Road Safety Data, Collection, Transfer and Analysis

Deliverable 6.1 Naturalistic Driving Observations within ERSO

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LIST OF ABBREVIATIONS

ADAS	Advanced Driver Assistance Systems
AT	Austria
BAC	Blood alcohol concentration
BE	Belgium
CAN	Controller Area Network
CARE	CARE is a European Community database on road accidents resulting in death or injury.
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DAS	Data Acquisition System
DD/MM/YY	Day/Month/Year
DE	Germany
DK	Denmark
DRL	Daytime running light
DUI	Driving under influence of alcohol
DUID	Driving under influence of (illicit) drugs
EC	European Commission
ECMT	European Conference of Ministers of Transport – now known as International Transport Forum
EE	Estonia
EL	Greece
ERSO	European Road Safety Observatory
ES	Spain
ESC	Electronic stability control
ETSC	European Transport Safety Council
EU	European Union
EUROSTAT	EUROSTAT is the statistical information service of the European Union
FI	Finland
FR	France
GPS	Global Positioning System
HH:MM:SS.FF	Hour/Minute/Second/Fraction

HU	Hungary
Hz	Hertz
ID	Identification
IE	Ireland
IL	Israel
IRF	International Road Federation
IRTAD	International Transport Forum – International Traffic Safety Data and Analysis Group
ISA	Intelligent speed adaptation
IT	Italy
ITS	Intelligent transportation system
IVIS	In-Vehicle Information Systems
km	kilometres
LT	Lithuania
LU	Luxembourg
LV	Latvia
MPV	Multi-purpose vehicle
MT	Malta
N/A	Not applicable
NHTSA	National Highway Traffic Safety Administration.
NL	The Netherlands
NO	Norway
OEM	Original equipment manufacturer
PL	Poland
PT	Portugal
RED	Risk exposure data
RFID	Radio-frequency identification
RPM	Revolutions per minute
RSPI	Road Safety Performance Indicators Expert Group of the EC
SE	Sweden
SI	Slovenia
SK	Slovakia
SPI	Safety Performance Indicators
TERN	Trans-European Road Network

UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
USA	United States of America
WP	Work package

EXECUTIVE SUMMARY

This is the first 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 30th June 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 for 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 with 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 Observations to continuously monitor relevant road safety data within the framework of the European Road Safety Observatory.

This deliverable reports the outcome of the first task which was to generate an inventory of variables and measurement tools necessary to monitor road safety through Naturalistic Driving Observations. This was achieved by performing the following activities:

1. Generating an inventory of relevant variables to monitor road safety within ERSO.
2. Generating an inventory of relevant variables to monitor through naturalistic driving observation.
3. Combining 1 and 2 to define the variables to be measured within ERSO by naturalistic driving observation.

Chapter 1 covers the first activity of task 6.1 and aims at generating an inventory of relevant variables to monitor road safety within ERSO. This involved identifying the types of data required to monitor road safety which would provide evidence to assist the process of developing road safety policy independently of Naturalistic Driving methodologies. Important Risk Exposure Data (RED: vehicle kilometres, fuel consumption, person kilometres, number of trips and time in traffic) and Safety Performance Indicators (SPI: alcohol and drugs, speed, protective systems, daytime running lights) for road safety analyses and policy development were selected on the basis of previous research within the EC project, SafetyNet. Additional research topics were selected for inclusion based on their considered relevance in the PROLOGUE project and the expertise within DaCoTA WP6 (fatigue, distraction/inattention and headway). So far no indicators on these topics have been developed within ERSO; therefore, the investigation of these topics was based on a broader literature review. Other sources were also investigated with the aim of deriving additional ERSO data needs: CARE (as reported in the outputs of SafetyNet WP1) and an EU-wide survey of national policy makers.

For each topic relevant contextual variables are identified with regard to driver, vehicle, network and other (transient) context variables. Driver, vehicle and network

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

are relatively permanent factors whereas the other contextual factors are more transient and likely to vary from one journey to the next.

Moreover the importance of Near Crash information for the assessment of road safety outcomes is described.

Chapter 2 outlined the work undertaken and the outcomes for the second activity of task 6.1; *Inventory of relevant variables to monitor through naturalistic driving observation*. Based upon literature and knowledge available from previous and current Naturalistic Driving studies, this activity has identified the research topics that can be addressed by Naturalistic Driving Observations and in particular those that are considered relevant and important in the context of road safety research and policy development. Regarding Near Crashes valuable information was gathered during the FOT-Net workshop, which was organised in partnership with DaCoTA and PROLOGUE.

This chapter identified the variables – both those related directly to the topic and more generally to the driving context – that have been collected or are necessary to collect to explore the topics covered in chapter 1 as well as a number of categories of driver related topics that were considered to be particularly appropriate for exploration using the Naturalistic Driving approach (Near Crashes, Lane change, lane position and lane keeping; Aggressive driving – compliance with regulations; Learning; Decision making, errors, driving style/performance)

Chapter 3 used the information presented in Chapter 1 and Chapter 2 to consider the feasibility, desirability and practicability of measuring variables that can be used to monitor road safety with Naturalistic Driving Observations. This was done within the framework of conducting a large scale activity. It is envisaged that the large scale activity will involve instrumenting a large number of passenger cars – perhaps 20,000 – within the EU27 countries. Such numbers necessitate a simple low cost device that is easy to fit. This will also result in a large amount of data being generated so another requirement is for the data to be automatically processed and analysed e.g. through the use of scripts etc.

Chapter 2 demonstrated that it is possible to collect a large number of variables using Naturalistic Driving methods, however high costs are associated with some variables – particularly those reliant on video analysis – and if many different sensors are required then the Data Acquisition System (DAS) becomes very complex and potentially unreliable. It is necessary therefore to balance the cost and complexity of the DAS with the ability to collect meaningful data.

Therefore, DaCoTA proposed two scenarios. Scenario 1 would be a basic DAS that comprises of a GPS logger and accelerometer. This would be a relatively low cost system that utilises existing technology such as that which exists on Smart Phones. Scenario 2 would supplement the Scenario 1 DAS with additional sensors or capability e.g. connecting to Controller Area Network (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. This is more of a tool box approach as it is not possible currently to measure certain variables due to cost (e.g. headway sensor), access (e.g. CAN) or availability of supplementary data (e.g. map detail) but maybe possible in the future. Video was not considered as part of Scenario 2 at this stage as it is currently considered to be too expensive to implement in the large scale activity. However this does not preclude the consideration of video at a later stage of the DaCoTA project.

Topics that rely heavily on the use of video are Fatigue, Distraction/Inattention, the Child Restraint component of Protective systems and Near Crashes. These were therefore excluded from consideration although it may be possible to measure some elements of Near Crashes with a Scenario 2 DAS. The topic Alcohol and Drugs was excluded as currently there is no reliable way of measuring whether drivers have drunk alcohol or taken illegal or medicinal drugs within a Naturalistic Driving study. The exposure measure Fuel consumption was suggested by SafetyNet as a proxy measure for Vehicle km and was only recommended to be considered if it was not possible to measure Vehicle km directly. As Naturalistic Driving allows the accurate recording of Vehicle km, Fuel consumption was not further considered. The final topic to be excluded was Learning. Although this could be seen as a policy priority, it was thought that learning would be best studied in a more detailed Naturalistic Driving study and that there would be little added value for including it in a long term monitoring activity beyond taking account of drivers' gained experience.

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

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
- Light Use

The deliverable concludes with summary tables of the specific variables that have been recommended for collection with a Scenario 1 and Scenario 2 DAS and the equipment/resources necessary. This was based on assessments of the current feasibility of collecting variables given the technology available now or in the immediate future. However this does not preclude the consideration of collecting additional variables within a large scale activity in the future if technology advances make this more practical.

As DaCoTA WP6 was tasked with defining which variables should be collected in a large scale Naturalistic Driving activity with the aim of monitoring Road Safety, the wider benefits of conducting such an activity have not been discussed. However if such a large scale activity was established, there may be benefits beyond road safety. For example, although excluded in this document as a measure of mobility or exposure to risk, Fuel consumption is relatively easy to measure and could provide valuable environmental and 'eco-driving' data.

INTRODUCTION

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Activity 1 examined the types of data required to monitor road safety which would provide evidence to assist the process of developing road safety policy independently of Naturalistic Driving methodologies. The main focus was on Safety Performance Indicators (SPI) and Risk Exposure Data (RED) as developed by SafetyNet as well as certain key topics thought to become more of a priority for policy making in the future (Distraction/Inattention, Fatigue, Headway). Chapter 1 reports on this activity by setting out the variables to be collected as recommended by SafetyNet for the RED and SPI and in the general literature for the other topics. Chapter 1 also discusses the data collection methodologies and issues in relation to RED, SPI and the other topics. Where possible, topics and variables with the highest policy priority were identified.

Activity 2 focused upon how the RED, SPI and other topics mentioned in Chapter 1 could be collected through Naturalistic Driving Observations. This activity also aimed to identify any additional topics that have been previously studied using Naturalistic Driving which would provide data useful in monitoring road safety. Chapter 2 presents the conclusions of this activity. It also examines the technical equipment and techniques required to collect such data through Naturalistic Driving Observations.

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The aim of activity 3 was to recommend the topics and variables that would be most appropriate to be collected as part of a large scale Naturalistic Driving activity. This was achieved by comparing the conclusions of activity 1 with regards to what data is important to collect to monitor road safety and the feasibility of collecting such data with Naturalistic Driving methodologies as indentified in activity 2. Chapter 3 describes the conclusions of activity 3. It sets out the considerations associated with a large scale Naturalistic Driving activity that aims to monitor road safety and describes the process of assessing which variables are appropriate to be collected within such an activity. DaCoTA's focus on using Naturalistic Driving Observations to monitor road safety throughout Europe imposes some limitations. The large scale activity is likely to collect data from at least 20,000 passenger cars. Such large numbers mean that only a limited number of variables can be collected with relatively basic equipment. In order to avoid limiting the scope of the large scale activity too soon, Chapter 3 proposes 2 Scenarios. The first sets out which variables could be collected through Naturalistic Driving Observations using basic low cost equipment and the second uses a 'tool box' approach to suggest how additional variables of potential interest but that require more costly and sophisticated equipment could be collected.

The outcomes from a relevant workshop are also incorporated into this report. On 30 November 2010 a workshop was held in Brussels to discuss common issues concerning the study of Near Crashes. The workshop was organised by FOT-Net, DaCoTA and PROLOGUE; workshop participants also included representatives from other key European activities including TeleFOT, EuroFOT SeMiFOT, INTERACTION, 2-BE-SAFE and the USA SHRP2 project (FOT-net, 2010). A key aim of this workshop was to work towards a common consensus of near crashes, and to reach a common definition across projects. DaCoTA WP6 delivered a presentation at the workshop on DaCoTA activities. The relevant outcomes from the workshop are presented in the relevant sections of this deliverable.

The deliverable concludes with a list of variables and the technical equipment necessary to collect them that should be considered for collection within a large scale Naturalistic Driving Observation activity.

Why monitor road safety with Naturalistic Driving Observations?

Accident and safety data have been shown to be highly informative about the issues preceding crashes and the circumstances of the event. However, there is still a substantial gap in knowledge concerning the driving decisions and actions taken in normal driving situations. Developments in technology now allow us to carry out the innovative observation methodology of Naturalistic Driving. This involves the unobtrusive collection of driver behaviour and vehicle data in naturalistic settings most frequently in the participant's own vehicle.

Data collected through Naturalistic Driving Observations has the potential to provide a high level of detail of driver behaviour in the pre-crash phase if a collision occurs and is thus a very useful complement to traditional accidentology approaches such as statistical database analysis and in-depth on-site studies. 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) and the investigation of driver behaviour. Naturalistic Driving Observations therefore have a great potential for road safety policy support relating to traditional measures such as education and training as well as technical measures. This view was strongly endorsed at the FOT-Net Near Crashes workshop and is discussed further in Chapter 1.

Liaison between DaCoTA WP6 and PROLOGUE

It was identified that there may be some overlap with the PROLOGUE project (PROmoting real Life Observations for Gaining Understanding of road user behaviour in Europe) which aims to contribute to the reduction of the number of road casualties in Europe by further exploring, developing and testing the Naturalistic Driving Methodology. The main objective of PROLOGUE is to prove the feasibility and usefulness of a large-scale European naturalistic observation study for road safety researchers, but also for other stakeholders with a direct or indirect interest in road safety, including the car industry, insurance companies, road user umbrella organisations, driver training and certification organisations, road authorities, and national and regional governments. An additional objective of the project is to assess the added value of the naturalistic observation approach for transport related environmental issues, e.g. eco-driving, and traffic management issues, e.g. highway capacity.

Therefore a liaison has been established between the two projects, DaCoTA and PROLOGUE, in order to best exploit the work being carried out for the benefit of both projects and to ensure that duplication of effort is kept to a minimum. A Memorandum of Understanding between the two projects has been established which sets out how they differ and how information and recourses can be shared between the two projects.

