerts the driver to the danger of an impending collision with the vehicle in front. The MobilEye calculates the expected Time to Collision (TTC) with the vehicle in front and, when the TTC drops to a dangerous threshold, it immediately generates an FCW alert.

Table 26: types of event-based measurements

3.3.2 Data handling

All data were received from the measurement systems as database format that were converted into Excel formats (it could be converted to any database software not only Excel). They were joined together to a single database that was used in the analysis presented in the next section. The conversion to the Excel format was done by the company responsible for the TrackTec equipment.

The Can-Bus data were received from one vehicle during one month (see Can-Bus section), and the fuel consumption data were received for four vehicles during four months (see the Exposure Measures section).

3.3.3 Data Analysis

Each observation (row) in the data, included information on:

Context variables	Collection methods
Date and time	TrackTec records date and time
Device number	vehicle record (+ questionnaire)
Event name and value (Time-based/Event-based	TrackTec and MobilEye
Speed	TrackTec and MobilEye (GPS)
Acceleration in two directions (lateral and longitudinal)	TrackTec
Road Type	GPS coordinates (longitude/latitude) + map matching

Table 27: Description and details of context variables

First, the GPS coordinates were uploaded to the GIS Israeli network using the TransCAD software. Using the GIS network information, each measurement was associated with a road type (6 road types were defined). Moreover, it was possible to identify the route of each trip.

The data were analysed using Excel pivot tables and graphs. The distributions of each variable were constructed using categories. In some cases joint distributions for two variables were also calculated.

Besides the time-based/event-based data, the Can-bus data and the fuel consumption data were analysed using simple pivot tables.

3.3.4 Institutions Involved

A number of organisations were involved in the Israeli trial:

- Technion – project managers
- Or Yarok – vehicle fleet, assistance with experiment management
- ITS Israel – assistance in experiment coordination and management
- Track Tec, MobilEye - System providers

3.4 Results

3.4.1 General

The results presented in this section are based on 283.490 measurements, Time-Based and Event-Based that were collected during six months from the seven vehicles. There were 3.459 trips that took place during this period of.

A trip is defined after a stop (engine switch off) of at least 15 minutes. A trip definition is determined by the researcher and can be changed.

According to Table 28, 64% of the trips were made by males and 36% by females, although only three out of seven drivers were males.

Gender	Number of trips	Per cent
Male	2210	64%
Female	1249	36%
Total	**3.459**	**100%**

Table 28: trips by gender

Table 29 indicates that about half of the trips are made during peak morning hours (6-8) and peak afternoon hours (15-19).

Time of day (Hour)	Number of trips	Per cent
0-1	37	1%
1-2	10	0%
2-3	23	1%
3-4	3	0%
4-5	2	0%
5-6	16	0%
6-7	258	7%
7-8	255	7%
8-9	146	4%
9-10	124	4%
10-11	159	5%
11-12	183	5%
12-12	198	6%
13-14	161	5%
14-15	212	6%
15-16	182	5%
16-17	239	7%
17-18	300	9%
18-19	266	8%
19-20	227	7%
20-21	167	5%
21-22	119	3%
22-23	119	3%
23-24	53	2%
Total	**3.459**	**100%**

Table 29: trips by time of day (hour)

Table 30 presents the number of trips by day of the week. 26% of the trips were made during the weekend (Friday and Saturday), most likely for leisure and various non-work purposes.

Day	Number of trips	Per cent
Sunday	526	15%
Monday	490	14%
Tuesday	506	15%
Wednesday	487	14%
Thursday	561	16%
Friday	521	15%
Saturday	368	11%
Total	**3.459**	**100%**

Table 30: trips by day of the week

Note: The weekend in Israel is Friday and Saturday

Table 31 and Table 32 present the trip durations and travel distances. About half of the trips are characterized as short trips - 51% of the trips took less than 20 minutes to drive, for a distance of less than five kilometres. Only 13% of the trips took more than 50 minutes to drive. The average distance of all trips is 11,8 km with a standard deviation of 20,3. The average travel time is 26,3 minutes and standard deviation of 27,5.

Trip duration	Number of trips	Per cent
Less than 5 min	685	20%
Between 5-10 min	412	12%
Between 10-20 min	672	19%
Between 20-30 min	573	17%
Between 30-50 min	653	19%
More than 50 min	464	13%
Total	**3.459**	**100%**

Table 31: trip duration

Trip length	Number of trips	Per cent
Less than 5 km	1671	48%
Between 5-10 km	517	15%
Between 10-20 km	733	21%
Between 20-30 km	227	7%
Between 30-50 km	114	3%
More than 50 km	197	6%
Total	**3.459**	**100%**

Table 32: trip distance

A number of analyses can be carried out as a combination of the different variables (number of trips, gender, time of day, day of the week, trip distance and trip duration).

Table 33 presents, as an illustration, the number of trips by gender and trip distance. The results indicate that males are more likely to carry out short trips than females: 66% of the male trips are less than 10 km, compared to 59% of female trips.

	Number of trips		Per cent	
Trip length	**Male**	**Female**	**Male**	**Female**
Less than 5 km	1226	445	55%	36%
Between 5-10 km	233	284	11%	23%
Between 10-20 km	368	365	17%	29%
Between 20-30 km	180	47	8%	4%
Between 30-50 km	85	29	4%	2%
More than 50 km	118	79	5%	6%
Total	**2.210**	**1.249**	**100%**	**100%**

Table 33: trips by distance and gender

3.4.2 Time-Based and Event-Based Analyses

According to Table 34, 64% of the measurements were Time-Based and 36% were Event-Based measurements. As mentioned above Time-based measurements were collected every 30 seconds, while Event-base measurements were collected whenever a pre-defined event occurred.

Time-Based measurements		180499	64%
Event-Base measurements	Cut off Warning	46503	16%
	Headway warning	16491	6%
	Night and Dusk Indication	15234	5%
	Lane Departure Warning	14324	5%
	Forward Collision Warning	8303	3%
	Light warning	2136	1%
Total		**283.490**	**100%**

Table 34: measurement distribution

An explanation of the meaning of each type of event is given in the appropriate section, following later in the report.

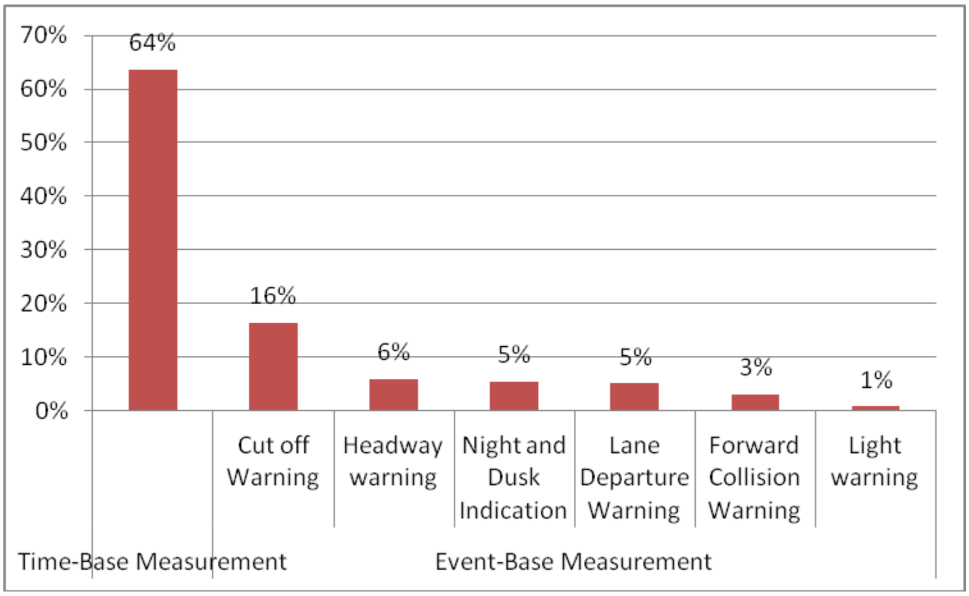

Figure 21: measurement distribution

3.4.3 Analysis of Time-Based Data

Time of Day Distribution

According to Table 35 20% of the trips the participants undertook was during the peak morning period (from 7 to 9), and 27% was during the peak afternoon period (from 15 to 19). The hourly distribution presented in Figure 22 matches the well-known morning and afternoon peaks reported in the literature.

Hour	**Per cent**	**Time category**	**Per cent**
0	0,9%	0-4 Night	2%
1	0,4%		
2	0,4%		
3	0,2%		
4	0,1%	4-7 Early Morning	5%
5	0,3%		
6	4,2%		
7	12,9%	7-9 Peak Morning	20%
8	7,2%		
9	3,7%	9-15 Day	29%
10	4,1%		
11	5,2%		
12	5,3%		
13	4,5%		
14	5,9%		
15	5,6%	15-19 Peak Afternoon	27%
16	6,1%		
17	8,1%		
18	7,1%		
19	5,5%	19-0 Early Night	17%
20	4,5%		
21	2,7%		
22	3,0%		
23	1,8%		
Total	**100%**		

Table 35: time of day distribution

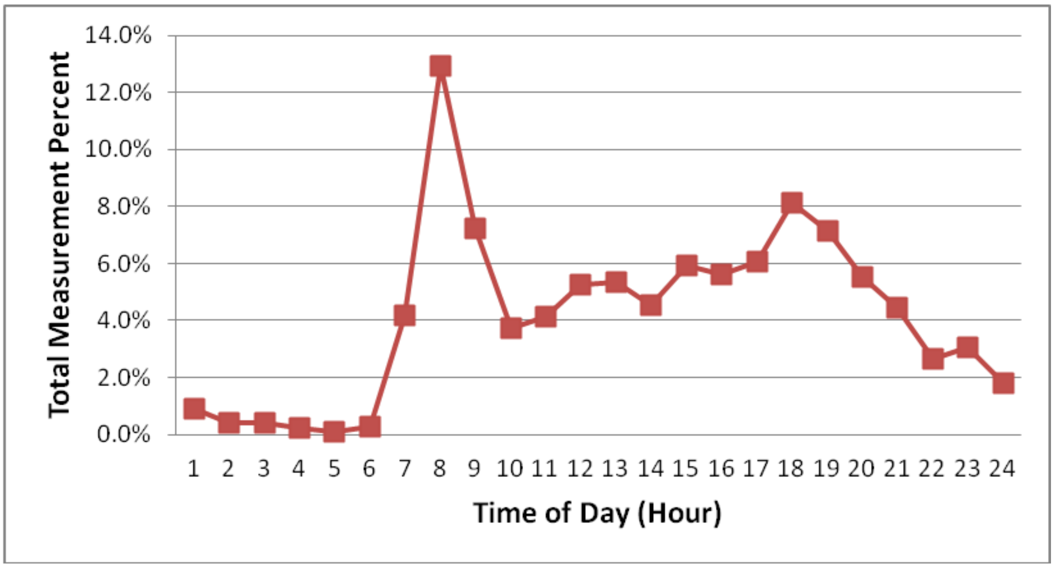

Figure 22: time of day distribution of travel

Road Type Distribution

The GPS coordinate measurements (longitude/latitude) were uploaded to the GIS road network using the TransCAD software. The geographic analyses presented here are based to a large extent on a classification of the road segments as urban or non-urban and into six functional categories. This classification is built into the definition of the GIS network. The functional categories are defined as follows:

Class 1: Urban collector segments that provide moderate speeds and volumes. The roads commonly connect between arterial segments and collect traffic from local roads.

