Road Safety Data, Collection, Transfer and Analysis

Naturalistic Driving for cross-national monitoring of SPIs and Exposure:

A Summary

Deliverable 6.5

Please refer to this report as follows:
Wegman, R.W.N., Bos, N.M. (2013) Naturalistic Driving for cross-national monitoring of SPIs and Exposure: An overview. Deliverable 6.5 of the EC FP7 project DaCoTA.

Grant agreement No TREN / FP7 / TR / 233659 /"DaCoTA"
Theme: Sustainable Surface Transport: Collaborative project
Project Coordinator:
Professor Pete Thomas, Vehicle Safety Research Centre, ESRI
Loughborough University, Ashby Road, Loughborough, LE11 3TU, UK

Project Start date: 01/01/2010 **Duration 36 months**

Organisation name of lead contractor for this milestone:
SWOV Institute for Road Safety Research, The Netherlands

Report Author(s): Wegman, R.W.N. and Bos, N.M. (SWOV).

Due date of Deliverable	**31/12/2012**	**Submission date:**	**15/02/2013**

Project co-funded by the European Commission within the Seventh Framework Programme	
Dissemination Level	
PU	**Public**

Project co-financed by the European Commission Directorate General for Mobility and Transport

Table of Contents

Acknowledgements

Special thanks go to the many individuals in addition to those named as authors who have contributed to this work from the following institutions:

Austria:	Austrian Road Safety Board (KFV), Test & Training International (TTI)
Belgium:	Belgian Road Safety Institute (IBSR)
France:	French Institute of science and technology for transport, development and networks (IFSTTAR)
Israel:	Israel Institute of Technology (Technion), Association for Safer Driving (Or Yarok)
The Netherlands:	SWOV Institute for Road Safety Research (SWOV)
United Kingdom:	Transport Safety Research Centre (TSRC)

Thanks also go to many persons at the European Commission and the members of the Consortium and Project Steering Committee.

List of Abbreviations

CAN	Controller Area Network
DAS	Data Acquisition System
ERSO	European Road Safety Observatory
EU	European Union
GPRS	General Packet Radio Service
GPS	Global Positioning System
ND	Naturalistic Driving
OBD	On-Board Diagnostics
RED	Risk Exposure Data
RFID	Radio-frequency identification
SD	Standard Deviation
SPI	Safety Performance Indicator

List of tables

EXECUTIVE SUMMARY

WP6 of DaCoTA, *Driver Behaviour Monitoring through Naturalistic Driving*, focuses on the usefulness and feasibility of applying the Naturalistic Driving method for monitoring within the framework of ERSO. The aim is to continuously collect comparable information about the road safety level in EU Member States and its development over time.

Naturalistic Driving methods are intended to gather data that represent the behaviour of the population of drivers in its basic state. Naturalistic Driving (ND) study can be defined as:

> *'A study undertaken to provide insight in driver behaviour during every day trips by recording details of the driver, the vehicle and the surroundings through unobtrusive data gathering equipment and without experimental control'*

Typically, in an ND study passenger cars are equipped with small sensors. These devices continuously and inconspicuously register vehicle manoeuvres (like speed, acceleration/deceleration, direction, location), driver behaviour (like eye, head and hand manoeuvres), and external conditions (like road, traffic and weather characteristics).

ND for monitoring purposes

ND data can be used to establish how often drivers routinely are exposed to or engaged in certain situations/behaviours that are known to increase the risk of a crash. This includes monitoring safety-relevant behaviour (Safety Performance Indicators - SPIs) and mobility (Risk Exposure Data – RED). Benchmarking is an important reason for monitoring road safety and comparing road safety levels and their developments over time. It allows countries to determine their relative position in comparison to other countries, to understand differences and find ways and get motivated to improve their position. Obviously, monitoring road safety also allow countries to evaluate their own road safety policy and road safety targets. ND is considered a promising approach for collecting reliable and comparable information about various RED and SPIs, as well as several relevant context variables. The main advantage of the ND approach for monitoring as compared to the more traditional SPI data collection methods, such as road-side surveys and questionnaires, is that ND ensures continuous, automatic and standardized data collection. This approach substantially increases international comparability and level of detail. Though the current Deliverable is purely focused on road safety and exposure data, the collected data will also be useful for other transport areas, in particular eco-driving and traffic management.

Three data collection scenarios

Depending on the variable of interest, ND data collection needs different technologies ranging from simple data acquisition systems to more sophisticated systems with several sensors and several videos. By combining the RED and SPIs of interest and the technological requirements for collecting that type of data, we distinguish three scenarios to collect meaningful data within reasonable limits of cost and complexity.

It is recommended to start off with **Scenario 1**: a low-cost simple, off-the-shelf simple data acquisition system (e.g. an OBD GPS tracker or a Smart Phone) and a limited number of additional sensors, basically measuring RED and speed.

At a later stage, successively additional sensors could be added to measure more advanced SPIs and network characteristics (**Scenario 2**).

SPIs that would need continuous video recordings do not seem to be feasible for monitoring purposes, because of huge amounts of data and high costs of data transfer and coding. That means that the SPIs like fatigue, inattention and distraction can currently not be monitored by means of ND research. Technical developments may allow reconsideration of this conclusion in due time.

It is recommended to equip a limited number of cars also with an event-triggered video in order to monitor numbers of near crashes as yet another relevant SPI (**Scenario 3**).

Study design and organisational issues

In principle, the techniques and procedures for ND data collection, transfer, storage and analysis are available and not too complicated. In order to get reliable information, a fairly large sample is needed. The exact size of the sample depends on the variation in behaviour in the population and the required level of precision of the results. Assuming that the sample is drawn in a cleverly stratified way a sample of around 10,000 drivers per country seems to be required for RED such as the annual mobility. This sample size is independent of the size of the country. Only if the sample size is larger than 10% of the population, a correction is applicable.

Participation in ND research is per definition on a voluntary basis and past experiences have shown that it requires special attention to find sufficient suitable participants. There are legal and ethical issues involved in ND research, in particular in the areas of privacy and data protection.

Exploring Scenario 4

In parallel to the implementation of the previous three scenarios, it is recommended to start exploring the possibility of a Scenario 4 now, i.e. a scenario where relevant data is extracted directly from systems built-in by the vehicle manufacturers. In theory, that way a lot of relevant information is already available with no or few additional costs; in practice, however, the information is not generally accessible nor comparable between car makes. So this is a scenario that cannot be realised overnight. One of the first steps, in consultation with the car manufacturers, is an elaboration of the requirements for this data: what is available, what is needed, what is feasible.

A central role for the EC

Since harmonisation and international comparability of data are the key reason for this effort, there is a central role for the European Commission in initiating this task and taking the lead from here, most likely within the ERSO framework. A stepwise approach is recommended, including successively:

1. Creating support and finding budget by presenting the case to the relevant road safety bodies at European and Member State level, explaining the need for harmonised, comparable international data, the ND approach, and its added value.
2. Preparing a detailed description of all practical implementation aspects, including the functional specifications of data collection equipment, participant selection, data transfer and storage, definitions of variables, disaggregation levels and analyses.
3. Identifying the relevant national organisations, responsible for national data collection and pre-analyses, and fine-tuning data collection procedures (including legal aspects) and variable definitions in consultation with them.
4. Developing and equipping a database at EU level and defining the required data to be provided and the procedures and time schedule, in consultation with the relevant national organisations.
5. Setting up European-wide communication strategies to guarantee maximum dissemination and use of the collected data.
6. Setting up one year national pilots in at least four Member States.
7. Adapting procedures and definitions, based on the pilot experiences.
8. Successive implementation of Scenario 1 in additional Member States.