The key differences between the projects are as follows. PROLOGUE has the objective of developing the methodology for obtaining an in depth understanding of normal and pre crash driving behaviour within a large scale Naturalistic Observation study. Whereas DaCoTA's objective is to set out the requirements of a large scale research activity that continuously monitors road safety and thus provides ERSO with data on Safety Performance indicators (SPI) and exposure to risk (RED). DaCoTA will not focus on establishing the crash risk of engaging in certain behaviours, instead the focus will be on how often drivers routinely engage in certain behaviours that are considered to increase the risk of a crash e.g. speeding. PROLOGUE will focus on a limited sample of countries whereas the activity proposed by DaCoTA should collect data in all European countries that is representative of the driver population. DaCoTA also focuses only on passenger cars.

1. INVENTORY OF RELEVANT VARIABLES TO MONITOR ROAD SAFETY WITHIN ERSO

1.1. Introduction

This chapter covers the first activity of task 6.1 and aims at generating an inventory of relevant variables to monitor road safety within European Road Safety Observatory (ERSO). The sources of the inventory include:

- SafetyNet deliverables on Risk Exposure Data (RED), Safety Performance Indicators (SPI) and CARE
- Scientific and policy related literature on selected road safety topics
- Expert Survey on ERSO data priorities and needs (joint DaCoTA WP2, WP5 & WP6 survey)
- Workshop on Near Crashes (a joint FOT-Net – DaCoTA – PROLOGUE activity)

The details on the methodologies can be found in the according sections.

The information on RED and SPI in this chapter is entirely based on the outcomes of the Integrated EC Project SafetyNet in which these indicators were developed. Within this chapter, important RED (i.e. vehicle kilometres, fuel consumption, person kilometres, number of trips and time in traffic) and SPI (i.e. alcohol and drugs, speed, protective systems, daytime running lights) for road safety analyses and policy development were selected. Their current methodologies and the methodological problems for collecting these selected RED and SPI, as described in SafetyNet, are included in the discussion.

A limitation of the SafetyNet overview on RED and SPI is its restriction to current practices and methodologies. This way certain relevant variables are often not or only in a limited way included as a need or priority in the SafetyNet suggestions. For example, when the current methods do not focus on the driver as a unit (e.g. excessive speed via speed surveys, focussing on the vehicle as a unit) driver characteristics are not considered in the needs for speed related context variables. Some additional literature analyse on the selected SPI topics were performed to close this gap.

A broader review of scientific and policy related literature was conducted with regard to additional research topics selected based on their considered relevance in the PROLOGUE project and on the expertise within DaCoTA WP6 (i.e. fatigue, distraction/inattention and headway). SafetyNet did not cover these topics, so until now, no indicators on these topics have been developed within ERSO.

Other information sources were also investigated with the aim of deriving additional ERSO data needs: CARE (as reported in the outputs of SafetyNet WP1) was investigated to determine whether useful topics or variables could be found via accident data. CARE is a Community database on road accidents resulting in death or injury in Europe (EU27 + NO and CH), established after a positive European Council decision in December 1993 for the creation of a highly disaggregate road accident database. The purpose of the CARE system is to provide a powerful tool to make it possible to identify and quantify road safety problems on European roads, evaluate the efficiency of road safety measures, determine the relevance of Community actions and facilitate the exchange of experience in this field (ERSO, 2010f). Furthermore, a survey of 'National Experts' who are experienced in road safety policy making and/or statistics, was conducted in order to gain an understanding of current road safety policy priorities and to reveal relevant topics for road safety monitoring not yet covered in this chapter.

The concept of Near Crashes, is considered to be important, but will be dealt with in Chapter 2, as it is based mainly on literature deriving from Naturalistic Driving Observations.

The inventory takes into account elements of practicability, desirability and technical possibility in order to identify ERSO's needs for a common European road safety monitoring activity. For each topic relevant contextual variables are identified with regard to driver, vehicle, network and other (transient) context variables. Driver, vehicle and network are relatively permanent factors whereas the other contextual factors are more transient and likely to vary from one journey to the next.

1.2. Risk Exposure Data (RED) defined in SafetyNet

1.2.1. General concept and selection of RED

Risk Exposure Data (RED) are used to calculate road safety risk indicators, which enable comparisons over time and countries relative to the amount of exposure (e.g. size of population, time in traffic, traffic density…). In other words, risk (road safety risk indicator) can be defined as a rate (ERSO, 2010a):

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

Figure 1 Road safety risk indicator equation

The EC Project SafetyNet analysed commonly used RED, which can be roughly classified into two groups (ERSO, 2010b): (1) traffic estimates: road length, vehicle kilometres, fuel consumption, and vehicle fleet; (2) persons at risk estimates: person kilometres, population, number of trips, time in traffic and driver population.

The SafetyNet investigation included several stages: (1) the EU-wide availability was first checked for all RED, then only for the ones considered sufficiently (at least partly) available for most (>60%) of the countries; (2) then the compatibility of at least partly available RED with EUROSTAT/CARE definitions was checked; (3) and finally a RED was defined as usable for EU road safety monitoring when the compatibility was also sufficient (at least partly) for most (>60%) of the countries (Lejeune et al., 2007).

EU-wide RED needs and comparable variables were furthermore analysed in order to find current and future potentials of RED (Yannis et al., 2008a), and SafetyNet finalised with recommendations and guidelines for collection and exploitation of RED (Duchamp et al., 2008).

As DaCoTA WP6 Naturalistic Driving observation has drivers and vehicles as measurement units this report will focus on the following relevant RED:

- vehicle kilometres;
- fuel consumption;
- person kilometres;
- number of trips;

- time in traffic.

RED that have not been considered are thus: road length, vehicle fleet, population and driver population.

The SafetyNet results with regards to these selected RED are summarised and discussed in the following sections. A more detailed description of the SafetyNet investigation can be found in the appendix.

In the following sections each selected RED is defined and described and the overall SafetyNet results on RED are summarised and discussed. More details on the current practice(s) of, and the SafetyNet recommendations for each RED can be found in the appendix.

1.2.2. Vehicle kilometres

Within the initial SafetyNet investigation “vehicle kilometres of a country is defined as the total number of kilometres travelled within the borders of the country by road vehicles, where road vehicle is a vehicle running on wheels and intended for use on roads (Yannis et al., 2005 p. 14; Lejeune et al., 2007 p. 7)”. There are somewhat different definitions of vehicle kilometres available from EUROSTAT depending on which publication one uses (Lejeune et al., 2007). In order to reach more uniformity across countries, the SafetyNet experts suggest in their final recommendations, to use the definition proposed by the Glossary of Transport Statistics (UNECE, EUROSTAT, ECMT, 2003), which focuses only on motor vehicles, as a base for a common pan-European definition (Duchamp et al., 2008 p. 25):

“Vehicle kilometre: Unit of measurement representing the movement of a road motor vehicle over one kilometre. The distance to be considered is the distance actually run. It includes movements of empty road motor vehicles. Units made up of a tractor and a semi-trailer or a lorry and a trailer are counted as one vehicle”.

The according unit is vehicles x km. For example “accident risk” is often described as road safety outcome per billion vehicle kilometres.

This RED (together with person kilometres) is most closely related to the theoretical concept of exposure and is considered most appropriate for the estimation of accident risk (Duchamp et al., 2008). Vehicle kilometres travelled are a direct measure of traffic volume, while the other indicators are approximate measures of traffic. They are most useful for traffic risk analyses related to the vehicle and the road network (Yannis et al., 2008a).

1.2.3. Fuel consumption

Fuel consumption of a country is defined within SafetyNet as: “the total consumption of energy by road motor vehicles in the country in terajoule. Energy can be in the form of gasoline, diesel, LPG, electricity, or some other energy type which is used for the propulsion of road motor vehicles (UNECE/ECMT/EUROSTAT, 2003 IN: Yannis et al., 2005 p. 14; Lejeune et al., 2007 p. 7)”. The according unit is terajoules.

Fuel consumption is an indirect indicator of traffic volume (Lejeune et al., 2007) and is mostly used when other indicators are not available, and especially as an alternative for vehicle kilometres. Compared to the actual vehicle kilometres though, a drawback of this indicator is that short term fluctuations in road use may not be easily captured (Yannis et al., 2005).

1.2.4. Person kilometres

SafetyNet defined person kilometres of a country as "the total number of kilometres travelled within the borders of the country by persons, regardless of their age (Yannis et al., 2005 p. 14; Lejeune et al., 2007 p. 7)". The according unit is persons x km. For example "fatality risk" is often described as road safety outcome per billion person kilometres.

The indicator person kilometres is quite similar to vehicle kilometres except that it gives an indication of the total number of kilometres travelled by individuals, rather than by vehicles. Both RED are considered to be the most appropriate measure of exposure, as they are closest related to the theoretical concept of exposure and can be available to a high level of detail (e.g. time/date, vehicle type, road type, driver characteristics) (Yannis et al., 2005).

Person kilometres are useful for traffic risk analyses related to the road user. Like time in traffic and number of trips, this RED is linked to both traffic and mobility (Duchamp et al., 2008). These three RED are roughly related to each other. When gathered together, calculations of their average relation – specified by characteristics like mode and age etc. – can be made, for instance an average of 30 person kilometres per day combined with an average speed of 40km/h indicates an average time in traffic of 3 quarters of an hour per day.

1.2.5. Number of trips

Within SafetyNet number of trips of a country is defined as "the total number of trips made by persons, regardless their age, in the country. A return trip counts as two (Yannis et al., 2005 p. 15; Lejeune et al., 2007 p. 7)".

Number of trips is, like person kilometres and time in traffic, also a traffic and mobility RED and is viewed as useful additional RED to be collected. It can be considered similar to person kilometres. They are mostly registered together, with the same disaggregation level, and both provide extra information for each other (Duchamp et al., 2008).

Within road safety analysis, data on the number of trips are useful for both public health risk analysis and traffic risk analyses, and are mainly related to the road user (Yannis et al., 2008a).

1.2.6. Time in traffic

Within SafetyNet time in traffic of a country is defined as "the total time spent travelling by persons, regardless their age, (or their mode or means of transport (addition in Duchamp et al., 2008 p. 33)) in the country (Yannis et al., 2005 p. 15; Lejeune et al., 2007 p. 7)". The according unit is a unit of time (hours, minutes, and seconds).

Time in traffic is also considered in SafetyNet as one of the most relevant risk exposure indicators, linked to both traffic and mobility. Within road safety analysis, time in traffic is considered useful for public health risk analysis as well as traffic risk analyses, mainly related to the road user (Yannis et al., 2008a).

1.2.7. SafetyNet recommendations for future RED measurement

Needs

Overall, the SafetyNet experts identified several limitations of existing RED in Europe and confirmed the need for a future European framework. In order to improve RED in Europe they suggest a two-step process: (1) “Harmonisation of existing data and methods: transformation rules for all countries and all exposure indicators, improvement of the national collection methods; (2) Collection of new harmonised data: data collection at European level with common definitions (Duchamp et al., 2008 p. 7)”.

A RED needs’ analysis at EU level clarified an overall need for the following indicators (Yannis et al., 2008a):

The highest priority RED needs of EU Member States include:

- vehicle kilometres per vehicle type, vehicle age, road type, area type and year
- person kilometres per person class, age, gender and year

SafetyNet proposes these to be harmonised as a priority (step 1)

Useful additional RED needs of EU Member States include:

- vehicle kilometres per engine size
- person kilometres per nationality and driving experience
- number of trips per person class, age, gender
- time in traffic per person class, age, gender

These are proposed to be important additional data to be tackled after step 1 (i.e. step 2).

Vehicle kilometres and person kilometres are most closely related to the theoretical concept of exposure and thus considered most appropriate for the estimation of accident risk (Duchamp et al., 2008). Vehicle kilometres are most useful for traffic risk analyses related to the vehicle and the road network (Yannis et al., 2008a). Person kilometres, time in traffic and number of trips on the other hand are linked to both traffic and mobility and are useful for traffic risk analyses related to the road user (Duchamp et al., 2008). These latter three RED are roughly related to each other, e.g. person kms being similar to (average speed x time in traffic) being also similar to (trip distance x number of days x number of trips per day). When gathered together, calculations on their average relationship can be made, for instance an average of 30 person kilometres per day combined with an average speed of 40km/h indicates an average time in traffic of 3 quarters of an hour per day. Restricted to one mode, the average speed is much more homogeneous, so the relation with number of trips and time in traffic is much stronger (i.e. a fixed ratio). These rough relationships also points out that it is not really necessary to quantify all these indicators with the same precision and possibilities to disaggregate by all variables.

Fuel consumption on the other hand is regarded as the least needed risk exposure indicator. It is an indirect indicator of traffic volume (Lejeune et al., 2007) and is mostly used when other indicators are not available, and especially as an alternative for vehicle kilometres. Compared to the actual vehicle kilometres, the drawback of this indicator is that short term fluctuations in road use may not be easily captured (Yannis et al., 2005).

Current practice: usability and methods

The SafetyNet analyses revealed that the data that currently exists on the more sophisticated indicators with greatest relevance for road safety research, hardly meet the data needs (Yannis et al., 2008a). The prioritised RED data, being also the more complex risk exposure indicators, are currently the least available and/or comparable across European countries, and thus, still lack usability for EU country comparisons and analyses (Lejeune et al., 2007; Duchamp et al., 2008).