Class 2: Urban arterial segments that support large traffic volumes at high speeds.

Class 3: Regional segments commonly connect between main cities and suburbs.

Class 4 and 5: two classes of Interurban (i.e. non-urban) segments that connect between cities (designated officially by a numbering system of two and three digits respectively)

Class 6 : Highway segments that provide largely uninterrupted travel between and through metropolitan areas. They are designed for high speeds and support large traffic volumes (these are mostly one digit roads). Highways are defined in this study as what is commonly defined as motorways, freeways or autobahn and such roads, characterised by divided highways, no slow moving traffic and no at-grade junctions.

It should be noted that this classification is the one used in the Israeli GIS maps. Different road classes and definitions may be used in other countries.

The results of the distribution of trips by road types are presented in Table 36. About half (51%) of the trips took place on urban roads, and half (49%) on interurban roads.

With the help of TransCAD, each trip sample can be uploaded on a geographical map and its geographic path is demonstrated (see Figure 23).

It can be seen that the geographic presentation of the samples are not located exactly on the driving route due to the accuracy of the GPS coordinates. This can be fixed with the help of a computer code that is currently being developed.

	Road type	Frequency of measurements by road type	
Urban	Collector	17%	51%
	Arterial	34%	
Interurban	Regional	13%	49%
	Interurban1	2%	
	Interurban2	11%	
	Highway	23%	

Table 36: road type distribution

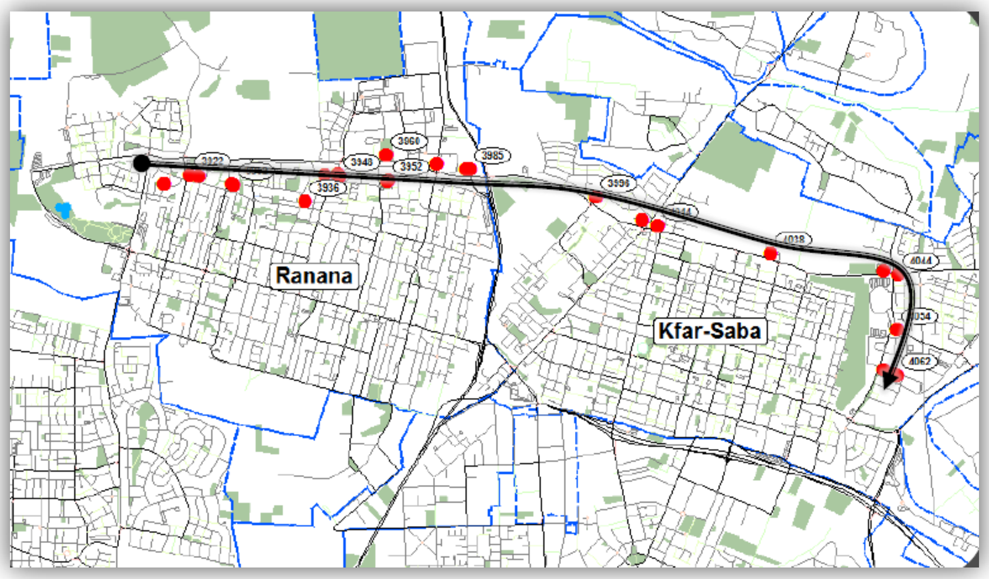

Figure 23: trip path demonstration

Speed Distribution

The speed distribution presented in Table 37 indicates that 63% of the measurements are in the speed categories under 50 km/h. Table 38 shows that the majority of those measurements are sampled within urban areas.

The link between speed and road type measurements is related to safety as it reflects the unsafe situations of high speeds on urban roads, especially those over 90 km/h on collector and arterial road types. Urban speed limits are generally 50 km/h and on certain sections 70km/h or 80 km/h at the most.

As presented in Table 38 and Figure 24, about 8% of the speed measurements over 90 km/h are recorded within urban areas (for example, the 90-100 km/h category: 8% of this category was sampled within urban areas).

Speed category (km/h)	Number of measurements	Per cent
0-10	40944	14%
10-20	55821	20%
20-30	43653	15%
30-40	24313	9%
40-50	14430	5%
50-60	11638	4%
60-70	12652	4%
70-80	16642	6%
80-90	22230	8%
90-100	20882	7%
100-110	15183	5%
110-120	4825	2%
Over 120	275	0%
Total	**283.490**	**100%**

Table 37: speed distribution

Speed (km/h)/ Road type	Collector	Arterial	Regional	Inter-urban 1	Inter-urban 2	High-way	Total
0-10	47%	34%	9%	2%	4%	3%	100%
10-20	31%	45%	12%	1%	5%	6%	100%
20-30	16%	54%	14%	2%	8%	6%	100%
30-40	10%	48%	18%	3%	12%	8%	100%
40-50	6%	43%	21%	3%	16%	11%	100%
50-60	3%	39%	19%	3%	19%	17%	100%
60-70	2%	29%	16%	3%	19%	31%	100%
70-80	1%	19%	14%	3%	19%	43%	100%
80-90	1%	11%	13%	2%	18%	56%	100%
90-100	1%	7%	9%	1%	16%	65%	100%
100-110	5%	4%	4%	2%	11%	75%	100%
110-120	6%	3%	3%	4%	7%	77%	100%
120-130	3%	5%	3%	5%	9%	75%	100%
130-140	0%	0%	17%	0%	0%	83%	100%

Table 38: speed distribution vs. road type

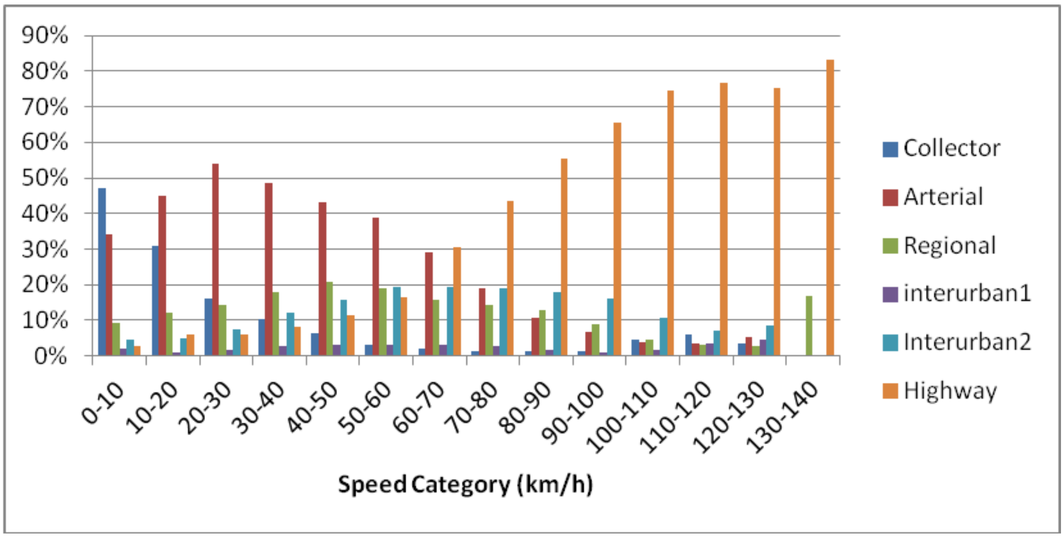

Figure 24: speed distribution vs. road type

Headway Distribution

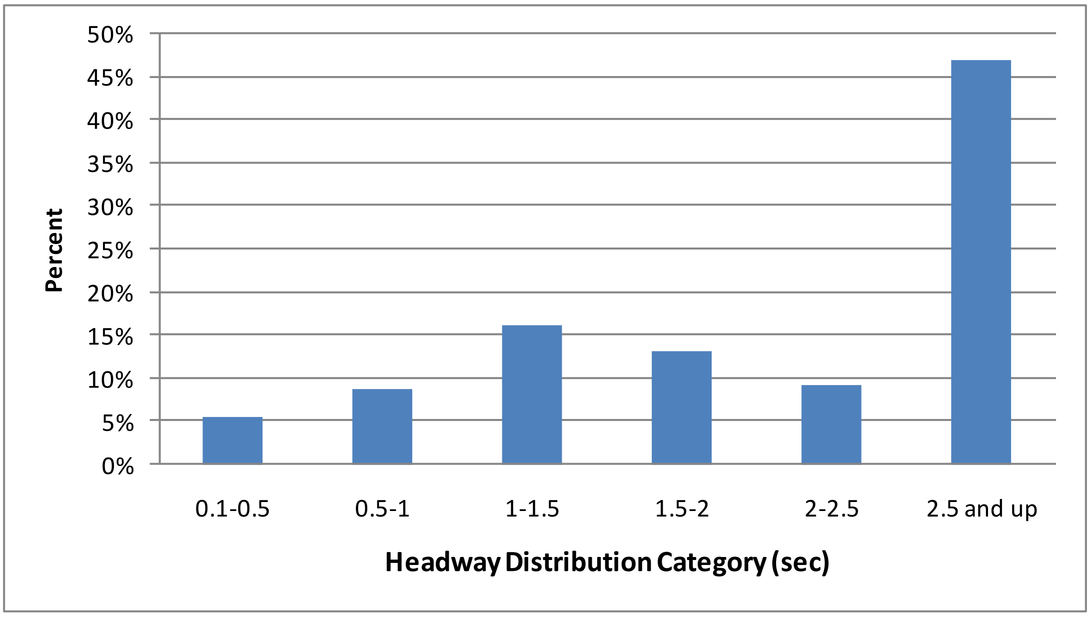

Figure 25: headway distribution

The headway distribution is related to safety as it reflects the following distance that drivers maintain to the vehicle in front.