Parallel to steps 6 and 7, Scenario 2 (additional SPIs/RED) and 3 (monitoring near-crashes) can be elaborated, piloted and implemented, applying a similar stepwise process.

From the very beginning, the EC is advised to initiate discussions with the car manufacturers, using existing discussion platforms, with the aim to explore longer term possibilities of Scenario 4, i.e. the scenario where relevant data is extracted directly from the vehicle.

1. INTRODUCTION

DaCoTA is a Collaborative Project under the Seventh Framework Programme, co-funded by the European Commission, DG Mobility and Transport. The project officially began in January 2010 and continued till December 2012. The six technical Work packages of DaCoTA 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 2010). 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 ERSO.

This is the fifth and final report of WP6, giving an overview of the previous reports. As each deliverable builds on one or more of the previous ones and this one builds on all the previous ones, inevitably there are overlaps. On the other hand it is equally inevitable that details from the other reports are missing in this summary. This report does not make reading the other reports superfluous. It is meant to present relatively concisely the main findings and considerations. For details, elaborations and sidesteps the original reports need to be consulted.

1.1 What is Naturalistic Driving observation

Naturalistic Driving methods are intended to gather data that represent the behaviour of the population of drivers in its basic state. Naturalistic Driving (ND) study can be defined as:

> *'A study undertaken to provide insight in driver behaviour during every day trips by recording details of the driver, the vehicle and the surroundings through unobtrusive data gathering equipment and without experimental control' (Van Schagen et al., 2011).*

Key features of ND studies include:

- Drivers use their own vehicles in their normal manner.
- The data gathered covers the driver, vehicle and surrounding road environment.
- The instrumentation is unobtrusive and drivers cease to be aware after a short period.
- There are no observers present in the vehicle.
- Data is recorded continuously during the driving process.

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

Ideally, a large-scale ND study includes a large number of fully equipped vehicles for a considerable period of time; the collected data being stored in a large database that subsequently is exploited to answer a wide variety of research questions.
The ND approach has become possible thanks to technological developments in data collection, data storage capacities, data-mining and image processing, with tools that become increasingly smaller, less obtrusive and less expensive.

Data collected through Naturalistic Driving observation has the potential to provide a high level of detail of (normal) driver behaviour in the pre-crash phase if a collision occurs and is thus a useful complement to traditional accidentology. In addition, it can provide important information on successful avoidance behaviour in near crash situations and it offers opportunities to quantify mobility (exposure to risk).

1.2 Naturalistic Driving observation and ERSO

Naturalistic Driving observation is commonly used for in depth study of specific road safety topics related to driver behaviour and driver condition. The objective of the DaCoTA Naturalistic Driving is **monitoring** the development of road safety by continuous data gathering in a harmonized way on a large scale (preferably all European countries, representative for each country and comparable between countries). It focuses on safety performance indicators (SPIs) and exposure to risk (RED) and on how often drivers routinely engage in certain behaviours that are considered to increase the risk of a crash. Obviously, monitoring road safety also allow countries to evaluate their own road safety policy and road safety targets. In this context Naturalistic Driving observation is for establishing trends in and between countries, which may be used for policy adjustments.

2. RELEVANT DATA TO BE COLLECTED

2.1 Variables to monitor within ERSO

In task 6.1 an inventory of variables which would be relevant to be monitored within the frame of the European Road Safety Observatory was made (Talbot 2010).

Risk Exposure Data (RED):
- Vehicle mobility
- Fuel consumption
- Person mobility
- Number of trips
- Time in traffic

Safety Performance Indicators (SPIs), priority, indicated in a national experts' survey:

- Alcohol and drugs	High
- Speed	High
- Protective systems (use of seatbelts and child restraints)	High
- Daytime running lights (drl)	Low

Additional SPIs from various sources:

- Fatigue	Medium
- Distraction/inattention	Medium
- Gap acceptance/headway	Low
- Near crashes	Low
- Accident causation	High
- Safety technology	Medium

The SafetyNet analysis on the current practices of monitoring RED and SPI topics showed that all these indicators lack availability and/or comparability across and within countries. Consequently, there is a need for improvement.

An additional level of disaggregate information on all topics is desired in order to do valid comparisons across the countries, see section 2.4.
Note that for a participant some variables are constant, such as his/her age, or the vehicle model. Others vary during the trip (e.g. road type, posted speed limit) and others are different each pass of the same road section, like the weather (transient).

2.2 Data collection through Naturalistic Driving observations

The next question is how the data on the topics identified can be collected through Naturalistic Driving observations and by what technical equipment.
It appears that the collection of a large number of these data depends on internal video, external video, or both, or on CAN data.
As the accumulation of video data takes large amounts of storage space and the analysis of these data is extremely time consuming, video is not suitable in a large

scale activity: large numbers of cars, long continuous periods of data collection. Besides, willingness to participate and privacy issues may complicate such a study.

Considerations for meaningful data collection within reasonable limits of cost and complexity:

- a large number of cars have to be instrumented within the 27 EU countries, which necessitates a simple low cost device that is easy to fit;
- a large amount of data will be generated, so the data must be automatically processed and analysed, e.g. through the use of scripts;
- because extended periods of monitoring are expected, the equipment used should be unobtrusive and any methodologies adopted should require minimal input from the participants.

As a result, two scenarios are proposed. **Scenario 1** would be a basic low cost Data Acquisition System (DAS) using existing technology, which comprises a GPS logger and accelerometer. It would be necessary to identify who is driving the vehicle and to derive certain variables using map matching in order to collect meaningful data. The availability of map data is a potentially limiting factor here.

Scenario 2 would supplement the Scenario 1 DAS with extra sensors or capabilities - e.g. a connection to CAN data -, allowing the collection of additional variables that are important in the monitoring but cannot be measured using the Scenario 1 DAS. The availability of CAN data depends on the preparedness of car manufacturers to let these data be collected and interpreted by others than themselves.

Scenario 2 is more of a tool box approach, as certain additional sensors and connections can be arranged in the future.

Various topics are not or hardly suitable for inclusion in one of the above scenarios, as there is no reliable way of detection or they depend on driver input (alcohol, drugs, medicines) or on video data (child restraints, fatigue, distraction).

2.3 Data selection

Now that two scenarios have been formulated, we can look which RED, SPIs and additional topics can be collected and by what means.

On the basis of the possibility to collect the data by Naturalistic Driving (excluding video) and national experts' priority, the following topics are recommended:

By Scenario 1 DAS:

- Vehicle mobility
- Person mobility
- Number of trips
- Time in traffic
- Speed – excessive (i.e. exceeding the general or posted speed limit)
- Driving style - acceleration

Additional topics by scenario 2 DAS:

- Speed – inappropriate (i.e. faster than the prevailing conditions allow)
- Seatbelt use
- Headway

- Lane behaviour
- Driving style – braking, signal/light use

2.4 Context variables

In order to draw meaningful conclusions about data collected, it is necessary to collect information about the driving context.
After consideration of the practicality of collecting certain variables for a large scale activity, the following tables summarize the recommended and optional context variables to be collected.