From the DaCoTA WP6 RED selection, only vehicle kilometres and fuel consumption are generally available indicators (Lejeune et al., 2007), and only vehicle kilometres are also at least partly compatible with EUROSTAT/CARE as fuel consumption for “transport-use” cannot be distinguished in most countries’ data collection. Although considered usable, SafetyNet found that the vehicle kilometres data still have a low overall comparability since the methods, variables and values differ significantly by country. Such a lack of uniformity also seems to be an important limitation of all other considered (not usable) RED.

The main limitation arises from the fact that often different methods or different combinations of methods are used to provide a national exposure estimate. Addressing incompatibilities arising from the data collection methods is complicated when examining the two main sample-based methods used for estimating vehicle kilometres (via surveys and traffic counts), and person-kilometres, number of trips and time in traffic (via surveys). Both methods are subject to various types of errors (Duchamp et al., 2008).

Although widely used, also for reasons of cost-effectiveness, there are several problems related to the use of surveys (Yannis et al., 2005). Problematic are the huge discrepancies with regard to: type of survey (e.g. telephone, roadside, diary etc.), unit (e.g. person, household etc.), target population (e.g. including pedestrians or not), coverage (e.g. rural areas included or not etc.), sample size, duration, and respondents' length of time covered (e.g. one day, one week etc.). Other problems are sampling errors[3] (e.g. age limitations, geographical limitation etc.), different degrees of non response[4], measurement errors[5] (magnitude mostly known); disadvantages are the subjectivity of the data and the periodicity of the data collection (Duchamp et al., 2008; Yannis et al., 2005). Although surveys have the strength of focusing on people as units (making it possible to compare groups of people) and allow a high level of disaggregate data on person-, road network- and vehicle characteristics to be combined, the actual number of available variables is rather limited, and the definitions of these variables are often incompatible between different countries (Duchamp et al., 2008; Yannis et al., 2005).

Traffic count systems, allowing the collection of time series data, are another main method for collecting vehicle kilometres data. Continuous data collection over time enables the estimation of seasonal (e.g. weekly, daily, hourly) variations. Common limitations of this system include the limited coverage of the road network (seldom for urban or rural roads), the limited classification by vehicle type (e.g. no two-wheelers),

[3] Sampling error: the error in the data caused by the fact that only a sample of the examined population is interviewed

[4] Non-response error: the error caused by the fact that some individuals that could or should have been interviewed are not interviewed

[5] Measurement error: the error caused by the fact that some individuals interviewed give wrong or inaccurate answers.

and the considerably different methods for calculating vehicle-kilometres from the traffic counts (Duchamp et al., 2008; Yannis et al., 2005). Furthermore, traffic counts are not suitable to distribute exposure according to person characteristics (age/gender groups) (Yannis et al., 2005).

Both surveys and traffic counts often have other main purposes than to provide exposure data, which often creates difficulties for the country comparisons as definitions differ (e.g. classification of vehicle types). SafetyNet suggests that a combination of several methods to collect raw data can optimise the data collection, as each method presents different features and difficulties: in essence, travel surveys, being more flexible in their design, can provide a higher level of disaggregation, having both people and vehicles as units, but on the other hand, traffic counts systems are the only method, which practically can provide continuous exposure measurements over time.

In order to overcome the methodological problems in future sample-based data collection, SafetyNet recommends establishing a pan-European data collection system, focusing on vehicle and person kilometres and including different data collection processes. This system should aim at meeting as many of the data needs as possible.

SafetyNet defines the initial list of data to be collected:

- Exposure indicators: vehicle and person kilometres, number of trips, time spent in traffic.
- Variables: vehicle type, vehicle age, road type, area type, month, day, hour, person class, person age, gender, driving experience and nationality (Duchamp et al., 2008).

It is furthermore proposed that “each country should calculate and provide indicators of reliability (e.g. confidence intervals, sample representativeness, etc.) for the sample-based exposure data (vehicle and person-kilometres), and each country should provide a comprehensive description of the data sources and calculations used for vehicle and person-kilometres (Duchamp et al., 2008 p. 12)”.

It is challenging though to collect these exposure indicators in the required level of detail on a systematic basis, which is the advantage of other RED, like road length, vehicle fleet or driver population.

In general, the SafetyNet experts recommend focusing on a highest level of disaggregation and cross-tabulation (per person, vehicle and road characteristics) as possible as well as continuity and comparability over country and time (Duchamp et al., 2008). On the other hand, “a balance should be made between the level of disaggregation, necessary for a more detailed approach, and the size of the sample; and interpretation of the results should be done with care (Duchamp et al., 2008 p. 117)”.

The current methodological problems to measure the selected relevant RED also indicate a need to explore the possibilities and added value of other/new methodologies (like Naturalistic Driving observation).

The following table gives an overview of the selected RED which may be of interest for the DaCoTA WP6 investigation on Naturalistic Driving observation within ERSO.

RED	Availability	Compatibility (EUROSTAT/ CARE)	Usability	Main method (raw data)	High priority variables (ERSO)	Medium priority variables (ERSO)	Priority needs (ERSO)
Road traffic estimates							
Vehicle km	Yes	Yes	Yes, but problem with comparability	Survey; traffic counts	vehicle type, vehicle age, road type, area type, year	engine size	High
Fuel consumption	Yes	No	No		-	-	X
Road user at risk estimates							
Person km	No	X	No	Survey	person class, age, gender, year	nationality, driving experience	High
Number of trips	No	X	No	Survey	-	person class, age, gender, vehicle type	Medium
Time in traffic	No	X	No	Survey	-	person class, age, gender, vehicle type	Medium

Available/compatible (EUROSTAT/CARE)/usable in at least 60% of EU member states + Norway; x = no further investigation within SafetyNet (Source: based on SafetyNet Yannis et al., 2005; Lejeune et al., 2007; Yannis et al., 2008a; Duchamp et al., 2008)

Table 1 Overview of selected RED

1.3. Safety Performance Indicator (SPI) topics defined in SafetyNet

1.3.1. General concept and selection of SPI

SafetyNet defined Safety Performance Indicators (SPI) as the "measures, reflecting those operational conditions of the road traffic system which influence the system's safety performance. Basic features of SPI are their ability to measure unsafe operational conditions of the road traffic system and their independence from specific safety interventions. The purpose of SPI is to reflect the current safety conditions of a road traffic system, to monitor the progress, to measure the effects of various safety interventions, and to compare the safety performance of different road traffic systems (e.g. countries, regions, etc). High quality SPI can be invaluable tools in future knowledge- and data-driven policy making in the EU (Hakkert & Gitelman, 2007 p. 2; ERSO, 2010c; Thomas et al., 2009 p. 47)".

Within SafetyNet, seven core problem areas in EU road safety were selected for the development of SPI in Europe: alcohol and drugs, speed, protective systems, daytime running lights, vehicles (fleet), roads (infrastructure layout and design) and trauma management (post-crash care). This selection was based on a report written by European road safety experts in 2001 "Transport Safety Performance Indicators" stressing the need for SPI (ETSC, 2001 IN: Hakkert et al., 2007).

As DaCoTA WP6 focuses on Naturalistic Driving observation of human behaviour as the cause of crashes or reduced road safety, further investigation in this chapter will be restricted to the following SafetyNet SPI topics:

1. Alcohol and Drugs
2. Speed
3. Protective Systems (seat belts and child restraints use)
4. Daytime Running Lights (DRL)

"While alcohol and drugs, and speed address road safety problems or unsafe system conditions, DRL and protective systems reflect countermeasures which are intended to prevent crashes or to reduce crash consequences, respectively (Thomas et al., 2009 p. 49)".

SafetyNet developed a common procedure for developing SPI. At first, the problem was defined, then divided into (a) measurable variable(s), which either is/are: (Hakkert et al., 2007; Thomas et al., 2009)

- a direct indicator ("ideal" SPI);
- (an) indirect indicator(s), based on indirect variables of the problem description, if 1) is not realisable ("realisable" SPI);
- sub-problem indicators, based on the division of the problem into several sub-problems, if 2) is not realisable ("realisable" SPI).

After that, the overall availability and country comparability of SPI data within Europe were investigated (Vis & Van Gent, 2007ab).

After the investigation and analyses, SafetyNet developed an SPI Manual in order to guide countries in their SPI data collection (Hakkert & Gitelman, 2007).

The SafetyNet results with regard to the selected SPI are summarised and discussed in the following sections. A more detailed description can be found in the appendix.

1.3.2. Alcohol and drugs

General concept and needs

Driving under the influence of alcohol (DUI) and drugs (DUID) is one of the most important factors increasing the risk of (severe) road accidents. As a result, most countries either ban the use of these psycho-active substances among drivers or set low legal limits for blood alcohol and drug concentrations. However, drink and drug driving is involved in a high proportion of fatal accidents in most countries (Vis et al., 2005; Hakkert & Gitelman, 2007; Thomas et al., 2009). Impaired driving may strongly vary by road type, period of the year, day of the week and time of the day. Moreover, driver variables like age (young), gender (male) and prior DUI offences also seem to strongly influence driving under influence (Hakkert et al., 2007; European Commission Road Safety, 2010b; Boets et al., 2008).

Theoretically the "ideal" SPI on alcohol and drugs should be the prevalence and concentration of impairing substances among the general road user population. However, the SafetyNet investigation showed major methodological problems related to such SPI, because of either judicial impediments (e.g. in some countries: no random testing by police allowed, only mandatory tests if suspected impairment) or methodological obstacles (e.g. sample representativeness). SafetyNet concluded that extreme difficulties are foreseen when all EU countries would have to agree on a common sampling and testing protocol on this topic; therefore this SPI for alcohol and drugs was rejected within SafetyNet (Hakkert et al., 2007).

SafetyNet focussed thus on crash based data, which should in general be avoided when developing road SPI (Hakkert & Gitelman, 2007). Three realisable SPI were developed, among which the last one is the most feasible (Hakkert et al., 2007):

- number and percentage of severe and fatal injuries resulting from road accidents involving at least one active road user impaired by psychoactive substance (concentration above a predetermined impairment threshold);
- percentage of fatalities resulting from accidents involving at least one driver impaired by drugs other than alcohol;
- percentage of fatalities resulting from accidents involving at least one driver impaired by alcohol.

Current practice: usability and methods

Most EU countries are able to calculate an SPI on alcohol, but the data are difficult to compare due to differences in definitions (e.g. different legal BAC limits), data collection and data analysis methods.

The analysis on the comparability of the crash data **alcohol** SPI showed the following difficulties:

- In most countries the data depend on the legal limit (0.0 up to 0.9 g/l BAC), as only data for drivers above the legal limit are provided.
- The percentage of drivers involved in fatal accidents who are actually tested for alcohol and/or drugs varies. Thus, it remains unclear whether the fatal accidents with alcohol-positive drivers should be related to the number of fatal accidents with drivers tested or to the total number of fatal accidents.
- In some countries only data from fatal accidents "caused" by impaired drivers were presented. This concept of cause causes difficulties and SafetyNet recommends that all fatal accidents should be included in the data collection.

- In small countries the number of fatal accidents is small and therefore subject to random variation. Consequently the experts suggest computing the SPI based on data for several years, rather than for one year.
- The definition of fatal accidents may in theory include “dead at the scene” as well as “dead 30 days after the accident”. In practice the SPI (alcohol/drugs) should be limited to drivers dead at the accident scene (step 1) and to drivers and road users involved in accidents where somebody is dead at the scene (step 2-3). “When severe injury accidents are included (step 4), the problem of people dying within 30 days of the accident will be reduced, as these cases will presumably be defined as severe injury accidents anyway” (Hakkert & Gitelman, 2007, p. 25).

Data for drugs are an even more complex issue. In the SafetyNet investigation on availability, only six countries were able to provide data on drugs other than alcohol, among which there was unreliable data as the number of tested drivers is too low. The number of drugs in use is very large and varies by country. Furthermore, drugs vary from medical drugs in prescribed doses, to medical drugs in abuse doses and to illicit drugs in varying doses and can be combined with each other or with alcohol. All this makes common definitions and approaches on the topic almost impossible.

The SafetyNet experts concluded that considerable effort in harmonizing definitions, data collection and data analysis methods, will be needed in order to do reliable and valid country comparisons on alcohol and drugs SPI.

Valid prevalence comparisons would require disaggregated information on driver, road network and other contextual variables. The DRUID[6] project aims at deriving epidemiological prevalence data based on hospital studies (crash based), but also on road side tests. Data from such kinds of road side tests, surveys or eventually naturalistic driving observation might be of high interest to verify accident based results. The drawback of these kinds of methods lies in the representativeness of the sample (private and ethical difficulties). Body fluid tests for alcohol or drugs are invasive and costly methods. They are in most cases only allowed on a voluntary base which might lead to a systematic sampling bias. Although these methods might have a high psychometric value the representativeness of the sample is in question.

1.3.3. Speed

General concept and needs

Vehicle speed is one of the main causes of accidents and has direct influence on accident severity (Transportation Research Board, 1998 IN: Hakkert & Gitelman, 2007; Thomas et al., 2009). Both excessive (i.e. exceeding the posted speed limit) and inappropriate (i.e. faster than the prevailing conditions allow) speed are important accident causation factors, and very common phenomena (SafetyNet 2009). Specific driver related variables have been found to influence speeding behaviour (e.g. age, gender, attitudes, personality characteristics like risk taking, perceptual skills and limitations). On the level of the vehicle, aspects like the size of the engine power and specific types of cars (e.g. landrover-types) may also increase the chance of speeding. Other relevant variables are related to the road (e.g. road and area type) or to transient contextual characteristics (e.g. professional or private driving purpose, traffic density, traffic composition, level of enforcement) (European Commission Road Safety, 2010d, 2010e Hakkert et al., 2007; SafteyNet 2009).