The headway distribution presented in Table 39 and Figure 25 shows that about half of the headway measurements are above 2,5 seconds. On the other hand 14% of the measurements are shorter than one second, which indicates very close distances between vehicles.

Table 39 shows the headway distribution vs. Speed (km/h). 43% of headway category between 0.5-1 occur at high speeds (over 50 km/h).

The link between headway and speed measurements is related to safety as it reflects the unsafe situations of high speeds and low headway values. For example, a headway of less than 0.5 seconds with speed of over 90 km/h.

The relationships between headways, speeds and safety have, so far, not been studied much in the literature. This is mostly the result of the fact that no such data are available for the general driving public or for a large enough sample of drivers. The capabilities of the naturalistic driving described in this project open up a whole new field of research which has great significance for safety improvements.

Headway value (s)	**Per cent**
0.1-0.5	6%
0.5-1	9%
1-1.5	16%
1.5-2	13%
2-2.5	9%
2.5 and up	47%
Total	**100%**

Table 39: headway distribution

Headway value (s)	**Speed in km/h**			
	0-50	**50-90**	**>90**	**Total**
0.1-0.5	85%	10%	5%	100%
0.5-1	58%	23%	20%	100%
1-1.5	69%	20%	11%	100%
1.5-2	67%	22%	12%	100%
2-2.5	60%	25%	15%	100%
2.5 and up	61%	23%	16%	100%
Mean	**64%**	**22%**	**14%**	**100%**

Table 40: headway distribution vs. speed

Acceleration Distribution

The acceleration distribution presented in Table 41 and Figure 26, shows that 44% of the measurements are within -0.1 **g** and +0.1 **g**. While 17% of the measurements are within the category of 0.25 to 0.5, only 1% is within the category of -0.25 to -0.5.

Figure 26 presents the acceleration distribution by road type. 75% of the measurements in 0-0.1 category are within urban areas.

The deceleration measurements are related to safety as it reflects the unsafe situations of high negative deceleration especially on interurban roads were it is associated with high speed, although they are considered as rare events (only 1% of total measurements). Again, this area has, so far, not been well researched because of the lack of relevant data and equipment. This is another new area of research which can now be explored.

Category (g)	Number of measurements	Per cent
more than 0.5	638	1%
0.25 _ 0.5	18231	17%
0.1 _ 0.25	25874	24%
0 _ 0.1	29509	27%
-0.1 _ 0	18362	17%
-0.25 _ -0.1	14817	14%
-0.25 _ -0.5	1579	1%
Upton -0.5	523	0%
Total	**109.533**	**100%**

Table 41: acceleration distribution

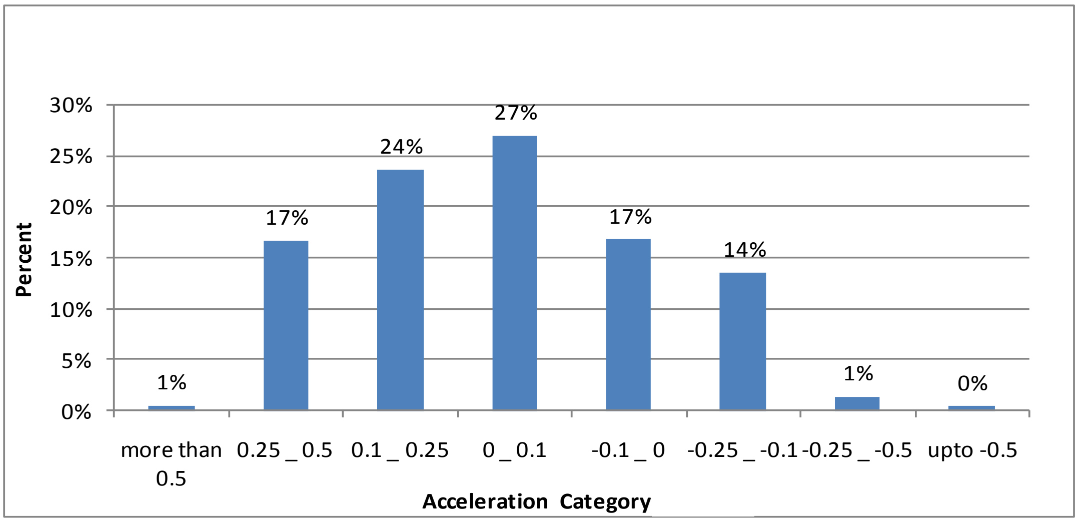

Figure 26: acceleration distribution

Acc. (g)	Urban	Interurban	Total
more than 0.5	65%	35%	100%
0.25 _ 0.5	49%	51%	100%
0.1 _ 0.25	53%	47%	100%
0 _ 0.1	75%	25%	100%
-0.1 _ 0	63%	37%	100%
-0.25 _ -0.1	48%	52%	100%
-0.25 _ -0.5	46%	54%	100%
up to -0.5	69%	31%	100%
Mean	51%	49%	100%

Table 42: acceleration distribution by road type

3.4.4 Analysis of Events

Cut-Off Warning Distribution

Definition: The MobilEye Cut-Off Warning alerts the driver when a third vehicle enters between his vehicle and the vehicle in front. This occurs when a pre-defined drop-off in the headway value take place.

The cut off warning distribution by road type is presented in Table 43. The distribution of cut-off warning events across road types is similar to the distribution of travel time on these roads. However, they are less frequent on collector roads. Table 44 shows the distribution of the speeds at which the cut-off events occur. It shows that they occur more at high speeds (over 50 km/h) than at low speeds (over 50 km/h).

The link between cut-off warning and speed measurements is related to safety as it reflects the unsafe situations of cut-offs occur on high speeds, especially on urban roads. A comparison across countries would be interesting as this type of behaviour is expected to be associated with driving styles.

Road type	Count	Per cent	Frequency of measurements by road type
Collector	5403	12%	17%
Arterial	15367	33%	34%
Regional	6656	14%	13%
Interurban1	717	2%	2%
Interurban2	5876	13%	11%
Highway	12476	27%	23%
Total	**46.503**	**100%**	**100%**

Table 43: cut-off warning distribution by road type

Speed category	Count	Per cent	Frequency of measurements by speed
up to 50 km/h	25780	55%	63%
50-90 km/h	12154	26%	22%
more than 90 km/h	8569	18%	15%
Total	**46.503**	**100%**	**100%**

Table 44: cut-off warning distribution by speed

Headway Warning Distribution

Definition: The MobilEye Headway Monitoring and Warning monitors the driving distance to the vehicle in front (headway) and alerts the driver when the headway is less than a pre-defined threshold. This can either be caused by braking by the vehicle in front, or by a higher speed of 'our' vehicle with respect to the vehicle in front.

The headway warning distribution by road type is presented in Table 45. The headway warning measurements occur less on urban roads, especially on collectors, and more on interurban roads, especially on highways. This may be related to the sensitivity calibration of the device Moreover, Table 46 shows clearly that headway warnings occur more at high speeds (over 50 km/h) compared to the average speed distribution.

The link between headway warning and speed measurements is related to safety as it reflect the unsafe situations of short headways occurring at high speeds, especially on interurban roads.

Road type	Count	Per cent	Frequency of measurements by road type
Collector	915	6%	17%
Arterial	4731	29%	34%
Regional	2284	14%	13%
Interurban1	181	1%	2%
Interurban2	2229	14%	11%
Highway	6145	37%	23%
Total	**16.491**	**100%**	**100%**

Table 45: headway warning distribution by road type

Speed category	Count	Per cent	Frequency of measurements by speed
up to 50	7213	44%	63%
50-90	5554	34%	22%
more than 90	3724	23%	15%
Total	**16.491**	**100%**	**100%**

Table 46: headway warning distribution by speed

Forward Collision Warning Distribution

Definition: The Forward Collision Warning alerts the driver to the danger of an impending collision with the vehicle in front. The MobilEye calculates the expected Time to Collision (TTC) with the vehicle in front and, when the TTC drops to a dangerous threshold, it immediately generates an FCW alert.

The forward collision warning distribution by road type is presented in Table 47. The forward collision warning events occur more on urban roads, and less on interurban roads.

Road type	Count	Per cent	Frequency of measurements by road type
Collector	2491	30%	17%
Arterial	3465	42%	34%
Regional	1335	16%	13%
Interurban1	81	1%	2%
Interurban2	405	5%	11%
Highway	523	6%	23%
Total	**8.303**	**100%**	**100%**

Table 47: forward collision warning distribution by road type

Table 48 shows clearly that forward collision warning events occur much more at low speeds (less than 50 km/h) compared to the average speed distribution.

Speed category	Count	Per cent	Frequency of measurements by speed
up to 50	7696	93%	63%
50-90	465	6%	22%
more than 90	142	2%	15%
Total	**8303**	**100%**	**100%**

Table 48: forward collision warning distribution by speed

Major differences can be observed between the headway warning distribution and the forward collision warning distribution. Whereas headway warnings occur mainly on interurban roads (66% of warnings, including the regional roads) and at higher speeds, the forward collision warnings occur more on urban roads and at lower speeds (93% at speeds up to 50 km/h). This is partly due to the algorithms defined by the manufacturer, which clearly disagree with urban driving practice, and partly due to the fact that in interurban conditions in dense traffic, it is very usual to drive at close following distances, not in agreement with safe following distances.

Night and Dusk Indicator Distribution

Definition: The MobilEye Night and Dusk Indicator operate when the MobilEye camera collects a light level less than a pre-defined threshold (by Traffilog – MobilEye provider). It usually occurs towards sunset time.

The night and dusk indicator distribution by road type is presented in Table 49. The night and dusk indications occur more on urban roads, especially on collectors, and less on interurban roads. Moreover, Table 50 shows clearly that night and dusk indicator measures occur more at low speeds (less than 50 km/h) and urban roads compared to the average speed and road type distribution. These results are related to the participant activity patterns during the evenings.