Driver	Vehicle	Network	Other (transient)
Age	Make & Model	Road type (motorway, non-, motorway rural, urban,	Time (Day, Month, year, HH:MM: SS.FF)
Gender	Style (e.g. hatchback, SUV)	Area Type (rural, urban)	Distance travelled
Driving experience	Vehicle Age	Speed limit	Start & End of trip
Level of education	Vehicle Mass		Trip km (derived)
Occupation	Safety systems		Trip time (derived)

Table 2.1. Summary of recommended Scenario 1 context variables.

Driver	Vehicle	Network	Other (transient)
Personal characteristics (attitudes, offences, risk taking, perceptual skills etc.)	Model Variant	Road Class	Journey purpose (private/ professional)
	Engine Size	Junction type	Traffic flow
			Road conditions (icy, wet)
			Light conditions
			Weather conditions (precipitation, temperature)
			safety systems in use

Table 2.2. Summary of recommended additional Scenario 2 context variables

2.5 DAS specification/technical requirements

2.5.1 Scenario 1 DAS

2.5.1.1 DAS equipment

The requirements for a Scenario 1 DAS would be:
- Integrated system, individual components synchronized (common time stamp)
- GPS, EGNOS-compatible (viz. D6.1, section 2.6.2)
- Accelerometer
- Unobtrusive, In-car (participants may forget to install portable devices)
- Reliable power management
- Appropriate sampling rate (once per 1 to 10 seconds)

2.5.1.2 Data storage and transfer

In vehicle storage possibilities are USB drives and flash cards of sufficient capacity to avoid data loss. Data transfer to a central database can be done by exchange of USB/flash drives or uploading data through GPRS/UMTS/WiFi. Driver involvement should be minimal, to avoid reluctance to participate and data loss.

The capacity requirements for data storage at country level depend on the period of data collection and the sampling rate.
The capacity and data protection issues for a central European database with aggregated data are much more limited.

2.5.1.3 Data analysis

There will be a need for data preparation before research questions can be answered. GPS data require matching to map data, to create many of the context variables. Map matching software can be purchased with the map data or a custom solution needs to be developed.
Any Naturalistic Driving Observation activity produces large volumes of data; therefore analysis software has to be capable of handling such quantities.

2.5.2 Scenario 2 DAS – additional requirements

The Scenario 2 DAS should be considered as a series of options that could be added to a Scenario 1 DAS to increase the number of topics that can be monitored in a large scale activity. These additions highly depend on available resources, which are influenced by technology development. From the start of the large scale activity an additional sensor could be added to collect additional data or additions could be made once the activity is established. Also such addition could initially be made in a subset of countries rather than all.

2.5.2.1 DAS equipment

To measure the proposed variables, additional sensors or access to the CAN is required. Any sampling rate used for a Scenario 1 DAS is also appropriate for recording temperature and the use of seatbelt, light and windscreen wiper.
Braking, signal use, headway, lane behaviour and activation of safety systems require a higher sampling rate, depending on the research question.

2.5.2.2 Data storage

The more variables are collected directly from the DAS and the higher the sample rate, the more data storage is needed in the car. It might also be necessary to upload data more often.
Of course the data storage needs for a central storage facility will also be greater, especially if many more derived variables are required.

2.5.2.3 Data analysis

If video is used to record driver ID there is a need to employ machine vision technology to automatically identify individual drivers so that analysis can take place.

3. STUDY DESIGN

The objective of task 6.2 of DaCoTA is to specify the study design of a naturalistic driving study in the perspective of the European Road Safety Observatory.
The task deals with three main issues:

1) The experimental design, which focusses on how to sample the 'population' to get reliable estimates of the indicators to be measured.
2) The procedures to RED and SPI estimation, first it is described how current indicators (in ERSO) compare to the ones that can be derived from ND data. Then it is described how to filter data to receive new homogenous and comparable indicators from ND data.
3) Legal, ethical and privacy requirements.

3.1 Experimental design

Deliverable D6.2B discusses what sampling and estimation methods can be used to obtain population values of RED and SPI items based on a naturalistic driving study, see Commandeur (2012).

Since it is impossible to study all car drivers of a country, a sample must be drawn.
In order to decide what sampling and estimation method is most appropriate, we first have to consider the type of sampling frame(s) that are available, i.e. the source(s) from which a sample is drawn.
When the sampling frame contains information on all individual population elements, a **simple random sample** (all car drivers have an equal chance to find themselves in the sample) or a **systematic sample** may be considered.

When it is possible to define subgroups of car drivers that can be expected to be more homogeneous with respect to the RED and SPI variables, then **stratified random sampling** is recommended. This means that the car driver population is first divided into mutually exclusive and homogeneous subgroups (strata); subsequently within each stratum a random sample is drawn. This decreases the required sample size for the same precision of the estimates
If the individual values of an additional variable that is highly correlated with the RED/SPI variable of interest are known for all car drivers in the sample, then precision can be further increased by replacing the direct estimator with a **ratio or regression estimator**. However, this usually requires knowledge of the sum total of the additional variable in the population. Should the individual values of such an additional variable also be known for all car drivers in the population, then the selection procedure with **unequal probabilities** can be considered.
When the sampling frame happens to be decentralised (e.g., municipal), on the other hand, then the **two-stage sampling methods** can be used.

In all these cases, given an assumed homogeneity of the SPI/RED in the population and a pre-specified precision and probability it is possible to obtain estimates of the minimal required sample size. This number is usually quite independent of the size of the population of car drivers in a country. Only if the sample size is larger than 10% (of a stratum) of the population, a correction is applicable (Commandeur, 2012).

The practical implication of the chosen precision level is that only changes between two consecutive time points or periods larger than twice this precision level will be detected with the corresponding sample size.

As an illustration, consider a population of car drivers who on average drive 15,000 kilometres a year. Using a probability of 95%, the minimal required sample sizes obtained in a simple random sampling scheme in order to estimate the annual mobility of cars with precision levels of ±5%, and ±1%, and population standard deviations of SD=10,000, and SD=15,000 are given in Table 3.1 below. As the table indicates, sample size increases both when the required precision of the estimate increases, and when the variation of the variable of interest in the population is larger.

- With a population standard deviation of 10,000 kms and a sample of around 700 car drivers, differences in the actual annual mileage up to 10% (plus or minus 5%) will remain undetected.
- With a population standard deviation of 10,000 kms, and a sample of around 17,000 car drivers only differences up to 2% will remain undetected.
- If, however, the population standard deviation is 15,000, a sample of over 38,000 car drivers would be needed to reach the level of precision of ±1%.

SD = 10,000		SD = 15,000	
±5%	±1%	±5%	±1%
683	17,074	1,537	38,416

Table 3.1. Sample sizes required for estimating the mobility of cars in a country with a given standard deviation, precision level and 95% probability

The sample sizes in Table 3.1 are conservative in the sense that they are based on the direct estimator in simple random sampling, which have the largest standard errors. Other estimators and other sampling techniques will require smaller sample sizes. The other approaches require more information about the population by additional variables. Required sample sizes may be up to 70% smaller when stratified random sampling is used instead of simple random sampling.