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[6] Driving under the Influence of Drugs, Alcohol and Medicines: http://www.druid-project.eu/

While excessive speed data can be collected on a large scale, this is considered impossible (too expensive) for inappropriate speed, as this is a more complex problem requiring information on the specific road, weather and traffic conditions and thus has to be studied case by case (Hakkert & Gitelman, 2007).

Therefore, the developed speed SPI and recommendations within SafetyNet concentrate only on excessive speed. The selected relevant SPI are (Hakkert et al., 2007):

- mean speed;
- standard deviation;
- 85th percentile speed;
- percentage of drivers exceeding the speed limit (later specified into (1) over speed limit and (2) 10 km/h over speed limit).

According to SafetyNet, these four indicators should ideally be disaggregated by road type, vehicle type, period of day (day-night time) and period of the week (week-days and weekends), and minimally by day versus night time. This selection is restricted by the data collection method that is mainly used at present (speed survey), which excludes the possibility to capture the relevant driver related variables.

Current practice: usability and methods

The analyses of SafetyNet have shown that many countries carry out large-scale speed surveys and most of them are able to compute the proposed speed SPI, but international comparison of the speed survey data are (strictly speaking) impossible, at the moment (Thomas et al., 2009). This is due to the huge variability of national (and even regional) methodologies (Vis & Van Gent, 2007a): e.g.

- Representativeness of measuring locations. Only 8 of the 18 countries that provided speed data use a sampling procedure to select the measuring locations. Some countries cannot produce aggregate data on a national level, as speed surveys are conducted by regional organisations.
- Traffic conditions. Due to the fact that traffic conditions have a significant impact on speed, the experts of SafetyNet recommend only comparing speed measurements that were carried out in similar non-congested traffic conditions. The criteria for traffic conditions under which the measurement is considered to be valid, varies between countries.
- Comparability of roads. The SafetyNet analysis found that road classifications and speed limits vary between countries and that at the moment it is impossible to find even one corresponding road in each country for each SafetyNet road category. The three most common road types were: motorways, single carriageways A-level road and urban single carriageway distributor roads. Most surveys only conduct speed measurements on free flowing traffic and straight roads.
- Period of measurement. The length of time of speed measurement varies across countries. In cases of a measurement of a few hours this is usually carried out during the daytime. The first country comparison carried out by SafetyNet supports the idea that speeds differ between day and night, which leads to the conclusions, that day and night speeds should be considered separately and not be combined into one speed SPI. Other time distinctions, such as weekday versus weekend or time of the year, are so far not common.
- Vehicle types. Speed indicators should not be aggregated over all vehicle types, as, for example, differences in vehicle fleet may influence the country comparison. The SafetyNet experts recommend comparing indicators for one vehicle type only (e.g. cars).

- Accuracy of data. At the moment it is impossible to determine whether any two values are significantly different or not. This is due to many sources of uncertainties in speed data, which make it impossible to calculate the margin of error. The experts of SafetyNet point out that in general, it is more accurate to compare trends of speed data than absolute values because internal country methodologies usually remain consistent in time.

Regardless of all these difficulties though, comparison of excessive speeds on motorways was indicated as feasible, accounting for relative similarity of road and traffic conditions on these road types across Europe (Thomas et al., 2009).

Besides the comparability problems related to excessive speed SPI, the investigation of the SafetyNet research reveals that a major problem relates to the fact that data collection of “inappropriate” speed, also an important speed problem area, is considered to be impossible on a large scale. The requirement of additional contextual data makes this a more complex phenomenon. Another gap relates to the lack of driver related information due to the reliance on speed survey data.

1.3.4. Protective systems

General concept and needs

Seat belts and child restraints are standard protective systems saving the most vulnerable parts of the human body from harm during crashes. Seat belt use is a key road safety issue and data requirement within ERSO. Other protective systems in regard to motorised vehicles are, for example, airbags or head restraints (Hakkert et al., 2007). While the use of seat belts and child restraints relates to human behaviour, airbags or head restraints are fixed characteristics of the vehicle (i.e. contextual vehicle variables) and therefore not further investigated on the level of protective system topics for ERSO monitoring.

Characteristics of the road user, such as age, gender and other socio-economical characteristics, have a significant influence on the use rates of protective systems in general. Besides that, road related characteristics may also affect usage rates, like speed regime (e.g. lower seat belt use in low speed zones) (Via Secura, 2008).

Based on the literature and practical availability of data, SafetyNet proposed the following direct SPI on protective systems use in passenger cars (extracted from Hakkert et al., 2007):

- daytime wearing rates of seat belts in front seats (passenger cars)
- daytime wearing rates of seat belts in rear seats (passenger cars)
- daytime wearing rates by children under 12 years old (restraint systems use in passenger cars)

The SafetyNet experts add that this data should at least be disaggregated by main road types (motorways, other rural roads and urban roads) (Hakkert & Gitelman, 2007). SafetyNet recommends using data from independent observational surveys carried out on an annual basis (Hakkert et al., 2007).

Current practice: usability and methods

According to the SafetyNet analysis, the suggested direct indicators are currently only partly available. Most of the observational survey data assess the seat belt use of the driver, less is known about the front and rear seat passengers and least about the use of restraint systems of children. A problem with regard to child restraint systems is that the legislation on usage (different limits of age/length) varies within Europe.

The SafetyNet investigation indicates a problem of data representativeness of seat belt daytime wearing rates in front seats and lacking data on rear passenger seat belt use and child restraint use. Moreover, according to the literature, disaggregate data on the usage of protective systems are considered highly important; besides road network variables, characteristics of the road user, like age, gender and other socio-economical characteristics also significantly influence the use rates. Disaggregate data are, in most countries, only available for the driver and passenger in front (Vis & Van Gent, 2007a).

1.3.5. Daytime running lights (DRL)

General concept and needs

Vehicle visibility is one of the contributing factors to the number of road accidents. A lot of traffic accidents occur because road users do not see each other (not in time or not at all). This happens not only in the dark but also in daylight. Consequently, the level of use of DRL can be considered as an indirect indicator for vehicle-visibility, as visibility cannot be measured directly (Hakkert et al., 2007).

Hakkert & Gitelman (2007) suggest considering the following road and vehicle types for the calculation of DRL indicators: (1) road categories: motorways, rural roads, urban roads, and DRL-roads, where the term “DRL roads” implies the road categories where the usage of DRL is obligatory (2) vehicle types: cars, heavy good vehicles (including vans), motorcycles and mopeds.

Current practice: usability and methods

The usage rates for DRL per road type are partly available and comparable, but country specific characteristics, such as legal obligation or recommendation as well as latitude of the country are very relevant factors in the interpretation of the comparisons. Furthermore, the prevalence of automatic switch-on of lights in vehicles influences the outcomes and might, in case this increases, lead to the future loss of relevance of DRL as a behavioural SPI in road safety. The data should be disaggregated at least by road type (motorways, rural roads, urban roads and DRL-roads) and vehicle type.

1.3.6. SPI conclusions

In general, use of SPI for comparisons or monitoring requires that the underlying data is of sufficient quality and that its collection is done in a harmonised way. SafetyNet concluded that a comparison of the countries’ “safety performances” is difficult. “The main reasons are: lack of data, suspicious data quality, or the incomparability of (seemingly similar) data due to different circumstances of measurement (Vis & Van Gent, 2007a p. 53)”. The experts of SafetyNet were able to do reliable comparisons for DRL and protective systems (seat belts and child restraints). Only limited comparisons were possible for speed. Comparisons in the area of alcohol and drugs are not possible, due to great differences in data quality (Vis & Van Gent, 2007a).

In theory all SPI topics may be available in a high level of disaggregation (driver, vehicle and network variables), but, at present, differences in the definitions and measurement of the variables/values remain and need to be solved (e.g. comparability / definition of road types). A pan-European sample study (e.g. survey or Naturalistic Driving observation) would have to overcome general difficulties like sample errors in respect to representativeness, but could enable a high level of disaggregation of harmonized variables.

1.4. Additional topics

As the determination of ERSO needs goes beyond the SafetyNet RED and SPI topics, a selection of additional sources was tackled in order to find other relevant research topics for ERSO monitoring. As the definition of ERSO needs can be indefinitely extended, a narrowed scope of the investigation sources was primarily decided upon. This does not exclude additional needs being added in the future.

The following were considered when identifying additional topics;

- The joint DaCoTA / PROLOGUE Workshop, October 2009
- SafetyNet deliverables relating to EU macroscopic accident data, in particular the CARE database
- Survey of national experts
- Discussion among experts within the DaCoTA WP6 consortium,

Based on a DaCoTA – PROLOGUE workshop (Brussels, 26th October 2009) “fatigue” and “distraction/inattention” were added to the core research topics (alcohol, speed and belt use) for DaCoTA WP6 (PROLOGUE/DaCoTA 2009). Expert consultation within the DaCoTA WP6 consortium furthermore added “headway”.

The SafetyNet outputs regarding EU macroscopic accident data (CARE database[7]) were also examined. Little additional input was found on topic level, but rather on the level of additional useful context variables (including values) for exposure data: age, gender, junctions, type of road (motorway, non-motorway urban, non-motorway rural), seasonality (Jan-Dec), day of week, time of day (per hour), area type (rural, urban), month of the year (Jan-Dec), lighting conditions (darkness, daylight or twilight) and weather conditions (dry, rain, other). Also manoeuvres like changing lane, overtaking, stops and stopping, driving straight ahead, turning and U-turn, are accident data needs. Based on a stakeholders’ survey on accident data priorities (according to degree and frequency of use), some variables came out as more significant (used by more than 50% of stakeholders): (1) driver related: in order of importance; age, gender, alcohol/drug test (i.e. topic alcohol) and psychophysical circumstances (i.e. driver variable or transient context variable); (2) vehicle related: in order of importance; vehicle type and security equipment (i.e. topic seat belt use); and (3) network related: in order of importance; speed limits (i.e. network variable), road type, area type, road surface conditions (i.e. transient context variable), region, junction control (i.e. network variable or transient context variable), road markings (i.e. network variable), junction type (i.e. network variable), number of lanes (i.e. network variable), carriageway type (i.e. network variable) and lighting conditions (i.e. transient context variable) (Yannis et al., 2008b). Accidents are not the scope of DaCoTA WP6 and the derived data needs from CARE essentially provide input on the level of exposure data context variables.

Certain relevant topics are not further explored in this chapter as they can be regarded as a specific constellation of several core topics, e.g. aggressive driving style requiring information on topical variables of speed, headway.

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[7] CARE is a Community database on road accidents resulting in death or injury in Europe (EU27 + NO and CH). See section 1.1.

Finally, within DaCoTA WP6 an EU-wide group of experts on road safety data was asked to provide additional topical needs for ERSO monitoring. The results of this Expert Survey are presented in section 1.5. “Fatigue”, “distraction/inattention” and “headway” are presented in more detail within the following sections as additional topical data needs for ERSO monitoring.

1.4.1. Fatigue

In 2009, the experts of SafetyNet summarised a web text on fatigue and road safety which can be downloaded from the EC homepage (SafetyNet, 2009). The following subchapters are mainly quoting or summarising this web text. More detailed information on fatigue and road safety can be found in the original text (see reference list for the direct internet link).

1.4.1.1. General concept

“In the literature many definitions are used for fatigue. The concepts of fatigue, sleepiness and drowsiness are often used interchangeably. Sleepiness can be defined as the neurobiological need to sleep, resulting from physiological wake and sleep drives. Fatigue has from the beginning been associated with physical labour, or in modern terms, task performance. Although the causes of fatigue and sleepiness may be different, the effects of sleepiness and fatigue are very much the same, namely a decrease in mental and physical performance capacity (SafetyNet, 2009 p. 4)”.

“The most general factors that cause fatigue are lack of sleep, bad quality sleep and sleep demands induced by the daily sleep cycle or biorhythm. Besides these general factors, prolonged driving (time-on-task) can increase driver fatigue, especially when drivers do not take sufficient breaks (SafetyNet, 2009 p. 4)”. There is a positive correlation between fatigued driving and some exposure variables: yearly/daily person kilometres and number of trips longer than 3 hours (McCartt et al., 1996 IN: Vesentini et al., 2003). Other factors have an indirect influence: age, physical condition, the use of alcohol, drugs and/or medicine, external factors such as temperature, noise, vibrations, and also the routine of a task (SWOV, 2008a). Overall, the main risk groups for fatigued driving are: professional drivers (including highly educated employees driving as part of their job), long distance drivers, night drivers, shift workers, young (male) drivers (< age of 25), and drivers with medical problems like sleep disorders (e.g. obstructive sleep apnoea, in 3 to 5% of the general population, contributes to above average day-to-day sleepiness) (SafetyNet, 2009; SWOV, 2008a; Vesentini et al., 2003).

“Fatigue leads to a deterioration of driving performance, manifesting itself in slower reactions, diminished steering performance, lesser ability to keep distance to the car in front, and increased tendency to mentally withdraw from the driving task (SafetyNet, 2009 p. 4)”. Driving simulator study results yield reasonably uniform results: tired people seem to have more problems in keeping to their lane, more often cross or nearly cross the side marking, and make greater steering adjustments and do so more abruptly; they also react less accurately to deceleration by the driver in front (SWOV, 2008a p. 2).