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Road type	Count	Per cent	Frequency of measurements by road type
Collector	5575	37%	17%
Arterial	5059	33%	34%
Regional	1370	9%	13%
Interurban1	350	2%	2%
Interurban2	898	6%	11%
Highway	1956	13%	23%
Total	**15.234**	**100%**	**100%**

Table 49: night and dusk indicator distribution by road type

Speed category	Count	Per cent	Frequency of measurements by speed
up to 50	11380	75%	63%
50-90	2266	15%	22%
more than 90	1588	10%	15%
Total	**15.234**	**100%**	

Table 50: night and dusk indicator distribution by speed

Lane Departure Warning Distribution

Definition: The MobilEye provides a Lane Departure Warning (LDW) to alert drivers when they are about to swerve unintentionally outside of the lane they are driving in. The LDW module uses the information from the lane detection module, on the basis of a Time to Lane Crossing (TLC) calculation, to provide a warning to the driver in case of unintentional lane departure. The warning mechanism can be tuned for sensitivity – for example, the system can be set to warn only when the vehicle is actually crossing the lane marking, or give an early warning, before lane markings are crossed. The warning can be adapted to the type of road – for example, it could provide the driver with more slack in case of narrow roads or allow the driver to “cut” curves.

The lane departure warning distribution by road type is presented in Table 51. The lane departure warning measurements occur more on urban roads, especially on collectors, and less on interurban roads, especially on highways. Moreover, Table 52 shows clearly that lane departure warning measurements occur more at low speeds (less than 50 km/h) compared to the average speed distribution.

The lane departure warnings seem to appear more on urban roads as there are more lane changes and movement between lanes in the city. A significant amount of accidents occur due to lane changes, both intentionally and unintentionally. Research on the relations between accidents and lane changing behaviour are an interesting and promising field of research. It is partly linked to what is currently described as inattention and its relation to safety.

Road type	Count	Per cent	Frequency of measurements by road type
Collector	3381	24%	17%
Arterial	5318	37%	34%
Regional	1760	12%	13%
Interurban1	394	3%	2%
Interurban2	1502	10%	11%
Highway	1959	14%	23%
Total	**14.324**	**100%**	**100%**

Table 51: lane departure warning distribution by road type

Speed category	Count	Per cent	Frequency of measurements by speed
up to 50	9672	68%	63%
50-90	3219	22%	22%
more than 90	1433	10%	15%
Total	**14.324**	**100%**	**100%**

Table 52: lane departure warning distribution by speed

Fuel consumption

The fuel consumption measurements presented in this section were collected from four devices (Vehicles 1, 2, 3, and 4). The results are presented in Table 53. According to the table, the average monthly distance driven per vehicle is 2.627 km. The average amount of fuel consumption is 251 litres per month. This average is 10,5 km/litre. It is interesting that there is a significant difference of vehicle kilometres and thus in fuel consumptions among vehicles and within different months of the same vehicle.

Vehicle nr.	Date	Distance driven	Fuel consumption (litre)	km/litre
Ford 1	May - 2011	3104	308,5	10,1
	June - 2011	3333	345,7	9,6
	July - 2011	3089	297,6	10,4
	August - 2011	3191	294,0	10,9
Hyundai	May - 2011	2139	203,1	10,5
	June - 2011	1520	154,6	9,8
	July - 2011	1609	162,5	9,9
	August - 2011	1540	146,5	10,5
Ford 2	May - 2011	2385	250,2	9,5
	June - 2011	3019	277,0	10,9
	July - 2011	3323	285,6	11,6
	August - 2011	1451	131,6	11,0
Citroen	May - 2011	2994	323,7	9,3
	June - 2011	3550	317,3	11,2
	July - 2011	2735	248,3	11,0
	August - 2011	3044	273,3	11,1
Mean		**2.627**	**251,0**	**10,5**
Min.		**1.451**	**131,6**	**9,3**
Max.		**3.550**	**345,7**	**11,6**

Table 53: exposure measure results

Can-Bus Data

The Can-Bus data were collected from one vehicle during September 2011. The Can-Bus data produces different types of information, for example accumulated mileage, speed, location, door open/close, engine switch, lights on/off and more. In this section we also introduce data analyses regarding the use of the car phone speaker.

It might be of interest to use the switch on/off facility to record trips and compare it with the trip definition used in our study. However this is not possible as we used as our trip definition each time the engine was switched off for 15 minutes.

From the engine switch indicator it is possible to obtain information about the number of trips.

The Can-Bus data regarding telephone calls is able to indicate about the time and length of telephone calls.

The data regarding lights (on/off) indicate that the lights were switched on each time the engine of the vehicle was switched on. In this particular vehicle, due to mechanical technical changes made by the driver, the lights turn on each time the switch is on, with no dependence on time of the day and season of the year. This is a common setup in Israeli vehicles, as the Israeli law requires daytime running lights usage in inter-urban roads in the winter months. The driver choose not to have to deal with the DRL issue according to months and type of road and choose for this, not uncommon, solution.

The data from the can-bus does not include seatbelt use information. That depends on the vehicle type and year. It would have been possible to collect this information in this specific vehicle if a special external code were connected to the Can-Bus system.

In general, Can-Bus data is difficult to obtain as it differs from one vehicle type to another.

Call duration	Number of calls	Per cent
up to 1 minute	48	34%
from 1-2 minutes	40	28%
from2-3 minutes	12	8%
from 3-4 minutes	4	3%
from4-5 minutes	6	4%
more than 5 minutes	33	23%
Total	**143**	**100%**

Table 54: calls duration

3.5 Lessons learned

The study has demonstrated the feasibility of using the equipment selected and the appropriateness of choice. These were relatively cheap, off-the-shelf devices that were installed in the vehicle without too many difficulties and at reasonable cost. It was also demonstrated that the equipment can be integrated and adapted to the purposes intended. The methodology demonstrated, for the first time to our knowledge, the use of such equipment on a continuous basis, in addition to the recording of events. The added value of introducing GIS capabilities, linked to the GPS capabilities of the equipment has been demonstrated. It enables the determination of the type of roads that drivers used, length of trip on each type even to the extent of obtaining detailed route plots. One problem encountered was the accuracy of the GPS, requiring the development of a map-matching tool associating the trips to the correct roads.

A major technical problem was related to the measurement of small headways, which were found to be noise measurements. This fact created a significant number of events such as cutting-off, lane departure, close following and imminent collision warning, as they are all calculated when a small headway is measured.
The formats in which the companies sent their data were not defined in advance. This caused a delay in analysing the data, which had to be put into a format suitable for analyses. The lesson is that in future, as part of any experiment, data formats should be specified in advance.

It can be said that the total period of installation took much longer than it was planned. This was due to people not arriving for installation when required and turn-over of qualified technicians. Initially the experiment was supposed to start in January 2011, with two months for installation. In practice, the installation took twice as long, with all kinds of problems and the data flow started in March 2011. The experiment ran for six months, collecting more data than planned.

3.6 Summary of the Israeli trial

This study has demonstrated the potential of a small-scale naturalistic driving study, using relatively cheap off-the-shelf measurement equipment. The study was planned as a small scale study in order to demonstrate the potential and capabilities and possible associated problems. It was not intended to be a large-scale, representative data collection effort.

The study demonstrated the capability and usefulness of collecting very detailed data on exposure, travel speed and associated characteristics. A very detailed continuous travel log was provided for the seven vehicles involved. Data on type of road, length of trip, travel speed and various characteristics were collected continuously at 30 second intervals and any time when a specific, pre-defined, event occurred.

For the seven vehicles involved, over a period of six months, a total of 3.459 trips were monitored and some 283.490 data points were measured. Details of the trip logs of the vehicles were analysed and are described in the report. The data were analysed by type of road, driver gender, time of day, day of week, trip length and various cross-tabulations. In total, more than 180,000 Time-based events were recorded.

In addition, a detailed record of more than 100,000 events that occurred during these trips is provided and the report details the various distributions of the variables. These included cut-off warnings, headway warnings, night and dusk indications, lane departure warnings, forward collision warnings and light on/off warnings. The definitions of these variables are given in the report.

The report also includes some indications as to the difficulties encountered in installing the equipment, causing it to be linked together and various other difficulties associated with continuous monitoring over a six months period. All these problems were solved and demonstrated that it is possible to install and operate off-the shelf equipment over a prolonged period.

The variables recorded, as pre-defined by the other parts of WP6, included exposure related variables, speed related variables and other safety related variables. The study demonstrated that it is possible to obtain a very detailed account of exposure and safety related behaviours which it was, so far, not possible to collect. Collecting these variables on a representative sample of drivers in all EU countries by means of these naturalistic studies would add a very valuable aspect to the ERSO data base and would enable many cross-country behaviour studies, eventually linking them to accident occurrence and safety. Many of the behaviours, including detailed, over-time, speed behaviour, headways, abrupt acceleration, lane-change behaviours and others were so far not economically feasible with other methods for the use in safety related research. It would be of great interest to link such observed behaviours to related data collected through driver surveys by means of the SARTRE project.

4 COMPARISON OF THE USED APPROACHES

The two field trials were based on two different Scenarios and used different technologies. The overall idea of this chapter is to illustrate the scope, the possibilities and the consequences linked to each approach. Therefore, the two field trials are compared.

Comparisons between the trials on result level are not meaningful due to the very small samples and missing representativeness. That is also not the aim of this task. It is rather important to show what is feasible, what the limits are and the differences in the results when using different approaches. The trials have also demonstrated that very interesting and meaningful data can be collected reliably with many implications for safety policy and research. Regarding this, it has to be reconsidered how the data was collected.

In the Austrian field trial a **trip** was defined as the episode from starting the engine to switching it off. The Israeli trial used another definition; there a trip was defined after an engine switch-off of at least 15 minutes.

Another difference is the **sampling**. In Israel, data on vehicle dynamics were recorded every 30 seconds. Furthermore, **event-based measurements** were collected based on cut-off warnings, headway warnings and other indicators. This procedure is described as Scenario 2 in Deliverable 6.1. In comparison, the Austrian trial was based on Scenario 1, where no predefined event-based measures were recorded. In Austria, all trips were recorded on a 10Hz sampling rate. By choosing this procedure, events (high acceleration measures, alternative definition of free choice of speed) could be filtered in the post processing.