In naturalistic driving study designs, the sampling technique of choice will depend on whether or not a centralized national sampling frame is available. In the Netherlands, for example, it seems obvious that the register containing all Dutch licensed vehicles is the most appropriate frame for sampling passenger cars. The database includes several technical specifications of each vehicle, being helpful additional variables for stratification. There is also a database containing all driver licences, including background of the drivers (age, gender). In the Dutch situation the available sampling frames imply that the units to be sampled should be the licensed drivers since they are the ones who give their consent to participate in the study.
If the sampling frame happens to be decentralised and municipal, for example, then a two-stage sampling design would be called for. An illustration of the latter approach is

presented in Rofique et al (2010). The methodology of this survey covers and combines many of the aspects of sampling and it is worth to examine in more detail.

A number of specific conclusions and recommendations apply for the selection of a probabilistic sample of passenger cars in a naturalistic driving study design, see Commandeur (2012). The most important ones are:

1. All sample size estimation methods have in common that they require an a priori specified **degree of precisio**n and **probability**. The degree of precision simply specifies how close we want the sample estimate (of the mean, the total, or a proportion) to be to its actual population value; For sample size estimation we also have to specify how certain we want to be of obtaining the precision with a sample.
2. Some knowledge of the populations **variation of the variable(s) of interest** is required (in the population or in the different strata or the primary and secondary units of the sample).
3. When the objective is to measure changes over time, the required precision should consider the minimal difference in estimates between consecutive time points that we want to detect with certainty.
4. When information on additional variables in the population is available that are correlated with the variable of interest this opens up the possibility of improving the precision of the parameter estimates by using stratified random sampling.
5. When several items in the population need to be estimated, then this requires sample size estimations for each of these items separately.
6. Since ND monitoring is expected to cover multiple years, the best strategy for measuring change is to use a **rotating sample** where one part (50-80%) of the sample is retained and the remaining part of the sample is replaced. The length of the **rotation period** should also take into consideration the costs and time required for the installation and de-installation of the ND device. In order to control for seasonal fluctuations (e.g., holidays) it seems that a period of 1 year is ideal. This can be combined with the rotation procedure.
7. The continuous nature of the measurements implies that the ratio and/or regression estimators are well-suited candidates for improving the precision of the estimates: the observations from the previous period can be used to statistically increase the precision of the sample estimates.
8. The estimation of the required sample size should take the problem of **non-response** into account, and the sample size should be increased accordingly.
   In some countries at least, it should be possible to get information on the characteristics of the non-respondents by using the double sampling for non-response approach.
9. Selection **bias** as a result of non-response should be corrected for by post stratification based on 1) demographic information of the driver population; 2) technical characteristics of the vehicle fleet; and/or 3) odometer readings of cars as registered during roadworthiness checks. If available this last source of information is to be preferred since it is the best indicator of the actual distance travelled by cars.

3.2 RED and SPIs to be monitored

The objective is to find the best complementarity between the classical methods of RED and SPI estimation (as defined in SafetyNet) and the potential new ones.
Classical methods typically measure the behaviour of many vehicles or drivers at a specific location, e.g. speed loops.
When using naturalistic driving observations, it is harder to control the data collection as the drivers drive on any kind of road, in any kind of traffic and in any kind of weather. This makes it crucial to be able to identify all the variables and circumstances that might have an impact on the SPIs & RED, in order to compute meaningful SPIs & RED with a proper filtering and aggregation.
The indicators have to be relevant for both national and ERSO levels. It is crucial to guarantee the validity of the collected data and determine, for each country, how representative of the country they are and how they can be compared with other countries. It is also important to define the accuracy of the RED and SPI values and to provide a probability for each of them.

3.2.1 Helpful considerations and definitions

Data exploitation design
To process the RED and SPIs it is proposed that each country is in charge of the calculation of their respective indicators; only the ones necessary for the ERSO are shared; details are stored at national levels.

Near crashes
As has already been explained near crashes will not be studied in the scope of DaCoTA. However data about the dynamics of the vehicle will be considered as a source of information for the future, when knowledge on this matter will permit to define more accurately extreme events (such as very strong braking, safety systems use (ABS, ESC)).

Key concepts
While designing Risk Exposure Data or Safety Performance Indicators some principles should be kept in mind.

- The data sources' relevance, accuracy and availability have to be investigated in detail and taken into consideration
  - Definitions of context variables might be different between countries, especially when using a GIS (for example, the meaning of "urban" or "motorway" or the availability of legal speed limit…) or any third party database.
  - Measurements might be different if collected through sensor or through CAN bus (for example, vehicle speed…)
  - When comparing countries, it is critical to make sure that comparisons are done with similar base data.
- The time window, the filtering and the clustering should always be balanced with the accuracy of the indicator and it is important to be able to pass this information to the final data set used for the SPI calculation. This can be achieved by use of "Sub Sample Characteristics", or SPI SSC.

    - At the participant level, when selecting the time window (for example, during March 2011), when filtering (e.g. peak hours…) and a specific clustering (e.g. to compare motorway and urban situations), each SPI should be given with its SPI Sub Sample Characteristics that gives, for each driver, the amount of data that corresponds to the constraints (e.g., the time driven during March 2011, in peak hours, on motorways).
    - At the country level, when aggregating data from all the participants, the participant SSC should be carefully studied to determine if it is relevant to use the data for the country aggregate (for example, include a driver that spent 1 minute within the SPI-constraints?). Once aggregated at country level, the country SPI should also have a Sub Sample Characteristic that describes the number of participants finally used for the calculation and their total driving time.
- It is necessary to apply filters that guarantee that the data that remains after filtering is homogeneous. This can be used in two contexts:
    - When trying to obtain homogenous situations in terms of traffic density. The filters consist in removing all the data collected during daily peak hours, which are more prone to traffic jams. The filter can be 7h30-9h30 and 16h00-19h00.
    - When trying to obtain homogeneous “actually driving” situations. The filters remove all data with a vehicle speed below 5 km/h.

While fully aware that it is possible to create other indicators than the ones proposed by DaCoTA, it is strongly recommended to follow these 3 basic principles as they should guarantee the relevance of the newly designed SPIs.

Definition of Trips

Some calculations will need to consider the concept of trips. The authors propose to consider a trip to start/finish once the ignition is switched on/off. A trip can be prevented to be erroneously divided into several trips (by events like switch off while waiting in a queue), by joining two successive trips if the delay between the end of the former and the beginning of the latter is short (Wolf et al., 2004).

Definition of Day time and night time

Some calculations propose to compare day-time and night-time conditions and aim to differentiate situations in daylight and at night. As daylight periods vary during the year and also according to the latitude, harmonisation to obtain comparable and relevant “day” and “night” conditions is required.

The methodology proposed is to use a floating hour range, computed according to the time and position of the observation. This can be done by using a table giving for each latitude, longitude and day of the year, the time of sunrise and sunset, and to compute the daylight, night and twilight (2 hours in between) period.

Definition of Weather conditions

For homogeneity, some calculations need to filter out data during bad weather.

It is possible to use the sensors available in the vehicle (like the screen wipers activation, or the luminosity sensor used for automatic light activation) or to use third party databases, giving weather information for each various location.

Combining the two pieces of information will increase the accuracy of the weather information. It is proposed to focus on only 2 classes : “good” weather, which is when the weather report is set to “sunny” or “cloudy” and “bad” weather, which includes all other possible weather reports (for example, like rain, snow, fog…).