“The withdrawal of attention and cognitive processing capacity from the driving task is not a conscious, well-planned decision, but a semi-autonomic mental process of which drivers may not be fully aware (SafetyNet, 2009 p. 4)”. Drivers may try to compensate for the influence of fatigue, for instance by either increasing the task demands (e.g. driving faster) or lowering them (e.g. driving slower or using longer following distances) (SafetyNet, 2009; SWOV, 2008a). “But crashes and observations of driving performance show that compensatory strategies are not sufficient to remove all excess risk (SafetyNet, 2009 p. 4)".

1.4.1.2. Impact on road safety

Prevalence

"Fatigue has many causes, so it seems valid to conclude that everybody is very tired once in a while (SWOV, 2008a p. 2)". Prevalence data of fatigued driving is mainly derived from surveys.

In regard to general information on the prevalence of fatigue in the population, the SafetyNet experts point out the results of the 2002 "Sleep in America" Poll. More than one-third of the adult population has impaired functioning due to sleep loss during one or more days each month, and 16% experience this level of daytime sleepiness a few days per week or more (WB & A Market Research, 2002 IN: SafetyNet, 2009 p. 13). Further survey results estimate that about 10% of the population suffers from a serious type of sleeplessness, and 3% suffers from a sleep disorder, of which sleep apnoea is the most common (SWOV, 2008a p. 2).

Many studies world-wide have shown that driving while sleepy is a very common phenomenon. More than half of private drivers say they have driven whilst being fatigued or drowsy at least once a year, and actually a sizeable proportion of the drivers (range 10% up to 40%) also nodded off or fell asleep behind the wheel within the last year. Amongst young drivers, driving while fatigued is quite common due to lifestyle factors. Adolescents need more sleep than adults so fatigue may affect them more. Looking at the elderly, negative effects of fatigue seem to be more pronounced in this group compared to younger persons. Most professional drivers and shift workers have to cope with fatigued driving on a frequent basis due to work related factors. About half of professional drivers take less than normal sleep time before a long-distance trip (SafetyNet, 2009 p. 4f, p. 12).

A road-side study in New Zealand (Connor et al., 2001 IN: SafetyNet, 2009) directly measured sleepiness in drivers in proportion to actual driving time (exposure to risk). The results showed that most driving was undertaken by drivers with normal scores on the Epworth Sleepiness Scale. An important minority though had characteristics that can impair alertness: 3.1% had 5 hours of sleep or less in the previous 24 hours, and 21.9% had 4 or less full nights of sleep in the previous week. 8.1% of those surveyed worked a pattern of shifts likely to interfere with normal sleep (SafetyNet, 2009 p. 14).

More detailed information on the target groups "professional drivers" and "shift workers" can be found in the original SafetyNet web text.

Relation to road crashes

It is very challenging to determine the extent of fatigue and its role in road accidents in an objective way, as it is quite difficult to be estimated in a direct way (SWOV, 2008a).

Different methods are used to estimate fatigue related crashes (e.g. police crash records, surveys, naturalistic observation studies or in-depth accident analyses). The different outcomes of these methods are summarized below:

- Police crash data are thought to generally give an underrepresentation due to difficulty of recognition (1% up to 4% of all registered crashes are sleep-related) (SafetyNet, 2009). In the Netherlands this is only reported for 0.3% of serious accidents. In most countries, police are not (yet) very alert to fatigue as a crash cause (SWOV, 2008a). When the crash-involved persons are interrogated, the percentage rises up to 7%; and focussing just on typical fatigue related accidents, accidents on high speed roads, at night time or involving risk groups, this percentage increases up to 15% or more (Vesentini et al., 2003).

- The estimated percentage of sleep related crashes in questionnaire data lays much higher (10 to 25 % higher compared to police reports). The survey of Maycock (1995 IN: SafetyNet, 2009) further indicated that the percentage varies by road type (higher on motorways than roads in urban areas or other roads outside urban areas).
- In a naturalistic driving study (100-Car Naturalistic Driving Study), fatigue – as measured by an observer rating of drowsiness based on the Wierwille and Ellsworth (1994) rating system for driver fatigue – was judged to be a contributing factor in approximately 12% of crashes, 10% of near-crashes (i.e. situations requiring a rapid, severe evasive manoeuvre to avoid a crash), and 7% of crash-relevant conflicts (Dingus et al., 2006 IN: SafetyNet, 2009).
- In-depth studies indicate fatigue to be the contributing factor in 10 to 20% of the crashes (In SafetyNet, 2009: Horne & Reyner, 1995; Philip et al., 2001; Langwieder & Sporner, 1994; Haworth et al., 1989; Amundsen & Sagberg, 2003).

A typical fatigue related accident occurs on motorways and monotonous roads, during late evening or early morning, after a long driving time. The driver sits mostly alone in the vehicle and results in going off the road or in a frontal collision with an opposite vehicle; the consequences are mostly severe, often fatal (SWOV, 2008a; Vesentini et al., 2003).

In general, the studies agree that fatigue related crashes are often associated with high injury levels and that fatigue is a major factor in a large proportion of road crashes (range 10-20%) (SafetyNet, 2009 p. 20). Several studies showed that fatigue is associated with increased crash risk and that this results from a combination of biological, lifestyle- and work-related factors. It is estimated that the crash risk when driving after being awake for 17 hours is comparable to the risk of crashing when being at the 0.05% BAC (i.e. twice the normal risk) (SafetyNet, 2009 p. 20). Persons with a sleep disorder or with an acute lack of sleep have a considerably larger (3 to 8 times) risk of being involved in an injury crash (SWOV, 2008a p. 3).

1.4.1.3. Discussion

Driver fatigue is a major factor in a large proportion of road crashes. Several studies suggest that fatigue is associated with increased crash risk. It is currently impossible though to calculate the exact amount of fatigue related accidents because of the difficult detection of fatigue as a contributing factor and the difficult assessment of the level of fatigue.

Information on the relationship between fatigue and crashes (or risk) is currently derived from different sources, but there are important drawbacks making it difficult to get a clear picture: e.g. the percentage of fatigue related crashes differ according to the method; difficult objective (post-event) determination of fatigue; reduced reliability of self-reported data on fatigue etc.

SafetyNet (2009) experts specifically indicate a need for more scientific evidence concerning the exact quantitative relationship between fatigue and risk.

Research on useable and reliable fatigue detection systems and the accompanying criteria is getting a lot of attention in Europe. Several technological systems to detect fatigue symptoms exist already via steering wheel movements, lateral position on the road, eyelid movements, reaction times, head position, brain activity etc. (Vesentini et al., 2003). With the further development of intelligent detection and warning systems, more possibilities for monitoring fatigued driving also arise. But still, some remaining technical problems need to be solved first (SWOV, 2008a).

A lot of information on fatigue and driving now derives from self-reported data (population poll, surveys; questionnaires e.g. Epworth Sleepiness Scale). So far there is no common approach for systematic data collection of fatigue related crashes or fatigued driving within Europe.

In the SafetyNet web text it is stated that in Europe it seems that determining the extent of the fatigue problem for road safety is regarded as less relevant. This may be linked to the consideration that it is sufficiently well known that fatigue is an important risk. The SafetyNet (2009) experts think though that, in spite of this, a well designed, large-scale epidemiological study on the risk-increasing effects of fatigue could be an important contribution to knowledge about this problem (SafetyNet, 2009 p. 29). Furthermore, the lack of knowledge about the size and consequences of fatigued driving has led (national) policy makers to advise further research on the topic (Vesentini et al., 2003).

Based on the literature, it can be proposed to collect prevalence/monitoring data of fatigued driving in a disaggregate way, considering increased risk related variables like road type (e.g. motorways versus other roads), age (young drivers, middle-aged and elderly drivers), and the relation to risk exposure (actual driving time or driver kilometres).

The SafetyNet experts furthermore underline the importance of studies on cost-effectiveness of measures to reduce the number of fatigue related crashes. So far, very little respective research has been carried out; an exception is Sassani et al. (2004 IN: SafetyNet, 2009). The objective determination of costs and benefits of fatigue management is seen internationally as one of the challenges in fatigue research during the coming years. Also, when one wants to implement fatigue detection systems on a large scale, their cost effectiveness will certainly be a topic of discussion; a lot more will need to be known about the fatigue problem (SafetyNet, 2009 p. 29).

1.4.2. Inattention & distraction

1.4.2.1. General concept

The applied psychological construct of distracted driving, has been variously and sometimes poorly defined in the research literature. There is no general accepted definition of driver inattention & distraction (Trezise et al., 2006 IN: Ranney, 2008).

Also due to these different definitions different types of categorisations exist. The National Highway Traffic Safety Administration (NHTSA) for example distinguishes four main types of distracted driving:

1. visual (taking the eyes off the road),
2. auditory (being startled by sound/noise),
3. manual (taking the hands off the steering wheel) and
4. cognitive (thinking about other things while driving).

On the other hand Young (2003) distinguishes inattention & distraction in technology-based and non-technology based causes. Furthermore, some studies use categorisation systems based only on concrete possible causes, e.g. Stutts et al. (2001, 13 categories) and Hanowski et al. (2005, 35 categories).

Often, a driver is distracted by a combination of causes (European Commission, 2009; European Commission Road Safety, 2010f).

The concepts of driver inattention & distraction are not uniformly used (sometimes they are used synonymously, other times they are distinguished) (Stutts et al., 2001; Ranney, 2008). According to Ranney (2008) distraction is a specific type of inattention that occurs when a driver's attention is diverted away from driving by an identifiable secondary task that requires focusing on an object, event, or person not related to the driving task. The Australian Road Safety Board (2006) presented the following comprehensive definition (IN: Ranney, 2008 p. 3):

"Driver distraction is the voluntary or involuntary diversion of attention from the primary driving tasks not related to impairment (from alcohol, drugs, fatigue, or a medical condition) where the diversion occurs because the driver is performing an additional task (or tasks) and temporarily focusing on an object, event, or person not related to the primary driving tasks. The diversion reduces a driver's situational awareness, decision making, and/or performance resulting, in some instances, in a collision or near crash or corrective action by the driver and/or other road user".

Such restriction creates a boundary with fatigue/drowsiness (related to vigilance) or cognitive distraction/loss of concentration/daydreaming (Ranney, 2008; SWOV, 2008b). As data collection possibilities are expanding (e.g. video data), better insight can be gained into the visual behaviours associated with episodes of cognitive distraction, which may facilitate broadening the definition to include behaviours not associated with an identifiable secondary task (Ranney, 2008). Alertness is also often referred to and is a requirement to attention.

Driver inattention & distraction can present a serious and potentially deadly danger. Involvement in secondary tasks can result in delayed recognition of information necessary for safe driving, less appropriate responses to changing road and traffic conditions, which can all lead to an increased likelihood of crash (Eby & Kostyniuk, 2003). Secondary task involvement can include for instance phone use and texting while driving, eating, drinking, and conversing with passengers as well as interaction with in-vehicle technologies and portable electronic devices (NHTSA, 2009). Loss of concentration can also lead the driver to not look properly, to react slowly, to be late or entirely fail to notice things, and when braking, this is often late and abrupt. Concentration problems can arise on the level of selectivity (when the driver thinks of other things than the driving task while driving), intensity (when the brain activity decreases; fatigue excluded) and motivation (to apply the required concentration to the driving task) (SWOV, 2008b p. 4, p.1).

Evidence highlights that there is a wide variety of everyday activities that may contribute to driver inattention- or distraction-related crashes. The continuing introduction of new electronic devices into vehicles (infotainment systems) provides additional sources of potential driver distraction (Road Safety Community, 2006). On EU road safety policy level there has been increased attention on the dangers of driver's inattention and distraction, especially of mobile phone use while driving (European Commission, 2009; Ranney, 2008).

1.4.2.2. Impact on road safety

Prevalence

A state of the art review on driver distraction (secondary task involvement) (2008) summarises that existing data on the phenomenon is inadequate and not representative of the driving population. It is estimated that approximately 30% of the driving time, drivers engage in potentially distracting secondary tasks. Conversation with passengers is the most frequent secondary task followed by eating, smoking, manipulating controls, reaching inside the vehicle, and mobile phone use (Ranney, 2008).

With regard to loss of concentration (no identifiable secondary task), results from an Australian telephone survey (McEvoy et al., 2006 In SWOV, 2008b) indicate that almost 72% of 1,347 subjects reported distraction loss during their last drive while with regard to the question if their concentration had slackened, hardly any information was received (SWOV, 2008b p. 3).

With regard to mobile phone use while driving, research indicates that it is widespread among young novice drivers, which adds to the problems experienced by this group who already have a higher crash risk. Older drivers on the other hand can find it more difficult than drivers in general to conduct the two tasks of phoning whilst driving at the same time. Few EU countries conduct systematic surveys of car telephone use by drivers. Observational studies (actual road exposure rates) in Europe, USA and Australia have, in general, shown that between 1% and 6% of drivers use telephones while driving, with many drivers reporting occasional use (European Commission, 2009 p. 2).