Differences regarding the data acquisition may have an influence on the results. For this reason, possible effects are shown in the following:

Risk exposure data

Different sampling rates and different trip definitions do not have any impact on overall driven kilometres. There may be a slight increase of driven time, if the breaks during trips are added to the trip duration. But it can be assumed that those changes are negligible.

Obviously, different trip definitions lead to different number of trips and as a consequence, different durations and lengths of single trips.

If conclusions are based on average trips, the trip definition might be important. For illustrating this, Table 55 shows the time gaps between the single trips in the Austrian trial. If time gaps (between switching off and on the engine) of less than 15 minutes are not counted as a break, the number of trips decreases by 26,7%. Thus, the redefinition leads to a decreased number of trips of 2.686 and consequently higher averages of length and duration. For example, the average trip length according the Austrian trip definition was about 19 km, according the Israeli trip definition the average trip length would be about 26 km.

Of course, as a consequence, the percentiles of driven time and driven kilometres will change.

Time gap	Per cent	Cumulated
< 1 min	0,8%	0,8%
1-2 min	2,6%	3,4%
2-5 min	10,2%	13,6%
5-10 min	8,4%	22,0%
10-15 min	4,7%	**26,7%**
15-30 min	8,7%	35,4%
30 – 60 min	8,0%	43,4%
1-2 h	9,5%	52,9%
2-5h	13,9%	66,8%
5h+	33,3%	100,0%

Table 55: time gaps between trips in the Austrian trial

In Austria, a travel diary served as an indication about how people define a trip (see Table 12). The deviant results of trips by the DAS and by the travel diaries imply that the understanding of the meaning of a trip is variable.

Thus, for implementing a comparable large scale monitoring study, a clear definition of trip is essential. As described in section 2.7, a post hoc change of trip definition and thus a reorganisation of the database may last weeks. A DAS-hardware dependent trip-definition may limit the possibilities to re-define the definition of trip.

Another issue that concerns exposure data is the target identification. Depending on the level of exposure (either related to a person or to a vehicle), driver identification is needed or not.

If conclusions should be drawn respective to age- or gender-differences, of course the driver has to be identified. But the person-kilometreage leads to another problem, which is the use of maybe more than one vehicle.

Safety performance indicators

The two trials mainly differ in their scenario-definition. In Austria, events showing high acceleration data were filtered by post processing. Assuming that data acquisition is done by scenario 1, the sampling rate might be relevant for gaining meaningful results. For evaluating the data benefit of higher sample rates verses the data loss of lower sample rates, different resolutions were simulated for analysing speed and acceleration data.

Figure 27 and Figure 28 show the frequency of average speed and lateral average acceleration measures per trip by different sampling rates. It can be observed that average data (regarding all trip) do not considerably differ when sampling rates change.

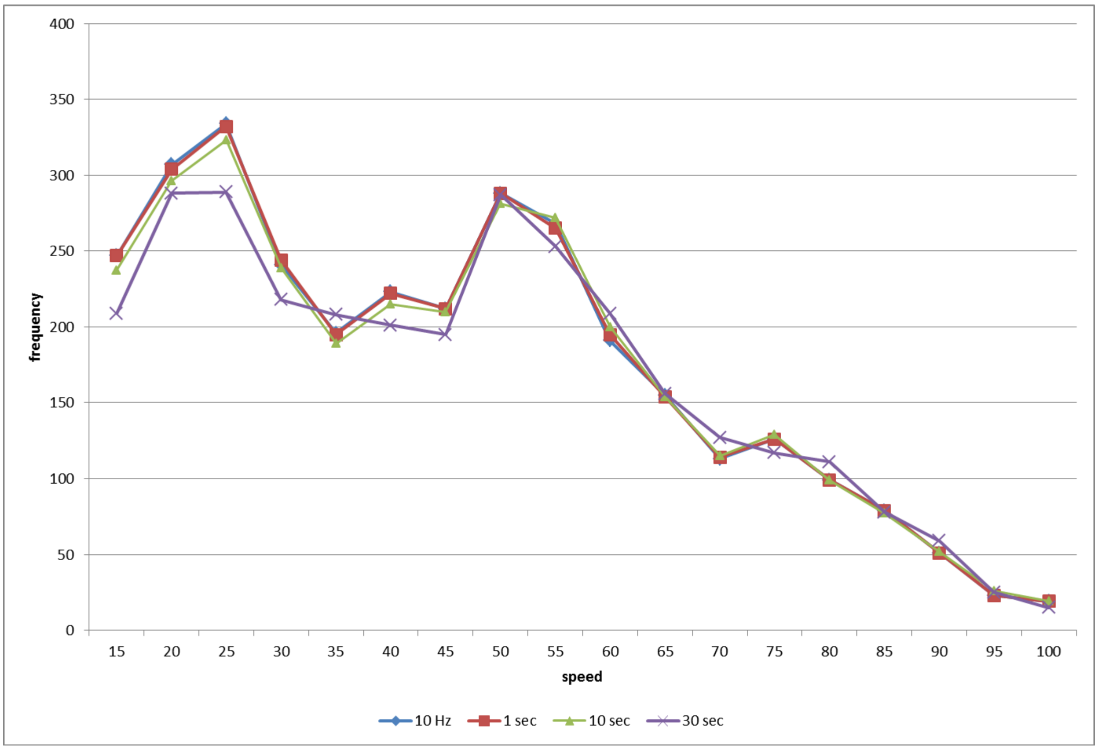

Figure 27: average speed by sampling rate

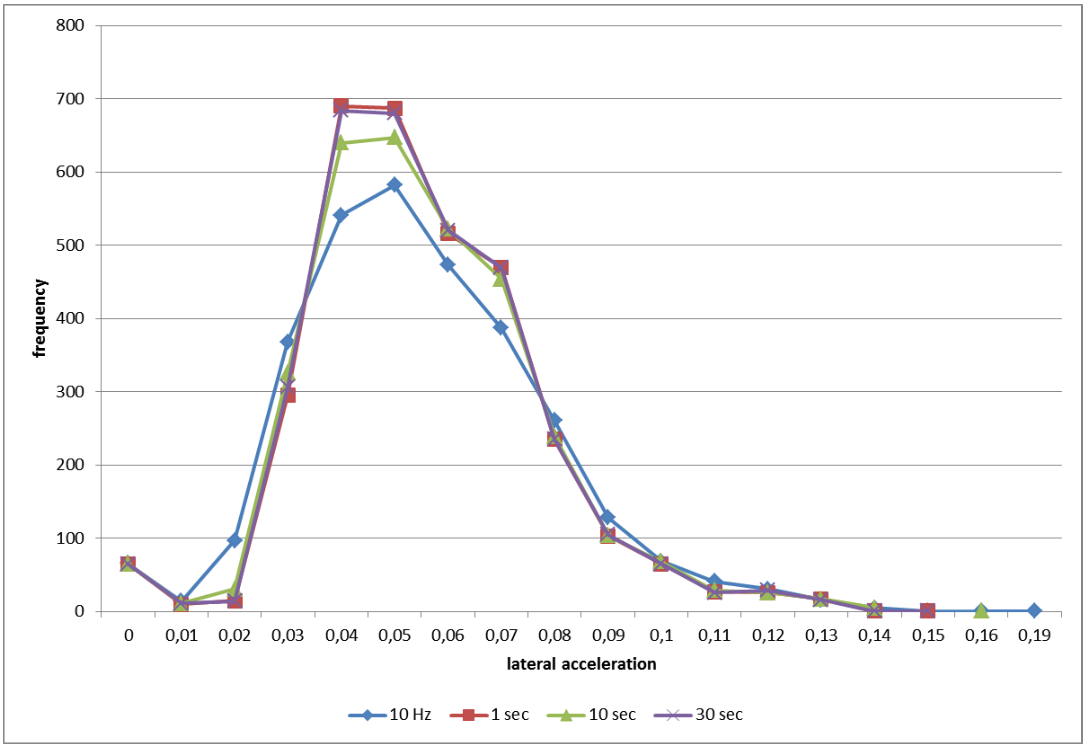

Figure 28: average lateral acceleration by sampling rate

Figure 29 and Figure 30 show the frequency of maximum speed and maximum acceleration measures per trip by different sampling rates. Also regarding maximum speed values, the sampling rate has no effect on speed data, as speed is a variable relatively constant, not varying that much within episodes of 30 seconds.

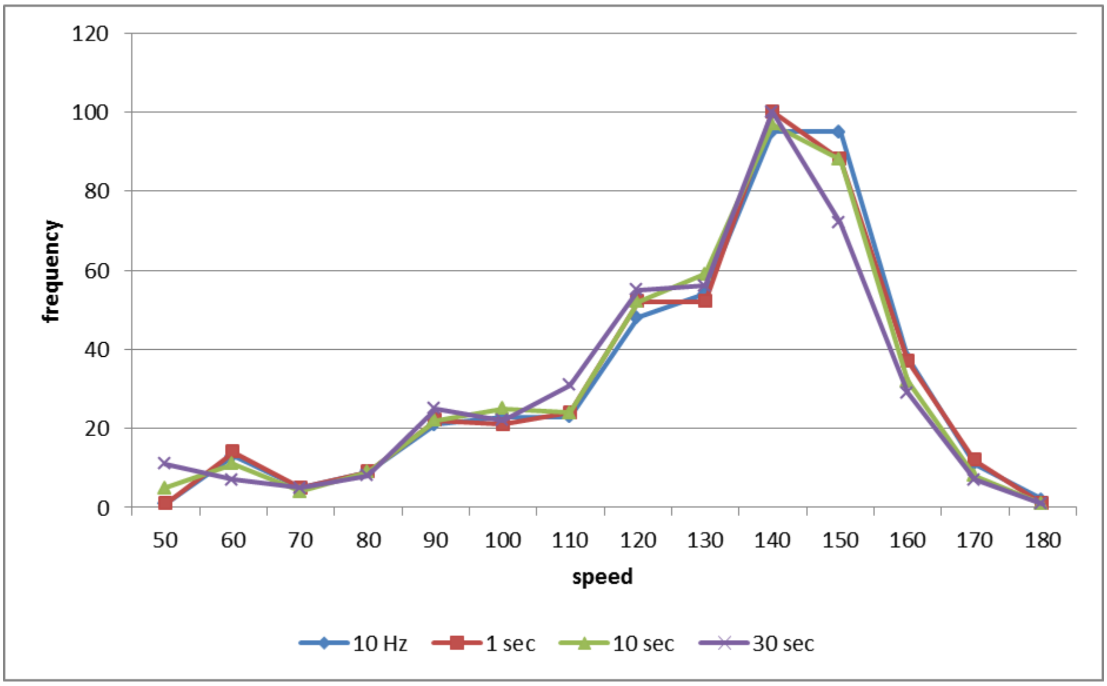

Figure 29: maximum speed by sampling rate

Regarding the maximum values in lateral acceleration, a noticeable difference in the results occurs, depending on sampling rates. This is due to higher fluctuations, especially regarding extreme values, of acceleration within a very short time.