3.2.2 Procedure to RED estimation

3.2.2.1 Context and definition

Risk Exposure Data (RED) is used to calculate road safety risk indicators, which enable comparisons over time and countries relative to the amount of exposure. In other words, risk (road safety risk indicator) can be defined as a rate (SafetyNet, 2005):

$$\text{risk} = \frac{\text{road safety outcome}}{\text{amount of exposure}}$$

Figure 1 Road safety risk indicator equation

The EC project SafetyNet has identified 4 Risk Exposure Data of major interest for Road Safety (ERSO, 2010b)

1. Vehicle mobility of a country: “the total distance travelled within the borders of the country by road motor vehicles”. The according unit is vehicles x km.
2. Person mobility of a country: “the total distance travelled within the borders of the country by persons, regardless of their nationality”. The according unit is persons x km. This includes passengers.
3. Number of trips of a country: “the total number of trips made by persons, regardless of their nationality, in the country.” A return trip counts as two.
4. Time in traffic of a country: “the total time spent travelling by persons, regardless of their nationality or their mode of transport in the country”. The according unit is a unit of time (hours, minutes).

The SafetyNet project proposes to base RED estimation on a data collection framework including both travel surveys and traffic counts elements, each method presenting different features and advantages. Travel surveys have the major advantage of providing exposure data combined per person, vehicle and sometimes road characteristics. On the other hand, traffic count systems are the only method which can provide practically continuous exposure measurements over time.

Naturalistic driving studies consist in the observation of a sample of drivers. The vehicle of each driver is instrumented in order to record during his/her everyday mobility information on behaviour, vehicle position/dynamics and driving context.
So ND forces us to focus on the individual mobility as a motorist. In balance, ND gives us the opportunity to monitor the distance travelled and the time spent driving according to the driving context that can be described in terms of road type, period of the day/week/year, weather conditions, presence of passengers… We have also access to descriptive statistics of the trips, in terms of average number of trips by year, distribution of duration and length of a trips.
Using ND data to estimate RED assumes that both the driver sample and the instrumented vehicle sample can be weighed to obtain representative outcomes of the countries driver population and vehicle fleet.

The authors propose to calculate the five following RED from the ND data, all calculated over one year, within the country:

1. Mean distance driven by a passenger vehicle
2. Mean distance driven by a driver at the wheel of his/her main vehicle
3. Mean time spent by a driver at the wheel of his/her main vehicle
4. Mean number of trips made by a driver at the wheel of his/her main vehicle
5. Characteristics of trips made by a driver at the wheel of his/her main vehicle: distribution of length, duration and speed.

Multiplied (weighed) by the number of vehicles or drivers these values also describe the total mobility in a country.

3.2.2.2 Measuring requirements

The calculation of RED requires basically the continuous measuring of a set of data including date/time and GPS position. The difficulty raised by the estimation of the RED is that we need to be exhaustive in the recording of the trips made by the instrumented vehicle. This means that the data acquisition systems (DAS) must be always present in the vehicle. This necessitates an on aboard system and not a mobile system, which may be forgotten at home. This also means that the DAS must be robust to limit the occurrence of breakdowns. The RED estimation is dependent on the GPS receiver that gives the position change of the vehicle. Unavailability and inaccuracy of GPS coordinates, will negatively impact their estimation.

The calculation of some RED needs to deal with the concept of trip (see 3.2.1).

Specific databases are necessary for the disaggregation or filtering of the RED according to the driving situation characteristics, like a geographic information system (GIS) (map GPS coordinates to infer the road type) and light condition and weather data bases (see 3.2.1).

The calculation of the RED needs to have an identification of the driver to keep only the trips where the ND participant is the driver. It will also be interesting to have an indication of the presence of passengers in the vehicle.

Lastly, the disaggregation per driver and per vehicle needs a set of data describing the participants sample in terms of driver characteristics and vehicle characteristics

3.2.2.3 Filtering of naturalistic data

Two filters have to be applied on the ND data for the calculation of RED.

The first filter concerns the identification of the driver. The four RED that describe the mobility (numbers 2-5, see above) keep only the trips where the vehicle is driven by the participant of the study. For the first RED only (total mobility of the vehicle), information is needed on the trips where the vehicle is driven by the secondary drivers of the car.

The second filter aims to select only the mobility within the borders of the country. The part of the trips outside the borders of the country needs to be removed. For the calculation of the trip number, the authors propose to exclude trips that cross the borders of the country.

3.2.2.4 Disaggregation of the RED

Apart from totals, also details on the mobility are needed. These details can be clustered into four areas according to the Driving situation, Trip characteristics, Vehicle characteristics and Driver characteristics.

Driving situation characteristics	• Road type (urban, outside urban area, motorway) • Hour and period of the day (dawn, daytime, dusk, night-time) • Day and period of the week (week day, week-end) • Month and period of the year (spring, summer, autumn, winter) • Weather condition (clement, adverse) • Presence of passengers
Trips characteristics	• Duration of the trip • Local or far distance mobility (around the participants home) • Regularity of the trip (done more than 10 times a year)
Vehicle characteristics	• Vehicle type • Vehicle age, engine size, mass
Driver characteristics	• Age ,Gender • Driving experience • Occupation[2] • Home location[3] • Country

Table 3.2. Clustering variables used for the disaggregation of RED

3.2.2.5 Aggregation of the RED at the level of the country

The values obtained for a given (stratified) sample of vehicles / persons need to be weighted to obtain a value describing the general exposure at the level of the whole fleet of motor vehicles or at the level of the whole population of the country.

3.2.3 Procedure to SPI estimation

It is possible to build 3 different types of SPIs.

- **Behavioural SPIs** refers to an indicator that describes drivers' behaviour toward a specific safety issue. The data may permit to identify some of its determinants (for example, speeding on motorways or seat belt use by age of the driver). Generally homogeneity filters are applied.
- **Descriptive SPIs** refers to an indicator that quantifies the occurrence of a phenomenon. This can be useful to assess if a safety policy is followed or not, but lacks the possibility to understand the causes (for example, time spent speeding or time spent without seat belt, the number of Left- or U- turns). Generally all data are to be used.
- **Situational SPIs** refers to an indicator that describes driver behaviour in very specific situations which are relevant in terms of road safety. They require an accurate assessment of the driving situation and manoeuvre (for example, adequate use of turning indicator when turning or overtaking). This will not be investigated in detail within the frame of DaCoTA.

[2] The occupation and more precisely the fact to be part of the working or non-working population, has a strong impact on mobility due to the part of professional trips, including commuting.
[3] The urban density of the home location has a strong impact on the motorization of a household and on the vehicle mileage and availability and use of public transport.

The three families are complementary. The SPIs of these categories sometimes differ only by a filtering or a clustering.

Table **3.3** shows an overview of the behavioural and descriptive SPIs to be monitored using Naturalistic Driving. Even if most of them are technically feasible without too many constraints, the limits of this feasibility are described in detail in the relevant chapters of D6.2A, as are their added value and the considerations to keep in mind when interpreting the results. For each SPI the process of data collection, filtering, clustering, processing and analysis is discussed.