Relation to road crashes

It is very difficult to find evidence of inattention and distraction and thus to relate these to the origin of an accident. Furthermore, data on inattention and distraction are based on different categorisation systems (different definitions) and measurement approaches which are difficult to compare.

Since 1995, US police officials do investigate the role of distraction in a crash. Analysis of these data (Stutts et al., 2001 IN: Ranney, 2008) has shown that, although driver attention status is unknown for a large percentage of crash-involved drivers, it is estimated that between 1995 and 2003 10.5% of crash-involved drivers were distracted by secondary tasks. Approximately 70% of distracted drivers' crashes were either non-collision (single-vehicle) or rear-end collisions (Ranney, 2008). Analysis of the police descriptions remained inconclusive though about the number of accidents caused by concentration loss (SWOV, 2008b p. 2).

Effects of distraction have been measured in several types of studies, each with its own advantages and disadvantages, including (Ranney, 2008):

- Experimental studies: mainly on the influence of technical devices such as radio or GPS, on driving performance (Haigney and Westerman, 2001; Otzelberger, B., 1998 IN: ARAMIS, 2010). These are conducted in controlled settings, including driving simulator laboratories and closed test tracks. Most of them measure as the independent variable driving performance (e.g. braking- and steering behaviour) and/or pupil-movement.
- Crash-based studies: as it is very difficult to accurately determine distraction as a contributing factor, it is generally thought that the incidence of distraction among crash-involved drivers is underestimated in crash studies (Trezise et al., 2006; Stutts et al., 2001; McCartt et al., 2006 IN: Ranney, 2008). Furthermore crash data is often limited by the absence of matched exposure data which are necessary to determine the relative crash risks associated with distraction. Crash data alone provide no information about crash causation.
- Observational studies (fixed-site observations and naturalistic in-vehicle observations): naturalistic driving observation studies may provide detailed crash and matched exposure data, and they provide direct information about the types and incidence of driver distraction. Limitations can be that drivers might not behave naturally if they know their vehicle is observed (need for long term

studies), the high costs associated with instrumenting each vehicle in a large sample and the low frequency of crashes which might be captured within a long term observation (need for large sample, use of Near Crashes).

The NHTSA has been thoroughly researching driver distraction. The following data (mainly from US crash databases) provide some perspective into the size of the problem of driver distraction (NHTSA, 2009 p. 1):

- "Driver distraction was reported to have been involved in 16% of all fatal crashes in 2008 according to data from the Fatality Analysis Reporting System (FARS).
- The age group with the greatest proportion of distracted drivers was the under-20 age group – 16% of all under-20 drivers in fatal crashes were reported to have been distracted while driving.
- An estimated 22% of injury crashes were reported to have involved distracted driving, according to data from the General Estimates System (GES).
- Based on data from the National Motor Vehicle Crash Causation Survey (NMVCCS), a nationally representative survey of the crashes in which the critical reason for the crash was attributed to the driver, approximately 18% involved distraction.
- During the 100-Car Naturalistic Driving Study, driver involvement in secondary tasks contributed to over 22% of all crashes and near-crashes recorded during the study period".

In the last study, loss of concentration – when a driver stares in a different direction than the direction from which the danger comes – was found in 7% of all crashes (SWOV, 2008b).

A significant proportion of the existing literature is devoted to assessing the impact of mobile phone use on driving performance and safety. Although mobile phone use represents a relatively small part of the overall distraction problem, use among drivers is steadily growing with approximately 10% of drivers using some type of mobile phone at any point in time. Although not representative of the US experience, the available evidence suggests that mobile phone use increases drivers' crash risk by a factor of 4 (Ranney, 2008). The study of the European Commission on car telephone use and road safety (European Commission, 2009) has shown that the extent of the negative effects of phone use while driving depends on the complexity of both the conversation and the driving situation. The collection of data about phone use involvement in road crashes in EU countries is neither widespread nor very systematic and few estimates have been made. Furthermore, the need for estimating the risk exposure through accurate data on the extent of telephone use in the EU is stressed.

1.4.2.3. Discussion

In summary, driver's inattention and distraction is a very complex phenomenon. The influence on the driving behaviour depends on the complexity of the distracting factor (e.g. intensive telephone conversation) and the complexity of the driving situation (European Commission, 2009). Furthermore these complexities are determined by characteristics of the driver, the vehicle and the network. The measurement is difficult and potentially imprecise due to self-reporting and timing of data collection. Furthermore, differences in methodology and definitions, conducted in each study or survey, may arrive at different results and conclusions with respect to the involvement of driver distraction during a crash (NHTSA, 2009).

One of the first steps in managing inattention and distraction as a road safety issue should be to develop common definitions. Those are the basis of common categorisation systems which are essential for enabling comparisons of findings across studies (countries) (Regan et al., 2009).

There is a lack of objective and representative data on the problem of driver inattention and distraction. Much more epidemiological research is required to enable accurate estimates of the problem of inattention and distraction while driving (Ranney, 2008; SWOV, 2008b; NHTSA, 2009).

The identification of inattention and distraction remains difficult, as does its role in a crash. In order to identify driver distraction related to crashes, Eby and Kostyniuk (2003 p. 3) propose that information should be gathered on: “1) distraction information (including sources of distraction inside and outside the vehicle that may have drawn the driver's attention away from the driving task at the time of the crash); 2) inattention information (including the driver's physical or mental condition at the time of the crash for determining the driver's level of attention to the driving task); and 3) driver demand information (including roadway, traffic, and environmental conditions at the time of the crash)”.

The added value of Naturalistic Driving Observations should be investigated in order to overcome difficulties such as matching exposure data or differences in the measurement.

Ranney (2008 p. iii) indicates the potential of the latest developments (e.g. large-scale naturalistic observation data collections or driver assistance technologies) to provide objective and representative data on inattention and distraction and crash risk and to monitor drivers’ visual behaviour and manage the flow of information to the driver.

Within his recommendations for future research, Ranney (2008 p. 22) states that Naturalistic Driving studies providing incidence data on distracting activities have typically been small-scale studies. He states that a larger, more representative, study of the incidence of distracting is required to ensure that appropriate data are obtained to better understand trends in driver distraction. Analysis of naturalistic data is needed to clarify which factors contribute to drivers’ willingness to engage in potentially distracting tasks while driving. He adds that information is also needed to determine the extent to which the presence of in-vehicle technologies encourages unnecessary or incidental use while driving. Furthermore, work should continue on the development of objective, standardised measures of distraction. Emphasis should be given to improving the reliability and validity of eye- glance measures. New evolutions in methods can allow better measuring/registration. Finally he aims at helping to anticipate future distraction problems, by arguing that segments of the driving population or other transportation system users who may have future potential for increased incidence of distraction should be identified (e.g. police officers, emergency responders, young drivers) (Ranney, 2008).

1.4.3. Headway

1.4.3.1. General concept

“Headway is a measurement of the distance between vehicles in a transit system. It is most commonly measured as the distance from the tip of one vehicle to the tip of the next one behind it, expressed as the time it will take for the trailing vehicle to cover that distance (Wikipedia, 2010)”. A headway time of two seconds is sufficient for the vast majority of drivers to prevent a rear-end collision with the vehicle in front, particularly on motorways where the traffic situation is not very complex. It gives the driver sufficient time to start emergency braking if necessary. If the headway time is considerably less than one second, this is called tailgating (SWOV, 2007 p. 1).

The phenomenon of following distances is quite complex though. They are highly variable and situation dependent and can not be compared straightforwardly. This makes it difficult to indicate appropriate safety levels (Brackstone and McDonald, 2007 p. 1193).

Following cannot be explained as a natural state of driving because any driver will attempt to move at his/her own desired speed. Drivers will only find themselves in a following situation when they arrive behind a vehicle travelling at a lower speed. Even if this should occur, drivers may lane change and accelerate past the vehicle blocking their path. In low traffic flow following is thus rare as there is sufficient opportunity for drivers to move into adjacent lanes to maintain their speed. However when traffic flow is high, it is common to follow until an appropriate gap occurs in an adjacent overtaking lane. There may be many reasons why a vehicle is following and this can affect the driver's motivation and willingness to take risks during this process (e.g. depending on the duration of the following or the distance to the destination) (Brackstone and McDonald, 2007 p. 1184).

Maintaining a safe headway can thus be considered a critical cognitive task for the driver (Shinar, 2004). Engaging in short headway could be explained by a misperception of one's own reaction times and braking skills. Furthermore, short distance keeping has been found to yield lower minimum time to collision values, meaning that it is related to a more risky driving style (Brackstone and McDonald, 2007).

It is still very challenging to provide clear unequivocal statements regarding car following and safety levels (Brackstone and McDonald, 2007 p. 1). This makes further research towards better understanding of (failure of) safe distance keeping an ongoing challenge with clear possible implications for improving road safety (Shinar, 2004).

Current research is essentially hampered by lack of data. There is little to no data on how close driver following distances typically are. The complexity of the process and its variability according to local conditions makes it very difficult to study. Whereas roadside/static snapshots of behaviour are unable to reflect the dynamics inherent to the process, the instrumented vehicle on the other hand is one of the best tools to examine this phenomenon (distance and speed measuring units providing time series information on inter-vehicle separation, relative speeds and ground speed). Together with the availability of cheaper sensor technology and increasingly flexible instrumented vehicles, headway has become a useful and frequently used indicator of driver performance (Brackstone and McDonald, 2007 p. 1183).

Potentials for long-term longitudinal monitoring of driving styles as a basis of headway related calculations across countries have been formulated in recent research. Brackstone and McDonald (2007) pointed out these kind of studies may allow insight into following behaviour and following distance choices and as such may allow profiling drivers that typically drive closer than others.

1.4.3.2. Impact on road safety

Prevalence

Instrumented vehicle studies indicate that a large proportion of drivers engage in close vehicle following. In fact, all drivers will at some point in time unavoidably be following closer than they would wish to be. The frequency and severity of this behaviour is influenced by education, desire, driving regulations and enforcement (Brackstone and McDonald, 2007 p. 1188).

In an attempt to measure the size of the problem, Marsden et al. (2003 IN: Brackstone and McDonald, 2007) examined, in the EU project DIATS, passive following data which were collected from three sites in three different EU countries (FR, DE and UK). The results showed that French drivers' average headway is lower than those in Germany and both are lower than the ones in the UK.

According to the SARTRE 2 survey results (SARTRE: Social Attitudes to Road Traffic Risk in Europe) “following a vehicle in front too closely” is judged a significant contributor to accidents (by 84% of respondents in SE and UK, and in most other countries (AT, FI, FR, DE, IE, IT, NL, HU, ES, BE and CH) by more than 70%). The role of close car following in road crashes is estimated to be greater than the contribution of tiredness, drug or medicine taking, but less than the role of drink driving and speeding. On the other hand only an EU-wide mean of 8% of the respondents report to engage “often, very often or always” in too close vehicle following, with a maximum of up to 21% in Greece (Cauzard et al., 1998 p. 22f). In the SARTRE 3 results, the frequency of this behaviour substantially increased in Greece (from 21 to 35%) and Belgium (from 8 to 17%), while the values of the other countries almost remained the same (Sartre 3 consortium, 2004). More than 1 out of 4 drivers (26%) report to do this “at least sometimes” (Sartre 3 consortium, 2004 IN: Via Secura, 1998).

Decreased headway is often related to inappropriate speed, excessive speed, reckless overtaking, and frequent lane changing (Via Secura, 1998). Furthermore, driver related states like alcohol intoxication or fatigue can typically affect headway (European Commission, 2010a&b).

Relation to road crashes

A safe headway is a buffer against rear-end collisions. It is obvious that the average headway distance and time influence the occurrence of rear-end collisions. Dutch police are convinced that rear-end collisions are the result of keeping too short distances; they register this as being the cause in 80% of rear-end collisions. The chance for such accidents is higher on motorways and main roads. Crash statistics in the Netherlands show that between 2001 and 2006 an average 42% of injury crashes on motorways and main roads were rear-end collisions. This was also the case in 36% of all registered accidents with only material damage, and in 20% of all fatal crashes (SWOV, 2007 p. 2ff).

In the USA, crashes due to insufficient vehicle headway are said to account for a significant portion of all crashes: over 29%. In Israel, this type of crash accounts for roughly 13% of injury crashes (Shinar, 2004).

The frequency of rear-end collisions depends on how busy the traffic is. Dutch data indicates that they occur more often during the rush hours than other hours, and they are more frequent than other crash types during rush hours. (SWOV, 2007 p. 2).

Safe headway distance has recently been introduced in engineering research as a new crash risk predictor (in statistical crash prediction models), to estimate traffic crash likelihood. The results showed that this measure was effective in predicting traffic crash occurrence. This shows a promising opportunity in traffic safety analysis by applying a safe headway distance based on individual car following behaviour data in crash prediction. The approach with a vehicle-based crash predictor could enable traffic engineers to have a reliable safety evaluation by location, time, and transportation management strategy under various traffic flow conditions (Hojun et al., 2008 p. 27).

1.4.3.3. Discussion

The literature indicates a current lack of data on headway. Several methodological difficulties exist, including the determination of safe versus unsafe headway which is linked to the context, but also the difficulties of measuring the required information on the dynamics inherent to the process. Nevertheless a (too) short headway is considered a significant contributor in road accidents, mainly on motorways and main roads. The phenomenon is quite spread: all drivers engage in too close following at least once, about a quarter of drivers state they do this at least sometimes. The best measurement tool is the instrumented vehicle, which is rather complex and expensive; although with time more and cheaper technology is (becoming) available. Headway measures provide an opportunity in getting information on driving styles and even in profiling them; they can also be used in estimations of crash likelihood.