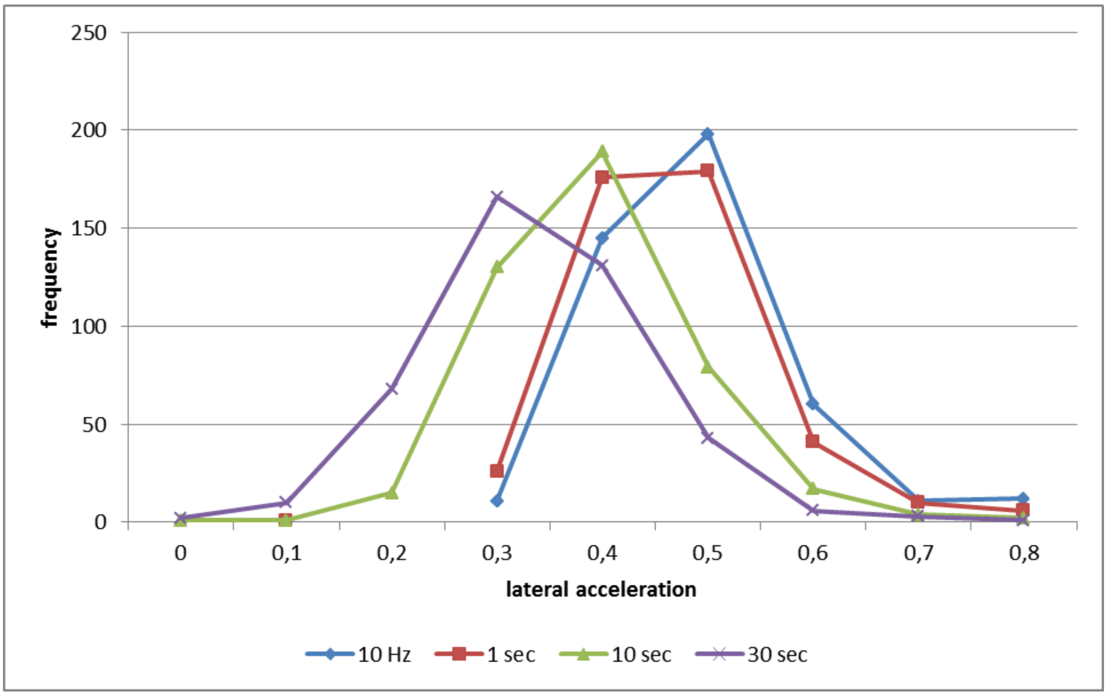

Figure 30: maximum lateral acceleration by sampling rate

To sum up, sampling rate plays an important role when deriving risk indicators based on maximum acceleration values from the entire trip data stream.

Results show that different parameters happen in different time slots. For instance, speed can be observed in a bigger time slot of minutes, whereas near misses are observed within seconds or under.

Depending on parameters of events that have to be monitored, the sampling rate has to be defined consistently for a large scale ND study. Thereby a compromise must be found between huge amounts of data and the gain/loss of events.

When defining speed, in terms of free chosen speed, two approaches are possible. One is a direct operationalisation by observing the headway. This can be done only by implementing Scenario 2. If a ND study is based on Scenario 1, the analysis of speed has to be done in the post processing.

Table 25 illustrated the operationalisation of speed by means of time and Table 22 showed average speed operationalised by constant speed episodes. A comparison of the different approaches is given in Table 56. Obviously, as the average speed rises more measurements are excluded from the analysis. By excluding speed measurements during rush hours, a huge amount of data is excluded (67% - see Table 24). Keeping in mind events of accidents, this fact has to be kept in mind.

		Speed		
		measurements above 5 km/h	above 5 km/h, excluding rush hours	defined as constant episode
Motorway	Mean	90,3	90,9	111,1
	SD	26,9	27,3	24,2
Interurban	Mean	65,4	66,5	82,5
	SD	18,7	19,2	18,4
Urban	Mean	38,9	39,4	58,3
	SD	12,2	12,4	22,3

Table 56: average speed by different operationalisation

The objective of the small scale Naturalistic Driving study was to test and refine the practical and technical feasibility of the method of data gathering.

Collecting these data on a representative sample of drivers in all EU countries by means of Naturalistic Driving would add a very valuable aspect to the ERSO data base and enable many cross-country behaviour studies - eventually linking them to accident occurrence and safety. Data availability is vital for a better understanding of driver behaviour. Some authors have indicated a relationship between realized acceleration and crashes or, at least, safety-related behaviour (e.g. Robertson, Winnet and Herrod (1992), Lajunen, Karola and Summala (1997), Ogle (2005), Wahlberg (2006), Toledo, Musicant and Lotan (2008) and Prato et al. (2010).

Two approaches are typically applied to construct acceleration-based risk parameters:

The first approach is to derive risk indicators from the entire trip data stream by creating simple and characteristic values, such as mean or variance of acceleration data. Here, acceleration values are meant to sufficiently represent a general expression of driver risk. Such an assumption is exemplified by Wahlberg (2006), stating that "...every behaviour that causes a change in speed also carries an infinitesimal risk of accident, which add up to a sum total equalling to the total number of accidents experienced.".

It has been shown, that both approaches, Scenario 1 as applied in Austria as well as Scenario 2 as applied in Israel, fulfil the requirements to draw conclusions based on this approach.

The second approach is to identify specific driving manoeuvres and generate risk parameters only for pre-defined situations (="events"), such as braking, accelerating and cornering. By segmenting a trip into continuous sequences of driving manoeuvres on specific road segments, it is possible to classify each and every manoeuvre carried out during a trip in manifold ways, for example by severity level, relative direction (to the left or to the right) duration or speed. This way, a risk index can be generated as function of frequency and severity level of realized manoeuvres (e.g. Toledo, Musicant and Lotan, 2008).

To reasonably apply this approach, the events have to be substantiated properly. The Austrian field trial tried to illustrate the possibilities of this approach. By doing so, research questions can be answered in a post process, data are flexible for further processing. The Israeli trial showed more options by including several pre-defined measurements that can serve as a basis for further research.

5 DISCUSSION

The deliverable at hand describes the implementation of a ND small scale study in Austria and Israel. The experiences of Task 6.3 serve as input for Task 6.2 that deals with the study design for large scale ND within ERSO.

Thus, two major outcomes were expected. Firstly, the technological equipment for observation, data handling and analysis - described in Milestone 6.2 - was used to collect data. Secondly, data collection provided a data set of naturalistic driving indicators that permitted interesting analysis.

The study demonstrated that it is possible to obtain a very detailed account of exposure and safety related behaviours, which was not possible so far.

The field trials in Austria and Israel focused on parameters on exposure on the one hand, and on SPIs, mainly on speed as an example, on the other hand.

Regarding the term exposure, first of all it has to be defined what to analyse. Depending on the level of exposure (either related to a person or to a vehicle), driver identification is needed or not. If person related variables should be examined, target-identification is essential. This is not the case when examining vehicle related exposure data. Both approaches are feasible by implementing ND studies.

Person related mobility data over all modes are not feasible for ND. Collecting general mobility data can be done by surveys. Another possibility to collect exposure is street-related. This can be done by counting on the spot. For analysing street-related exposure data, a giant sample would be needed.

In summary, realistically, ND is a good alternative for collecting person and vehicle related mileage. It has to be taken into account that ND is able to illustrate only a specific snapshot of person’s mobility. Thus, vehicle-related data are the most accurate. Person-related data are useful when observing behaviour.

Regarding SPIs, the DaCoTA ND small scale study leads to advice on definition and on sampling rates. Sampling rate plays an important role when deriving risk indicators based on maximum acceleration values from the entire trip data stream. Depending on the parameters that have to be monitored, the sampling rate has to be defined consistently for a large scale ND study. Thereby a compromise must be found between huge amounts of data and the gain/loss of events.

When defining speed, different approaches have been compared within this task. One is a direct operationalisation by observing the headway. For observing the headway, a Scenario 2-approach would be necessary. Another approach is the operationalisation by means of time. In this case, a huge amount of data is excluded. Keeping in mind events of accidents, this fact has to be taken into account.

As described in chapter 4, different trip definitions lead to different number of trips and as a consequence, different durations and lengths of single trips. Thus, for implementing a comparable large scale monitoring study, a clear definition of trip is essential.

6 CONCLUSION

In task 6.3 two small scale Naturalistic Driving trials were performed in order to test and refine the practical and technical feasibility of the method of data gathering suitable to reach the objectives of ERSO as were previously defined in task 6.1 and 6.2.

Both small scale trials, although based on different scenarios and using different technical solutions, demonstrated that using low-cost off-the-shelf equipment, the SPI's and RED's as proposed in DaCoTA milestone 6.2 could be generated.

Basic parameters such as average speed, vehicle kilometres, person kilometres and time in traffic were generated in both field trials using slightly different operationalization. In the Austrian field trial for example, speed measures were based on samples where a more or less constant speed was detected for at least ten seconds whereas in the Israeli field trial, all speed measurements were included in the analysis and generation of the SPI's. In the current report, it has been demonstrated that different approaches for generating the speed SPI's could have a large impact on the SPI's and should therefore be carefully defined. The trials also demonstrated that the definition of a trip, as arbitrary as it may seem, is a definition that should be carefully considered as it may have a major effect on the outcomes of the RED's.