	Behavioural SPIs	Descriptive SPIs
Excessive speed	-Mean speed and standard deviation of speed in free flowing traffic conditions -V85 in free flowing traffic conditions -Percentage of driving time over the legal speed limit in free flowing traffic conditions -Percentage of driving time 10 km/h over the legal speed limit in free flowing traffic conditions	-Percentage of driving time over the legal speed limit -Percentage of driving time 10 km/h over the legal speed limit
Seat belt use	-Percentage of trips by seat belt use (with, without, partial) -Systematic use of seat belt: percentage of trips with immediate seat belt fastening	-Percentage of driving time with seat belt fastened for drivers. -Possibly front passengers and rear passengers.
Daytime running light use	-Percentage of trips by DRL use (with, without, partial) during daytime and clement weather conditions -Systematic use of DRL: percentage of trips with immediate DRL switching on during daytime and clement weather conditions	-Percentage of driving time with DRL switched on during daytime. -Idem during clement weather conditions
Short headway	-15th percentile of the headway in vehicle following situations -Percentage of driving time by headway-class (>2 sec, 1–2 sec, 0.5–1 sec and <0.5 sec) in vehicle following situations -Frequency of occurrences of short headways periods (headway less than 0.5 second during at least 0.2 seconds) in vehicle following situations	-Percentage of driving time by headway class (>2 sec, 1–2 sec, 0.5–1 sec and < 0.5 sec) -Frequency of occurrences of short headways periods (headway less than 0.5 second during at least 0.2 seconds)
Strong deceleration	-15th and 85th percentile of the vehicle in deceleration situation -Percentage of deceleration time by deceleration class (>-0.25g, -0.25g – -0.50g and < -0.50g) in deceleration situations	-Frequency of strong decelerations (deceleration inferior to -0.5g during at least 0.2 seconds) by hours driven
Safety Systems use		-Frequency of safety system activation (Anti-lock braking system and Electronic stability control system…) by hours driven

Table 3.3. Overview of behavioural and descriptive SPIs

3.3 Legal and ethical issues

Data collection by Naturalistic Driving can give rise to legal and ethical issues. The overview in this section is based on the FESTA-Handbook on conducting Field Operational Tests and Naturalistic Driving trials (FESTA-consortium, 2011) and recent Naturalist Driving projects such as PROLOGUE and INTERACTION.

3.3.1 Legal requirements

At the European level there are at least two relevant directives. Directive 95/46/EC concerns the protection of individuals with regard to the processing of personal data and the free movement of such data. Directive 2002/58/EC concerns the processing of personal data and the protection of privacy in the electronic communications sector.

Key issues raised by Directives 95/46/EC and 2002/58/EC

- Personal data must be processed fairly and lawfully, and collected for specified, explicit and legitimate purposes, only after consent by the subject from whom data are collected. Objections are still possible afterwards;
- The controller must give information relating to the identity of the controller, the purposes of the processing, recipients of the data etc. He must implement measures to protect personal data against accidental or unlawful destruction or accidental loss, alteration, unauthorized disclosure or access;
- The controller must report the processing to a supervisory authority that keeps a register of reported processing operations.

In addition to the EU requirements, states often have relevant national Acts, Regulations, Directives and requirements when conducting a study using personal data.

3.3.2 Participants

Recruitment

In participant recruitment it is important to ensure that participants hold valid driving permits. The coverage of their insurance needs to be checked, in particular whether participating in the trial doesn’t invalidate the insurance.

Agreement

In the agreement all arrangements between participant and research organisation and the responsibilities of both parties are stipulated. There are a few topics that should at least be covered by the participation agreement:

- Costs; who is responsible for certain costs (e.g. vehicle maintenance, damage to vehicle, insurance excess, traffic penalties)
- Benefits; what is the allowance the participant will receive and are there possible other benefits (e.g. use of instrumented vehicle, fuel cost reimbursements)
- Risks; is the participant exposed to increased risks (involvement in crashes or theft of the vehicle or ND-device) and if so, what is done to minimise the risks?
- Withdrawal; is the participant free to withdraw his/her participation to the trial at any moment and how will this affect the agreed participation allowance.

- Confidentiality of recorded data; what will/won't be done with the data gathered? Which parties will own and have access to the data (during and after the trial)?
- Who is allowed to drive the vehicle, how will data recorded of non-participating drivers be dealt with?

3.3.3 Data protection and ownership, risk assessment

Data acquired by means of Naturalistic Driving will contain privacy sensitive data. It is important to determine what data is gathered and how this data will be protected.

Some personal data are needed to communicate with the participant and to describe the sample for stratification purposes. These should be stored separately. All other data gathered should be properly anonymized. Data that could lead to identification of the participant should never be released to other parties.

In the process of collecting data to building a database, several operations are required. In data transfer from the vehicle to the research institute it is important that access is regulated and data is stored secured in such a way that unauthorized access is impossible. This implies that in-vehicle stored data should be secured (or encrypted) to avoid unauthorized access (e.g. in case of burglary). Also data transfer should be a secured process and intermediate storage devices should be properly cleaned after use.

Also on the final storage device, data should be stored properly secured and access to the data should be regulated. All 'users' of the data should be briefed in case the data contains privacy sensitive information and confidentiality agreements should be signed.

Vehicle instrumentation and approval

Observation equipment shouldn't interfere with the normal functioning of the vehicle and its (safety) systems. Vehicles should be instrumented by professionals that are authorised to perform the installation and make the necessary adjustments, without invalidating the approval for on-road use of the vehicle.

Risk assessment

A comprehensive risk assessment plan should be prepared that demonstrates that the risks have been properly managed. The plan should contain all identified risks and describe how each specific risk is approached. A lawyer could be consulted to help identifying potential risks and advise on managing these risks.

4. SMALL SCALE NATURALISTIC DRIVING PILOTS

In task 6.3 two pilot studies have been done, in Austria and Israel. In Deliverable D6.3 the pilots are described, one for each of the two DAS scenarios of D6.1.

4.1 Austrian pilot (scenario 1)

For Scenario 1 an off-the-shelf system for Naturalistic Driving observation (pDrive lite®) was installed in 10 cars. It collected date/time, speed, acceleration and GPS positions. For the identification of the driver a video camera was used.
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. Data was available for road type but not speed limits. Without headway measurement it appeared difficult to know whether the driver had a free choice of speed or that he/she was influenced by the vehicle in front.
At the beginning of the field trial people filled in a questionnaire on driver and vehicle characteristics. During the study, every participant was asked to fill in a travel diary for one week, which should provide information of every trip, e.g. the distance travelled, the number of trips as well as possible correlation of subjects' information and collected technical data. Once during and once after the field trial the participants were asked for their experiences with pDrive lite®, such as awareness of its presence, influence on their driving behaviour and difficulties with the system.

4.2 Israel pilot (scenario 2)

The Israeli study aimed to collect data according to Scenario 2. 7 participants were recruited. The DAS consisted 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 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. 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 measurements were taken when a predefined event occurred, for example when the lane departure and collision warning thresholds were met.
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, which rely on Can-Bus data, were more problematic.

4.3 Conclusions from the pilots

For the results of the pilot studies in terms of data gathered we refer you to D6.3. 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. Different approaches used by the studies highlight the importance of defining sampling rate and trip definition precisely before data collection starts. Although different sampling rates and trip definitions do not impact the total distance and driving time, the trip definition does affect the number of trips recorded and results in different lengths and durations of single trips. The trip definition must be carefully defined as it may have implications for database structure and handling.

Regarding sampling rate a compromise must be found between huge amounts of data and the gain/loss of events missed by averaging the data over the sampling interval time.