When measuring headway, several variables related to the risk, can be taken into account, like driver characteristics (e.g. Driving under the influence of alcohol or fatigued driving), period of the day (rush hour; high-low flow) and type of road (at least motorways and main roads, where the situation is less complex).

1.5. Survey of national policy makers

The aim of the survey of national policy makers was to gain an understanding of the current policy priorities of national administrations and to investigate additional road safety issues which so far have not been selected by the expert consortium of DaCoTA WP6 and PROLOGUE. As part of a larger questionnaire activity conducted by DaCoTA WP2[8], with contributions from WP5 and WP6, “National Experts” were asked to rate selected topics according to their country’s road safety policy priorities. The list of topics presented to the National Experts comprised mainly of the topics which DaCoTA WP6 focused on: SPI, the additional topics and ‘Near Crashes’. Accident Causation was added as this was a topic of interest for DaCoTA WP2 and ‘Safety Technologies’ was included to provide DaCoTA WP5 ‘Safety and e-safety’ with information. The National Experts group was set up by the European Commission, DG MOVE[9], to liaise with the commission in relation to the development of the CARE database and provision of data. An additional experts group, the RSPI (Road Safety Performance Indicators) Group was set up for the SafetyNet project to assist in the development and provision of data for the RED and SPI. Both the CARE and RSPI elements of the National Experts group continue to provide further assistance to the Commission. National Experts are chosen to represent national administrations and the group currently includes representatives from the EU 27 plus Norway, Iceland and Switzerland. The questionnaire was distributed by email and was explained to the Experts at a meeting in June 2010 (Brussels, European Commission), by the DaCoTA WP2 partners.

In the following question, National Experts were asked to rate a list of topics according to whether they are low, medium or high (policy) priority:

“Assuming that you would be able to monitor all possible road safety issues, using a variety of methods, please rate the following topics according to their priority in your country’s current road safety policy (low/medium/high priority).

- Accident Causation

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[8] For more information on the other DaCoTa Work Packages see: http://www.dacota-project.eu

[9] formally DG TREN

- Alcohol
- Daytime running Lights
- Distraction/Inattention
- Fatigue
- Gap Acceptance (headway)
- Near Crashes
- Safety Technologies (infrastructure or vehicle)
- Seatbelt use
- Speed".

The question also allowed the National Experts to indicate further areas of (policy) priority that were not covered by the topics listed. Answers received from the National Experts before 10th September 2010 were included in the analysis.

1.5.1. Policy priorities

21 National Experts sent their feedback and answered the above mentioned question (response rate 70%).

The following figure illustrates the answers of the National Experts by country:

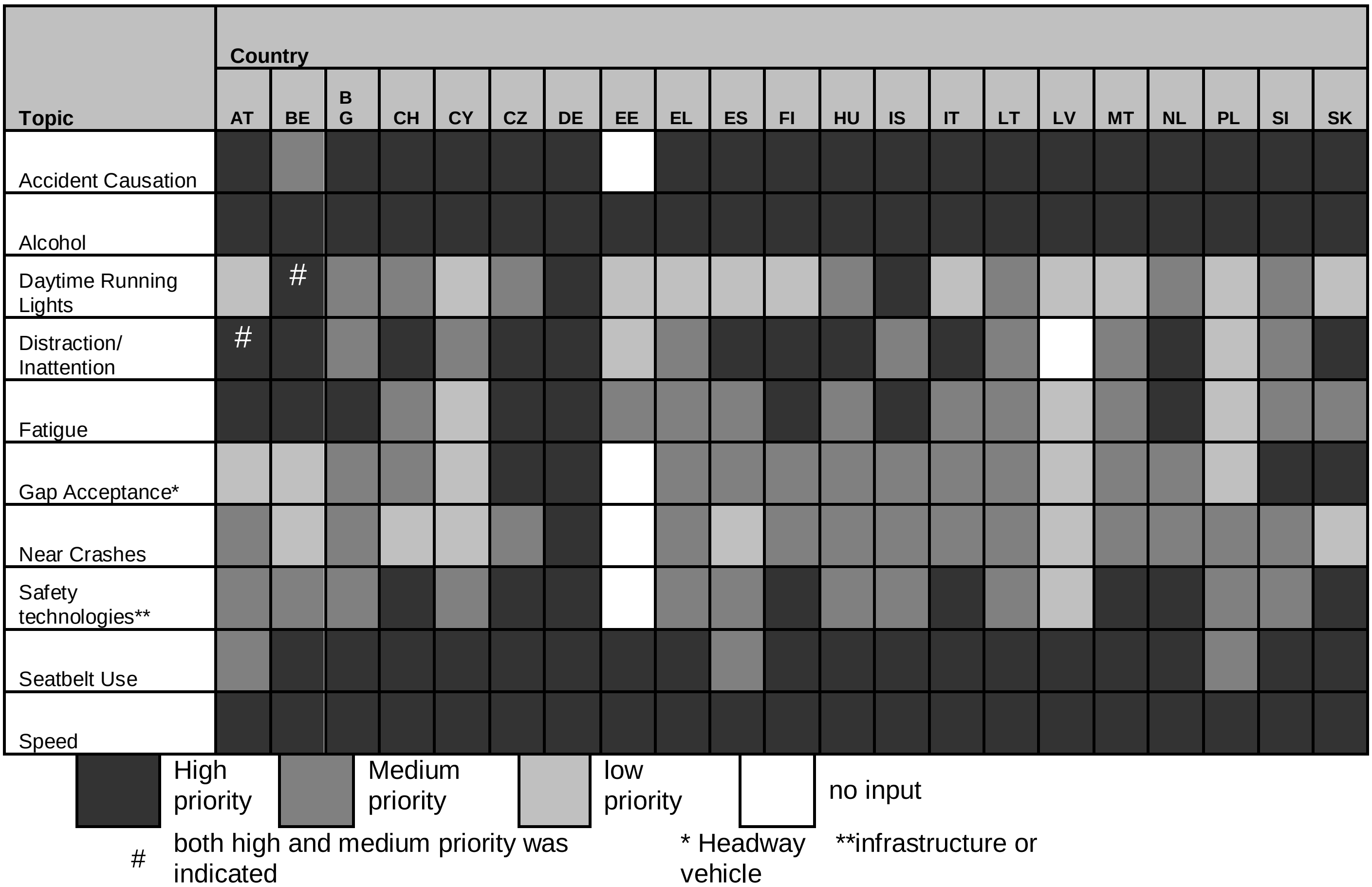

Figure 2 Rated priority level of road safety topics by country

Based on the percentage of high (policy) priority ratings the following ranking could be identified:

- high priority: speed (100%), alcohol (95%), seatbelt use (86%) and accident causation (86%);
- medium priority: distraction/inattention (52%), fatigue (38%) and safety technologies (38%);
- low priority: gap acceptance (headway) (19%), daytime running lights (14%) and Near Crashes (5%).

1.5.2. Other road safety issues

Furthermore, the National Experts were asked to indicate road safety areas of interest which might not have been listed in the DaCoTA WP6 question.

Linking the question on additional topics of interested to current “policy priorities” might have restrained the experts to name topics which have not yet been investigated properly. Policy is essentially based on identified problem areas, which assumes by itself that data on the problem already exists. Thus, topics which have not been investigated so far by the traditional methods might not have been captured by this question and the aim of investigating additional road safety issues beyond traditional topics might have been only partly fulfilled by this question.

Nine countries provided input on OTHER possible road safety issues:

Three of these issues are not applicable for DaCoTA WP6 (Naturalistic car driving observation). They are: helmet use (CY), pedestrians’ offences (LT) and vulnerable road users (SK).

Most of the additional input covered variables which refer to potential context variables within DaCoTA WP6. The ones mentioned were: medical problems, ageing, young drivers, road and traffic characteristics, road maintenance (winter) (FI), licenses, education, law obedience (previous offences) (NL), traffic education, ITS implementation and black spot management (SK).

The following additional road safety issues might be of interest for the Naturalistic Driving observation within DaCoTA WP6: illicit drugs and medicines (BE, CZ, FI, NL), mobile phone use (BE, EL) and blind spot accidents and - management (BE, SK). The feasibility of measuring these topics within an EU wide monitoring approach (Scenario 1 and 2), will be discussed within chapter 3.

1.6. Value of near crashes for safety outcomes

A number of researchers (e.g., Reason, 1990), and those present at the FOT-Net workshop (FOT-Net, 2010), have highlighted the potential advantages associated with the collection and analysis of near crash data. The utility of such data collection lies in the ability to generate large amounts of data that would otherwise go un-noticed. These data are useful in that they contain information about incidents or accidents that are, in a sense, waiting to happen. Near crash data also contain information regarding the types of errors made, the causes of the errors made, and also recovery strategies for the errors made. The study of near crashes is therefore particularly important for a number of reasons including the following:

- From a sample size viewpoint, near crashes occur more frequently that actual accidents and therefore provide the number of cases necessary to perform more pertinent quantitative analysis;
- Near crashes provide a qualitative insight into how small errors and failures can line up to create large disasters;

- Near crash data are important to better understand the relationship between behaviour and safety outcomes.
- Near crash data can also provide insights into how accidents were avoided, which could provide important data for accident prevention measures.

It is important however to establish a typology of how near crashes relate to accidents involving injury. It may be that particular types of near crashes are more highly related to actual accidents in terms of the circumstances under which they occur and the errors involved. This needs to be established with large-scale research programs, and the large scale observation that will be proposed by DaCoTA may have a large role to play in this regard.

The implications of this type of work for the assessment of road safety outcomes is potentially very significant. Currently the calculation of risk, outlined in Figure 1, relies primarily on the use of accident data for the inputs to safety outcomes. If research could establish reliable relationships between near crashes and accidents involving minor and severe injury, then safety outcomes in Figure 1 could be substituted with near crashes. The resulting risk estimates would be based on a data set considerably larger by an order of magnitude. Another advantage would be that the exposure data is measured simultaneously with the corresponding near crashes.

1.7. Conclusions on relevant variables

It can be concluded that all investigated topics can be considered as relevant topics for ERSO monitoring. Based on the indicated policy priorities in the national expert's survey the topics can be ranked according to the following order:

- high priority: speed, alcohol, seatbelt use;
- medium priority: distraction/inattention, fatigue;
- low priority: gap acceptance (headway), DRL.

The SafetyNet analysis on the current practices of monitoring RED (vehicle km, person km, number of trips, time spent in traffic and fuel consumption) and SPI topics (speed, alcohol/drugs, protective systems and DRL) showed that all these indicators still present major difficulties in regard to availability and/or comparability of the data. Consequently, a need for improving the existing data collection methods is indicated. The SafetyNet experts furthermore pointed out that a high level of disaggregate information on all topics is desired in order to do valid comparisons across the countries. Common context variables mentioned within SafetyNet include:

- Driver variables: age, gender
- Vehicle variables: vehicle age
- Network variables: road type, area type
- Other contextual variables (transient): year, month, day, hour

These could be proposed as "minimal wish list" for all selected RED and road safety topics within DaCoTA WP6.

Variable values that are currently used show great discrepancies across countries (even national); a way to overcome these problems (a "pragmatic" approach) is to limit the values to some broader – more common – categorisations (e.g. as suggested by SafetyNet; Road type: minimally urban road, rural road and motorway, or year-month-day-hour: minimally week-weekend and day-night)

Based on the more specific SafetyNet suggestions per topic and the investigation of additional literature on speed, alcohol/drugs, protective systems and DRL, the following context variables might also be considered interesting for the DaCoTA WP6 Naturalistic Driving observation study.

- Driver variables: nationality, driving experience, level of education, prior traffic offence(s), personal characteristics (e.g. attitudes, risk taking, perceptual skills and limitations), other socio-economical characteristics.
- Vehicle variables: engine size, specific make of car (e.g. Land Rover) (speed).
- Other contextual variables (transient): professional or private driving purpose, traffic density, traffic composition, level of enforcement, speed limit (speed, seat belt use), passenger age (seat belt use), passenger gender (seat belt use), child age (child restraints) , body length of child (child restraints)

This overview should not be seen as an exhaustive list. It is meant to give an indication of relevant variables, which can be expanded and, if necessary, adjusted to the possibilities of Naturalistic Driving observation. Context variables relating to road safety topics which were not investigated within SafetyNet (fatigue, inattention/distraction and headway) are not included in this overview, as these involve complex measurements which will directly be discussed within the scope of monitoring through Naturalistic Driving Observations (see Chapter 3). SafetyNet did not develop or suggest any indicators on these topics.

2. INVENTORY OF RELEVANT VARIABLES TO MONITOR THROUGH NATURALISTIC DRIVING OBSERVATION

2.1. Introduction

This chapter outlines the work undertaken and the outcomes for the second activity of task 6.1; *Inventory of relevant variables to monitor through Naturalistic Driving observation*. Based upon literature and knowledge available from previous and current Naturalistic Driving studies, this activity has identified the research topics that can be addressed by Naturalistic Driving Observations and in particular those that are considered relevant and important in the context of road safety research and policy development.