For a considerable amount of the SPI's and RED's computed in the small scale field trials, the drivers identity has related to the recorded data. This is a necessary step in order to relate the recorded data to driver characteristics (such as age and gender) and in order to compute mobility related indicators on a person based level. In the Austrian trail, short video clips were watched in order to relate the trip to the participating driver or to exclude the data from the analysis. For a large scale trial that aims at continuous monitoring of road safety indicators, this procedure would have to be further automated in order to reduce the handling time of the data gathered.

The Scenario 2 based Israeli trial included measurements from additional sensors and CAN-bus data that allowed the computation of additional SPI's when compared to the scenario 1 based trial. The additional sensors used in the Israeli trial demonstrated the ability to enable computations of valuable additional indicators. However, the opportunities of using CAN-bus data for generating relevant additional SPI's and RED's proved to be rather limited. Only a limited part of the data recorded in the CAN-bus is publicly accessible, and apart from diagnostic measures (as specified in the OBD-II protocol) data availability differs between manufacturers.

For most measurements, the large difference in sampling rates of the in-vehicle recorded data between the two trials proved not to have a major impact on the generated indicators. When it comes to deriving risk indicators from accelerometer derived data however, the sampling rate seems to be more critical. To reduce the amount of recorded accelerometer data, but still accurately reflecting the vehicles accelerations, data of a higher sampling rate could possibly be pre-processed and reduced on the in-vehicle data logger before it is recorded (in a similar way the accelerometer data was now post-processed in the Austrian field trial).

The field trials lead to the following practical recommendations when implementing a ND study:

- Besides a detailed planning and recruitment procedure, a ND study needs to be well structured and organised (support team). Continuous support allows errors/defects to be corrected as soon as possible (to prevent of data losses).
- Relatively cheap, off-the-shelf devices can be sufficient for a ND study. But it is essential to have a storage capacity that is big enough, as data can be lost when the storage device approaches its capacity. A buffer battery is very useful to guarantee a safe storage of the data.
- For a large scale activity it is recommended to stream data onto some form of solid state storage device, e.g. by transmitting the data automatically by UMTS and to store them on a server.
- Numerous secondary variables or indicators can be calculated from the raw data. The problem is more how to define them and how to operationalise them. Depending on what conclusions need to be drawn, more or less additional information may be needed.

DaCoTA WP6 T6.3 demonstrated the capability and usefulness of collecting very detailed data on exposure, travel speed and associated characteristics. It shows that it is possible to obtain a very detailed account of exposure and safety related behaviours which it is, so far, not possible to collect.

The experience gained in the small scale study in T6.3 will flow into the recommendations for implementing large scale ND within ERSO (D6.2 “Study design for large scale study”).

Collecting these variables on a representative sample of drivers in all EU countries by means of these naturalistic studies would add a very valuable aspect to the ERSO database and would enable many cross-country behaviour studies - eventually linking them to accident occurrence and safety.

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Projects:

Prologue: http://www.prologue-eu.eu/

SafetyNet:
http://ec.europa.eu/transport/wcm/road_safety/erso/safetynet/content/safetynet.htm

Other websites:

Supplier of pDrive: http://www.test-and-training.com/

pDrive: http://www.pdrive-system.com

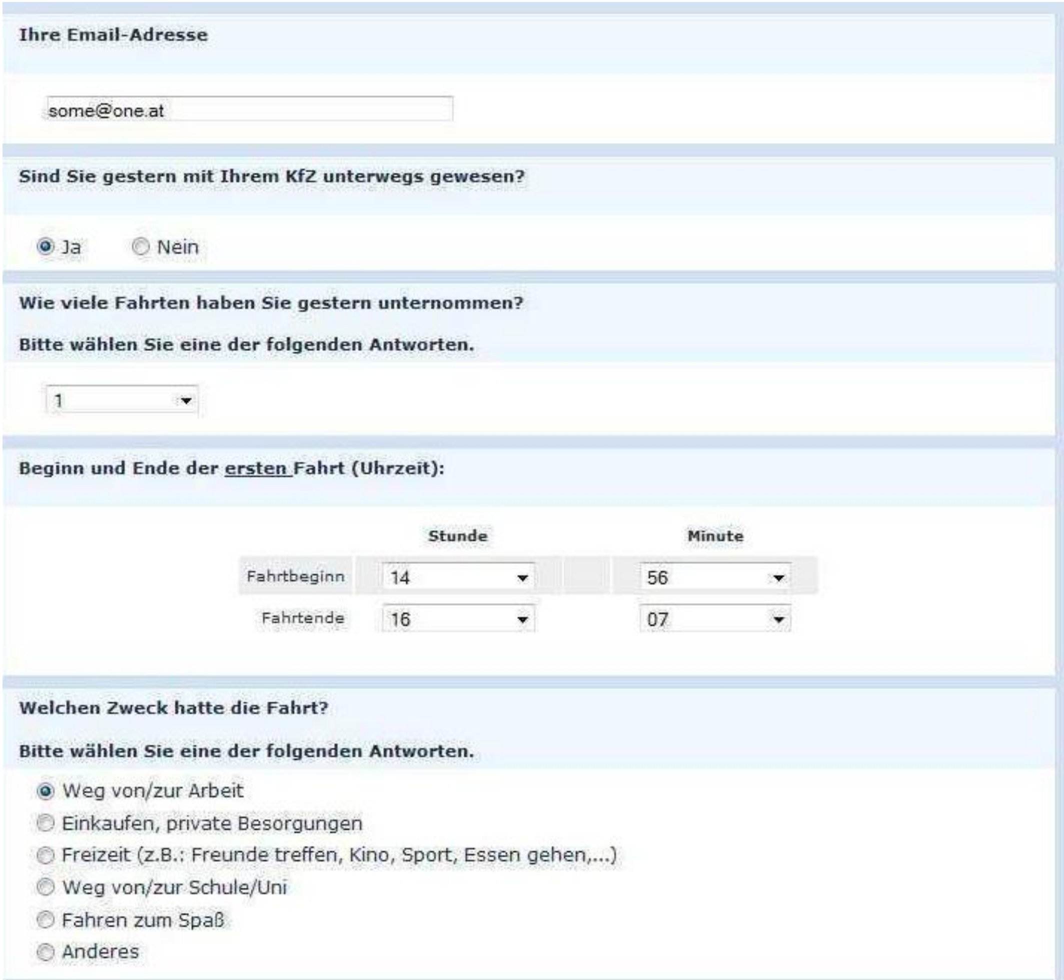
mobilEye: http://www.mobileye.com/

TrackTec: http://www.track-tec.com/fleetsl/Contact.aspx

TransCAD: http://www.caliper.com/tcovu.htm

ANNEX

Travel Diary (Austrian small scale study)



Ihre Email-Adresse

some@one.at

Sind Sie gestern mit Ihrem KfZ unterwegs gewesen?

(•) Ja ( ) Nein

Wie viele Fahrten haben Sie gestern unternommen?

Bitte wählen Sie eine der folgenden Antworten.

1

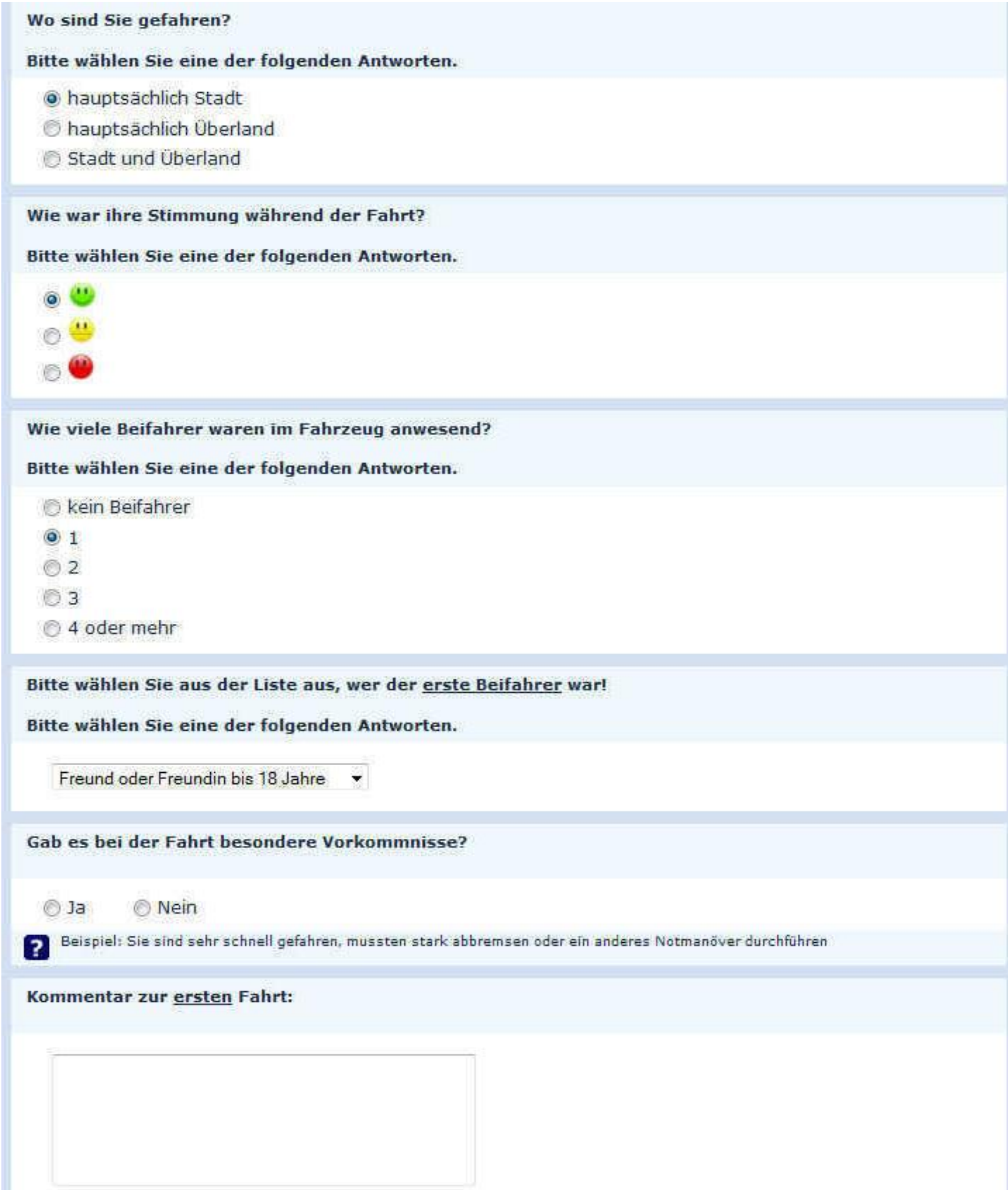
Beginn und Ende der ersten Fahrt (Uhrzeit):

	Stunde	Minute
Fahrtbeginn	14	56
Fahrtende	16	07

Welchen Zweck hatte die Fahrt?