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

- A detailed planning and recruitment procedure in necessary. Besides that 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 data losses).
- Relatively cheap, off-the-shelf devices can be sufficient for a ND study. 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 and to store it 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 operationalize them. Depending on what conclusions need to be drawn, more or less additional information may be needed.

DaCoTA Task 6.3 demonstrated the capability and usefulness of collecting very detailed data on exposure, speed and associated characteristics. It shows that it is possible to obtain a very detailed account of exposure and safety related behaviour, which it is, so far, not possible to collect by other methods. The scenario 1 data are limited to exposure, speed and acceleration. Scenario 2 data covers a wider range of variables and would seem to have an added value to scenario 1.

5. ND FOR MONITORING PERFORMANCE AND EXPOSURE: CONSIDERATIONS FOR IMPLEMENTATION

In task 4 a broader look is taken of the aspects to be taken into account when implementing ND research for monitoring purposes, based on and reviewing the findings of the preceding deliverables in this Work Package, and discussing a number of practical issues.
The final chapters of deliverable D6.4, contain a concise summary of the whole project and are therefore largely reproduced in the sections 5.4 and 5.5.

5.1 Budget allocation and priorities

The available budget will be a decisive factor shaping details of the study. When implementing a naturalistic driving study, one should dimension carefully (at least) 3 major budget allocations:

- For the data collection systems,
- For the sample recruitment,
- For the development of SPIs & RED calculations and analysis.

The part of the budget of the study dedicated to data collection systems should be significant enough to permit the purchase of a device corresponding to the scenario 2 specifications.
The budget of the study dedicated to the sample should be spent by favouring the size of the sample over the number of countries that perform the study. This will make it possible to immediately obtain results that are meaningful for the country and that can be compared relevantly to the other countries' results. It will also decrease the time necessary to investigate in detail the legal and ethical requirements. Once the first countries are operational, it will be possible to extend the study to other new countries in a second step, which will also allow the use of the experience obtained during the first implementation.
The budget of the study dedicated to the SPIs & RED development should be spent by favouring the RED development and the SPIs linked to excessive speed, as they can be compared to classical SPIs and act as a way to evaluate the methodology and the results, and the SPIs that have a clear added value compared to classical methods (Short Headways, Strong deceleration and braking, Safety System use, …). Once the first SPIs are operational, it will be possible to extend the study in a second step to other SPIs.

5.2 A third scenario

Following the wish to monitor also other safety relevant SPIs, such as drug use, inattention, distraction, fatigue and near crashes, it is explored what would be the consequences if a part of the sample is equipped with video cameras. This leads to the introduction of a third scenario in addition to the two scenarios introduced in D6.1 (of which scenario 2 substantially depends on CAN data, which on the short and medium long term is hard or impossible to come by). With increasing complexity and costs, this will result in an increasing amount of information. The third scenario that is presented is monitoring near crashes by event-triggered video recordings. In combination with RED, near crashes can be a useful SPI to compare countries and developments over time.

Minimally this requires a video camera with a fairly wide-angled view, which permanently records the traffic situation ahead of the vehicle. To prevent unmanageable quantities of data the recordings are discarded after a short time, except data of periods immediately before, during and after events indicating a near accident, such as harsh braking, accelerating or steering movements (thresholds to be defined).

The events that trigger the video recording can be seen as near crashes, however, video data is necessary to judge the correctness and to minimise false positives. Thus a more reliable picture of the number of real near crashes can be drawn. In addition, the video data gives background information about the seriousness of the near-crash and the road and traffic circumstances. The video data can be used for research purposes as well, studying the circumstances of near crashes.

It must be noted, however, that an event-triggered video does not give the full picture; it does not provide information about near crashes that did not involve an action (braking, steering correction) of the driver, but where a crash was avoided by an action of another road user.

5.3 Towards a scenario 4?

So far, the scenarios presented have in common that SPIs and RED data is collected through equipment and sensors added to the vehicle. This has proven to be a feasible approach that can provide useful information. However, given that fairly large samples are needed, it is also a rather costly and labour intensive approach. In addition, the reliability of the data depends on the recruitment of a representative sample of the population, an effort that is not easy at all.

In theory there is a fourth scenario, that is not dependent on equipping cars nor on voluntary participants, but a scenario that extracts data directly from all cars based on CAN-data, OBD, and other trip and travel data collected automatically by the vehicle (e.g. trip recorder, event recorder, E-call-related data). This approach would result in more reliable data because it would include the complete passenger car fleet and other motor vehicles.

This option, however, is not something that can be realised overnight. One important aspect is that, currently, car manufacturers apply their own technical specifications for most of the CAN and OBD data and they are not very keen on sharing these with other car manufacturers or external parties. This means that this type of data is not widely accessible nor comparable between car makes and models.

Given the theoretically promising characteristics of this approach, it is time now to explore the feasibility and future options and the roles of the various parties involved. As a first step, the requirements for this data need to be elaborated:

This is a process that needs to take place in consultation with the car manufacturers. Timely involvement may help to realise their commitment and a positive attitude.

Furthermore, the European Commission can play an important role as well by promoting or maybe even regulating harmonisation of, and free access to the

relevant data of the different European car makes. An important condition is that the access and use of the data do not conflict with European or national privacy legislation. Since, eventually, also non-European car makes and models would need to be included, this effort would also affect car manufacturers outside Europe, because it might result in specific requirements for non-European cars that are imported in the EU.
An important other aspect related to this approach would be the public support for transferring all sorts of privacy-sensitive data from their car to a central database. Even though subsequent data aggregation and data storage can be arranged so that information cannot be traced back to individual vehicles, it is not unlikely that a majority will develop strong anti-'Big Brother' sentiments. If this means that people have to give their informed consent for logging the data of their car, there is again the issue of a representative sample.
It will take a long time to make this approach work. But in the end, an approach that directly extracts the relevant information from the vehicle, seems to be a more solid and sustainable approach than monitoring through ND research. Therefore, it is recommended to start discussions now, trying as a first step to break the taboo of sharing some information between different car manufacturers.

5.4 Conclusions & Recommendations

The main conclusion of the project is that, in principle, the ND approach has substantial added value compared to more traditional data collection methods like crash registration and surveys, because ND ensures continuous, automatic and standardized data collection. This is true for both SPIs and RED. A prerequisite is that similar data acquisition systems and methods/definitions are applied. These systems as well as technology for data transfer and data storage is available and has proven to be operational. Though the current Deliverable is purely focused on road safety and exposure data, the collected data will also be useful for other transport areas, in particular eco-driving, traffic management and even road maintenance.

In order to get reliable information, a fairly large sample is needed. The exact size of the sample depends on the variation in behaviour in the population and the required level of precision of the results. Assuming that the sample is drawn in a cleverly stratified way, a sample of 10,000 drivers per country seems to be the absolute minimum for RED such as the annual mobility. Experiences in the USA show that it may require substantial effort to get sufficient participants with the required characteristics to allow for a good stratification.
With regard to data collection, based on cost considerations, three scenarios are distinguished. It is recommended to start off with Scenario 1: a low-cost simple, off-the-shelf simple data acquisition system (e.g. an OBD GPS tracker or a Smart Phone) and a limited number of additional sensors, measuring:

- Vehicle mobility
- Person mobility
- Number of trips
- Time in traffic
- Speed (excessive)

- Seat belt use
- Light use

In addition, the data acquisition system would need to register continuously the time, the date, and the location (GPS). In combination with a map matching tool, and an indication of the road class and the speed limit, this would allow comparisons of the mentioned RED and SPIs and would give an indication of the occurrence of excessive speed. For cross-national comparisons it is important to define a (limited) number of comparable road classes. Furthermore, as a relatively simple driver identification method, it is recommended to use a magnetic swipe card or an RFID tag.

At a later stage, additional SPIs and network characteristics could be added successively (Scenario 2), including:

- Time headway
- Acceleration
- Lane departures
- Inappropriate speed
- Signal use
- Junction type

A few SPIs are very relevant from a safety point of view, but with current techniques cannot be measured reliably in an unobtrusive way. This applies, in particular, to alcohol and drugs use.
In addition, SPIs that would need continuous video recordings do not seem to be feasible in the short term, because this results in huge amounts of data and extreme high costs for the related data transfer and data coding. That means that the SPIs fatigue, inattention, distraction and the (proper) use of child restraints cannot be monitored by means of Naturalistic Driving.

Furthermore, as Scenario 3, it is recommended to equip a limited number of cars also with an event-triggered video in order to monitor numbers of near crashes as yet another relevant SPI. As a very useful side product, this effort will provide data that can be used to further specify and refine the quantitative and qualitative relationship between near crashes and real crashes.

For all three scenarios very strict European and national legislation applies in relation to data protection and privacy, among others requiring all participants to sign an informed consent.
Though it is impossible to give a reliable estimate of the costs involved, the costs can be expected to be fairly high. Just assuming a simple OBD GPS tracker of €100 and a participant incentive at the value of €400 would add up to an annual 5 million euro per country assuming the recommended sample size of 10,000 drivers. And this amount does not include the costs of man power related to participant recruitment and contact, and the organisation and management of the data collection, transfer, storage and analysis.

In short:

- ND research can provide very useful information about several very relevant SPIs and RED for cross-national comparisons and comparisons over time.
- Technology for data collection, data transfer and data collection is available and has proven to be operational, at least on a small and medium scale.
- Bottlenecks in the successful implementation of ND research for monitoring may be:
  - Recruitment of sufficient participants
  - Harmonization of definitions of variables, disaggregation levels and analyses
  - Operation costs

Hence, in parallel, it is recommended to start exploring the possibility of a scenario 4 now, i.e. a scenario where relevant data is extracted directly from the vehicle via CAN-bus, OBD, and other data collected automatically by the vehicle. In theory, a lot of relevant information is already available with no or little additional costs; in practice, however, the information is not generally accessible nor comparable between car makes and models.

One of the first steps, in consultation with the car manufacturers, is an elaboration of the requirements for this data: what is available, needed, technically feasible. The European Commission can play an important role as well by promoting or maybe even regulating harmonisation of, and free access to the relevant data of the different car makes and models.

Whatever data is collected, whatever data acquisition system is applied, the ND approach for monitoring, as discussed in this report, is largely oriented towards passenger cars and their drivers; as a consequence, the resulting information about SPIs and RED is restricted to that user group.

The ND methodology can also be applied to other vehicles, but that will involve several additional organisational and technical requirements and related efforts. Current technology is not sufficiently robust and stable to apply to cyclists on a large scale, nor to pedestrians. This all means that getting an overall view of the safety related behaviour and the exposure to risk of *all* road users, requires more additional methods including the more traditional surveys, trip diaries, and observations.

5.5 A central role for Europe

Despite various bottlenecks and challenges, the potential of ND research for monitoring purposes is sufficiently large to start off with the implementation of Scenario 1. Since harmonisation and international comparability of data are the key reasons for this effort, there is a central role for the European Commission in initiating this task and taking the lead, most likely within the ERSO framework. A stepwise approach is recommended, including successively:

1. Creating support and finding budget by presenting the case to the relevant road safety bodies at European and Member State level, explaining the need for harmonised, comparable international data, the ND approach, and its added value.
2. Preparing a detailed description of all practical implementation aspects, including the functional specifications of data collection equipment, participant selection,

data transfer and storage, definitions of variables, disaggregation levels and analyses.

3. Identifying the relevant national organisations, responsible for national data collection and pre-analyses, and fine-tuning data collection procedures (including legal aspects) and variable definitions in consultation with them.
4. Developing and equipping a database at EU level and defining the required data to be provided and the procedures and time schedule, in consultation with the relevant national organisations.
5. Setting up European-wide communication strategies to guarantee maximum dissemination and use of the collected data.
6. Setting up one year national pilots in at least four Member States.
7. Adapting procedures and definitions, based on the pilot experiences.
8. Successive implementation of Scenario 1 in additional Member States.

Parallel to steps 6 and 7, Scenario 2 (additional SPIs/RED) and 3 (monitoring near-crashes) can be elaborated, piloted and implemented, applying a similar stepwise process.

From the very beginning, the EC is advised to initiate discussions with the car manufacturers, using existing discussion platforms, with the aim to explore longer term possibilities of Scenario 4, i.e. the scenario where relevant data is extracted directly from the vehicle.

Finally, in order to elaborate these steps and to assist the EC in performing these steps, it is advised to compose a consortium of organisations. Possibly, this can be part of the future research agenda that is currently being prepared by the PROS consortium.

REFERENCES

Bonnard, A., Brusque, C., Hugot, M., Commandeur, J. and Christoph, M. (2012). Study design of Naturalistic Driving observations within ERSO – Development of innovative indicators for exposure and safety performance measures, Deliverable 6.2A of the EC FP7 project DaCoTA.

Commandeur, J.J.F. (2012). Sampling techniques and naturalistic driving study designs, Deliverable 6.2B of the EC FP7 project DaCoTA.

ERSO (2010). Information on SafetyNet Available at: http://ec.europa.eu/transport/wcm/road_safety/erso/safetynet/content/safetynet.htm [21.10.2010].

FESTA-consortium (2011). FESTA Handbook Version 4. Deliverable 6.4.

Pilgerstorfer, M., Runda, K., Brandstätter, C., Christoph, M., Hakkert, S., Ishaq, R., Toledo, T., Gatscha, M. (2011). Small Scale Naturalistic Driving Pilot, Deliverable 6.3 of the EC FP7 project DaCoTA.

Rofique, J., A. Humphrey, K. Pickering, and S. Tipping (2010). National travel survey 2010. Technical report, London, United Kingdom.

SafetyNet, Yannis G.Y. et al. (2005). State of the art Report on Risk Exposure Data. Deliverable 2.1 of the SafetyNet IP. European Commission, Brussels. See also http://ec.europa.eu/transport/wcm/road_safety/erso/data/Content/definition_road_safety_risk_indicator.htm

Talbot, R., Meesmann, U., Boets, S. and Welsh, R (2010). Naturalistic Driving Observations within ERSO, Deliverable 6.1 of the EC FP7 project DaCoTA.

Van Schagen, I. and Reed, S. (2012). Naturalistic Driving for monitoring safety performance indicators and exposure: considerations for implementation. Deliverable 6.4 of the EC FP7 project DaCoTA.

Wolf, J., Schönfelder, S., Samaga, U., Oliveira, M., and Axhausen, K.W., (2004). 80 weeks of GPS-traces: Approaches to enriching the trip information, Transportation Research Record, 1870, 46-54.