Bitte wählen Sie eine der folgenden Antworten.

(•) Weg von/zur Arbeit
( ) Einkaufen, private Besorgungen
( ) Freizeit (z.B.: Freunde treffen, Kino, Sport, Essen gehen,...)
( ) Weg von/zur Schule/Uni
( ) Fahren zum Spaß
( ) Anderes



Wo sind Sie gefahren?

Bitte wählen Sie eine der folgenden Antworten.

- (x) hauptsächlich Stadt
- ( ) hauptsächlich Überland
- ( ) Stadt und Überland

Wie war ihre Stimmung während der Fahrt?

Bitte wählen Sie eine der folgenden Antworten.

Wie viele Beifahrer waren im Fahrzeug anwesend?

Bitte wählen Sie eine der folgenden Antworten.

- ( ) kein Beifahrer
- (x) 1
- ( ) 2
- ( ) 3
- ( ) 4 oder mehr

Bitte wählen Sie aus der Liste aus, wer der erste Beifahrer war!

Bitte wählen Sie eine der folgenden Antworten.

Freund oder Freundin bis 18 Jahre

Gab es bei der Fahrt besondere Vorkommnisse?

( ) Ja ( ) Nein

Beispiel: Sie sind sehr schnell gefahren, mussten stark abbremsen oder ein anderes Notmanöver durchführen

Kommentar zur ersten Fahrt:

Road Safety Data, Collection, Transfer and Analysis

Austrian and Israeli Small Scale Study "Added values"

Monika Pilgerstorfer, Kerstin Runda, Christian Brandstätter (KFV)
Shalom Hakkert, Tomer Toledo (Technion)

1. Introduction

The objective of the Small Scale Naturalistic Driving (ND) Study within the framework of DaCoTA is to **test and refine the practical and technical feasibility of the method of ND data gathering as defined in task 6.1 and 6.2**.

Compared to other Naturalistic Driving initiatives, the unique objective of Naturalistic Driving observation within ERSO, for which DaCoTA was the pilot, is the **continuity of data gathering**, the **scale** (all European countries, representative for a country and comparable between countries) and the **focus on SPIs** and **mobility** (exposure to risk). Whereas in Prologue the focus is more on safety related events (risky behaviours), in DaCoTA the focus is, on continuous sampling of driving behaviour under normal driving conditions, on a representative basis, both for safety and mobility purposes. One aspect which is addressed in DaCoTA is the management and maintenance of such a sample over time. Keeping ERSO in mind and considering a sample of 200-400 cars per country, properly sampled and continuously running, this is not a trivial task. The information to be gathered over time could be very useful in evaluating the effect on behaviour of various policies that might be introduced, e.g. changes in speed limits, daytime running light legislation, the introduction of various safety devices or technologies.

Regarding the SPIs of SafetyNet, the main focus of this study will be on the measures on speed, both at an absolute level and compared to the speed limit. Furthermore, data will be collected on speed related behaviour (e.g. pre-defined manoeuvres which can be used to monitor more detailed speed behaviour) and it will be explored if it is also possible to measure other SPIs such as daytime running lights or seatbelt usage. The questions to be addressed here are what ND behaviours can and should be monitored on a large and representative scale to be included in an ERSO database.

Regarding Exposure: the focus of the study will be to **develop a full logbook of trip duration, trip length, trip timing, possibly trip location, and drivers' identification and explore possibilities to stratify this for different road types or vehicle types**. There is no question that the extent of information on vehicle use (mobility) that can be collected through ND technologies is on a totally different scale from what used to be the standard ways of collecting such data, either from representative samples of traffic counts or through travel surveys and vehicle kilometreage monitoring.

Data on crashes or near crashes is currently not collected directly. In this WP it will be explored if certain manoeuvres could be defined that can be used as a proxy for near crashes, to be detected as extreme events (such as: very strong decelerations, extreme sharp turning manoeuvres).

The small scale study will result in a report, describing the design of the study, the results and conclusions on questions within the study, as well as a description of experiences, insights and recommendations for large scale data gathering within ERSO.

2. Added values in the Austrian field trials

2.1. Different aims/research question

The objective of the DaCoTA Small Scale Naturalistic Driving Study is to test and refine the practical and technical feasibility of the method of data gathering.

Focus on EXPOSURE: The focus of the study will be to develop a full logbook of trip duration, trip length, trip timing, possibly trip location, and drivers' identification and explore possibilities to stratify this for different road types or vehicle types.

The main focus of this study will be on the measures on speed. Furthermore, data will be collected on speed related behaviour (e.g. pre-defined manoeuvres which can be used to monitor more detailed speed behaviour) and it will be explored if it is also possible to measure other SPIs such as daytime running lights or seatbelt usage.

Other than in DaCoTA, the Austrian field trial in PROLOGUE aimed to demonstrate the potential usefulness of naturalistic observations within the field of driver training and novice driver behaviour and to serve as a pilot for a future large-scale naturalistic study by revealing strengths and weaknesses of the data collected.

The focus was on the one hand to use ND-measures as trigger for feedback regarding the driving behaviour in the training phase of novice drivers. On the other hand, at the end of the final assessment using two groups (with and without feedback) to evaluate the advantage of the feedback-training was evaluated. This was mainly done on the basis of values of driving behaviour, which were calculated from braking- and lateral acceleration characteristics from ND-observation.

Thus, the outcomes of PROLOGUE can be used in DaCoTA for improving the method. The PROLOGUE data will provide input for SPIs, but RED have to be investigated in another way/with another sample.

The processing of data is one main objective in DaCoTA. Challenges will be the collection, communication and reduction of data in terms of aggregating data by means of ERSO (e.g. extracting speed, weekdays etc.)

2.2. Differences in the method

Target group:

In PROLOGUE, relevant driving parameters of 12 (6 male, 6 female) novice drivers were collected up to two months after receiving their driving licence.

In DaCoTA the sample is split not only in gender, but also in age and therefore driving experience.

As all of the subjects in PROLOGUE were 18, all of them finished high school in summer 2010 and therefore had to learn for the final examination. It turned out that subjects used their or their parents´ vehicle less than normal. In addition to the holiday season in summer, subjects would go on a class trip after their graduation, which is a national tradition in Austria. This circumstance also led to **limited exposure in the observation period**.

Although the hardware and software used has been tested thoroughly, authors had to tackle some equipment-related problems. Instead of informing the investigators, some of the subjects "solved" this problem by disconnecting the power supply of the equipment. Hence, **potential trip data was lost**.

The mentioned problem cases clearly influenced the overall quality of data, i.e. the rate of faulty recordings was 15%. Another 9.5% of the recordings could not be used as the person driving the car was not the respective test subject. Therefore, the recorded data had to be excluded from the analysis and was deleted. Both aggravating facts led to an overall percentage of 75.5% data used in the analysis.

For obtaining the objectives of DaCoTA, there is a need of continuous monitoring, to generate and maintain a sample over time.

The sample of the Austrian field trial was too exotic to do any interpretation based solely on the exposure data. Furthermore, analysing exposure data only makes sense if full records of individual data sets are available. In the Austrian field trial, it was not possible to collect a single full data set due to a number of already mentioned problems.

2.3. System design differences

Based on the lessons learned of PROLOGUE, the technical equipment could be improved for the DaCoTA study.

pdrive light is a simplified version of the *pdrive system* used in PROLOGUE. As pdrive was originally developed for motor sport, it has features for driving training, it is able to show the driver different variables and forces and to give feedback.

pdrive light focuses on the ND purpose. Thus, it is smaller and also cheaper.

3. Added value in the Israeli field trials

3.1 Brief introduction

The Israeli trial uses four types of in-vehicle data recording devices, a camera based forward looking warning device (Mobileye), a data recording device logging the Mobileye data, GPS, speed and acceleration data and connects to the vehicle CANBUS (TrackTec), an accelerometer based data recorder which records pre-defined safety events(GreenRoad IVDR) and a fuel billing system which records vehicle fuel consumption and costs (Dalcan).

10 vehicles will be monitored over a period of time, two of these vehicles will also record additional data collected from the CAN. Data will be sampled continuously each 30 seconds and in addition events will be recorded

3.2 Different aims/research questions

Because we are interested in continuous monitoring and not just events, as was the case in Prologue, measurements are taken every 30 seconds from which a meaningful database will need to be created. This applies to both to a safety related record and to the exposure data. In creating the database, data reduction will need to be applied. Also to be considered is the need to maintain a consistent sample over time, once this method will be applied on an EU wide scale.

Whereas in Prologue the use of a number of devices was demonstrated for the purpose of conducting experiments that answered a number of innovative research questions, in the DaCoTA small scale trials similar devices are being used to demonstrate the additional value of collecting safety related and exposure related information, continuously recorded for the purpose of evaluating safety and mobility related policies and countermeasures.

3.3 Differences in method

In Prologue, in the Israeli field trials, a number of small scale experiments were conducted, mostly involving young drivers, to demonstrate the value of these technologies and the added value of ND methodology. In the DaCoTA small scale experiments, the value of these technologies is demonstrated for different purposes. Another difference in methodology lies with the continuous monitoring versus the event based monitoring in Prologue.

A continuous record of speeds, accelerations, headways and some CANBUS related information will be collected to demonstrate that this can be recorded in a database over time, to be used for policy oriented decision making, for evaluation studies and for research questions which could not before be answered.

3.4 System differences

One of the major differences between the experiments in Prologue and DaCoTA is that in DaCoTA a number of systems will be applied simultaneously in the same vehicle. This creates technological problems not previously solved. It is also an attempt to create an open system which will support the addition or change in data collection systems which can be added when they become available or when the need arises.

One of the major new issues tackled deals with collection of data via the CANBUS. This is problematic because the vehicles to be used are of different makes and models and thus data collection and data recording have to tackle different vehicle CANBUS systems.