The aim of this chapter is twofold:

- To outline how the topics discussed in Chapter 1 have been studied using Naturalistic Driving Observation or could be in the future
- To highlight additional topics that have been studied with Naturalistic Driving but have not been covered in Chapter 1.

This chapter will identify the variables – both those related directly to the topic and more generally to the driving context – that have been collected or are necessary to collect to explore these topics. In addition a general overview of the technical equipment needed for Naturalistic Driving and the measurement tools necessary to collect these variables will be given. This chapter does not seek to define the variables and technology that should be considered in a large scale activity, instead it gives an overview of what is achievable using Naturalistic Driving Observation.

This exploration of Naturalistic Driving studies and safety related research topics draws on the work already undertaken by the EC supported project, PROLOGUE. This is to avoid the duplication of work in both projects. PROLOGUE undertook an extensive review of Naturalistic Driving literature (Backer-Grøndahl et al, 2010) and set up a User Forum in order to assess the priorities of potential users of data produced by Naturalistic Driving (Van Schagen et al 2010). These activities were used alongside a review of the early outputs of SHRP2[10] to generate a list of general research topics and suggestions of more specific research questions that should be considered in future large scale Naturalistic Driving studies (Sagberg and Backer-Grøndahl, 2010). In parallel with this, PROLOGUE drew on the published literature, experts in the field and the experience of current Naturalistic Driving studies to identify the requirements for conducting Naturalistic Driving studies in terms of methodological and organisational considerations (Groenewoud et al, 2010) and the technologies required for data collection, storage and analysis (Welsh et al, 2010).

In addition to the PROLOGUE deliverables, a number of Naturalistic Driving study reports have been reviewed and where available information has been gathered about current Naturalistic Driving projects. The expert knowledge of the work

[10] Strategic Highway Research Program (USA) including a Naturalistic Driving research program

package partners and the workshop on Near Crashes (FOT_Net, 2010) has also been drawn on to inform this chapter.

2.2. Research topic priorities from a Naturalistic Driving perspective

Backer-Grøndahl et al (2010) identified 3 types of Naturalistic Driving Study:

1. 'Normal driving focused' aiming to investigate driving behaviour in its own right.
2. Critical event/Near Crash event focused which aims to investigate these types of events and identify associated behaviour.
3. System focused aiming to study the interaction between the driver and system elements for example, in vehicle technologies. Field Operational Trials fall into this category.

More specifically, a number of safety related topics were identified that have, in the past, been studied using Naturalistic Driving methodologies:

- Driver distraction and inattention (particularly well studied)
- Drowsiness and fatigue
- In-vehicle systems
- Lane-change behaviour
- Heavy vehicle – light vehicle interaction
- Driver characteristics and states
- Applied use of Naturalistic Driving observation.

However the above topics are not necessarily those which are of most interest to potential users of Naturalistic Driving data/results and policy developers. Van Schagen et al (2010) conducted an online survey which asked a variety of road safety professionals, including policy makers and researchers, which topics they would like to be examined using Naturalistic Driving methodologies. 72 road safety professionals filled in the survey and the following topics were rated to be important or very important by over 80% of respondents [percentages in brackets]:

- Risk-taking behaviours (speeding, alcohol use) [93%]
- Crash avoidance behaviour [90%]
- In-vehicle safety support systems (cruise control, ISA, navigation, warning systems) [88%]
- Normal behaviour (gap acceptance, overtaking, gear choice) [88%]
- Pre-crash behaviour [86%]
- Driver condition (fatigue, stress, use of medication) [85%]
- Distractions inside the vehicle (passengers, mobile phone use, eating) [83%]
- Driver characteristics (gender, age) [81%]

What is interesting is that the first 2 topics rated as being important by the most respondents have, in the past, been rarely if at all been studied using Naturalistic Driving. The findings of the Expert Survey reported in (section 1.5) suggest that the risk-taking behaviours of speeding and alcohol use are a high policy priority more broadly.

2.3. The study of road safety topics using Naturalistic Driving Observation

The road safety topics considered in Chapter 1 were:

- Alcohol and Drugs
- Speed
- Protective Systems (seat belt and child restraint use)
- Daytime Running Lights (DRL)
- Fatigue
- Distraction and inattention
- Headway
- Exposure measures:
  - Vehicle km
  - Fuel consumption
  - Person km
  - Number of trips
  - Time in traffic

The following sections will give a brief overview of the potential contribution of Naturalistic Driving to the understanding of these topics. Where appropriate, past studies have been used as an illustration. Sagberg and Backer-Grøndahl (2010), drew on previous PROLOUGUE deliverables (Schagen et al (2010); Backer-Grøndahl et al (2010)), to identify road safety topics that are considered to be particularly appropriate for exploration using Naturalistic Driving Observations. Their work has informed this overview. For a more through literature review of topics studied through Naturalistic Driving Observations, see Backer-Grøndahl (2010).

2.3.1. Alcohol and Drugs

This topic could include both the use of prescription and illegal drugs as well as driving while under the influence of alcohol. This topic has not been directly addressed through Naturalistic Driving yet, although SHRP2 have considered using a sensor to detect alcohol. The difficulty a Naturalistic Driving study would have in attempting to explore these is that they are not observable behaviours. The consequences e.g. drowsiness, inattention or erratic driving can be observed but unless the driver provides information on their ‘impairment’ then the cause of such behaviour cannot be known.

2.3.2. Speed

Speed can relate to both speed choice and violation, whether unintentional or intentional. It has long been considered an important contributory factor for accidents. Van Schagen et al (2010) reported that 99% (66/67) of road safety professionals who thought that risk taking behaviours were important topics to study using Naturalistic Driving also thought that speeding was of particular importance. PROLOGUE points out that although average speeds and speeds at a particular point of time have been examined by Naturalistic Driving studies, speed profiles have received little attention. Of particular interest would be speed adaptation behaviours of particular groups of drivers to environmental factors such as road layout and weather conditions. For example do young drivers choose to alter their speed when approaching a bend in a different way to older drivers? Naturalistic Driving would also allow the examination of how often particular drivers exceed the speed limit and the duration of these violations. Naturalistic Driving Observations also allow the study of acceleration which could provide additional information about drivers' behaviour in relation to speed.

2.3.3. Protective Systems and Daytime Running Lights

Protective Systems (seatbelt and child restraint use) and Daytime Running Lights (DRL) have been grouped together here as they deal with very specific aspects of driver behaviour, namely whether car occupants choose to put on their seat belt and the choice to use headlights or not when driving during the day. Neither topic is likely to be the sole focus of a Naturalistic Driving study but within the context of monitoring road safety Naturalistic Driving Observation has the potential to provide useful information about the frequency of and circumstances surrounding not using a seatbelt or the use of DRL. This could also lead to the identification of which groups of drivers are more likely to engage in this behaviour. Knowledge about who consistently do not use seatbelts, for example, would be useful for policy makers so that interventions/countermeasures can be targeted. This is of particular importance in countries where the seatbelt wearing rate is high for the general population and there is an overrepresentation of unbelted occupants among road crash fatalities.

2.3.4. Fatigue

Fatigue has been thought to increase crash risk for many years. Similarly to distraction, Naturalistic Driving offers an opportunity to study the relationship between fatigue, behaviour and crash risk in a realistic setting. A number of studies have examined fatigue in commercial truck divers (e.g. Hanowski, 2007) with fewer focusing on car drivers. Issues that need to be addressed in research focusing on fatigue are how to measure fatigue, the prevalence of driver drowsiness and what affect this has on behaviour and crash risk.

2.3.5. Distraction and Inattention

Distraction/Inattention is one of the most common topics to be addressed in studies that utilised Naturalistic Driving techniques. Studies have looked at drivers' exposure to distraction/inattention, how distraction/inattention affects driving behaviour and whether distraction/inattention increases crash or near crash risk. One of the advantages of using Naturalistic Driving to explore distraction and inattention is that it can provide reliable information about their prevalence and their true relationship with crashes/Near Crashes, i.e. the actual risk level. For example, Klauer et al (2006) examined the crash risks associated with driver inattention. They found that if the driver took their eyes of the road for more than 2 seconds, this increased crash and Near Crash risk.

2.3.6. Headway

The gap a driver is willing to leave between themselves and the vehicle in front is thought to be related to accident risk. Aspects that may be interesting to study using Naturalistic Driving include time headway to the car ahead, time gaps between crossing vehicles when waiting at a stop sign or the gap between an overtaking vehicle and an oncoming vehicle. Behaviour in relation to gap acceptance has been studied though Field Operational Trials aiming to examine the effect of warning devices, for example Regan et al (2006).

2.3.7. Exposure measures

One of the advantages of Naturalistic Driving methodologies is that they aim to record 'normal' behaviour and therefore can monitor how often drivers engage in certain behaviour or events that do not lead to a crash. For example how often people drive while fatigued and for what distances without incident compared with how often fatigue related crashes occur can give an incite about the relative crash risk of fatigue and in what circumstances this risk is increased. Thus Naturalistic Driving can provide data on exposure. The type of exposure measures discussed in Chapter 1 depend on having a representative sample of the population. The majority of Naturalistic Driving studies have involved relatively small number of participants and therefore do not provide the representation needed for this type of exposure data. However it is possible to record data on how far a vehicle travelled during Naturalistic Driving Observations (Vehicle km), to identify the driver (Person km) and to identify the 'Number of trips' and how long drivers are on the road (Time in traffic). Fuel consumption has been recorded in Naturalistic Driving studies however this has related to 'eco-driving' rather than road safety (E.g. Beusen et al. 2009).

2.4. Other topics addressed with Naturalistic Driving

'Near Crashes' was also identified by DaCoTA as an important topic to be examined by Naturalistic Driving Observations, however it is a topic that has gained the most interest within Naturalistic Driving and is discussed here.

Sagberg and Backer-Grøndahl (2010) also identified a number of categories of driver related topics that were considered to be particularly appropriate for exploration using the Naturalistic Driving approach, but were not the focus of Chapter 1. These were

- Lane change, lane position and lane keeping,
- Aggressive driving: compliance with regulations,
- Learning.
- Decision making, errors, driving style/performance

As elements of these may become more important or more of a priority for monitoring road safety in the future, these additional topics and Near Crashes will be discussed in the following sections.

2.4.1. Near Crashes

The primary aim of road safety is to reduce the number of crashes that occur and the level of injuries. One of the advantages of Naturalistic Driving methodologies is that it allows the study of driving in as close to normal driving situations as possible. As previously discussed, this 'exposure data' allows the incidence of aspects that are known to be associated with crash risk e.g. distraction/speed, to be examined under 'normal driving' conditions. To find out the crash risk, the incidence in 'normal driving' has to be compared with how often this aspect was present in a crash situation. However crashes are relatively rare events. For example, only 82 crashes were observed in the 100 car study (Dingus et al., 2006) where around 2,000,000 vehicle miles were recorded. Therefore it is necessary to use some kind of surrogate measure to look at crash risk. Many Naturalistic Driving studies have used 'Near Crashes' as such a measure. This is where a driver encounters a conflict situation but does not actually result in a crash.

Klauer et al. (2006, p154) uses the term 'near crash' defined as "a subjective judgment of any circumstance that requires, but is not limited to, a rapid, evasive manoeuvre by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash". A rapid evasive manoeuvre was defined as an action that approaches the limits of the vehicle's capability including steering, braking, accelerating, or any combination of control inputs.

A Naturalistic Driving monitoring activity would seek to measure the number of Near Crashes that occur in specific circumstances rather than identify specific crash risks per se. In previous Naturalistic Driving studies Near Crashes have been identified using data logger readings e.g. braking at pre-defined severity, which are then verified by reviewing video data. McGehee et al. (2007) report that the setting of the logger/sensor values which indicate an event of interest is of great importance. If these are set too low then too many events that are not Near Crashes will be flagged, if too high then events of interest will be missed. This is of particular importance if event triggered logging is used, where data is only stored (logger and video) for the period around which an event occurs.

The 'trigger values' chosen to indicate that a Near Crash has occurred vary from study to study. Klauer et al's (2006) report which utilised the data gathered during the 100 car study, considered the values 0.5g for braking and 0.4g for lateral acceleration as a result of steering (swerve measure) as guides that a 'rapid evasive manoeuvre' had occurred. The trigger values, however, to indicate that a ''safety-relevant conflict' had occurred were set higher at 0.76g for braking and 0.8g for lateral acceleration. McGehee et al. (2007) used the figures 0.5g for braking and 0.55g for lateral acceleration to indicate that an 'event' had occurred; however these events were not necessarily 'Near Crashes'.

There was consensus at the FOT-Net workshop that further work is needed to refine the definition of a near crash and how these can be measured quantitatively, that is, how to refine the triggers for near crash data collection. The existing definitions of near crashes are qualitative, for example, the definition used in the US 100 car study. Researchers know qualitatively what a near crash represents, yet translating that to a quantitative definition with robust incident descriptions remains a significant challenge.

It was also recognised that certain near crashes go undetected, including those in which no driver or vehicle reaction is present. In these cases only continuous external video cameras could capture information on critical situations, which makes it very labour intensive to detect their number and circumstances. For certain near crash types, such as rear-end and side impacts it seems more feasible to define trigger values.

As noted earlier, any trigger value by definition involves a cut-off, meaning there is a necessary trade-off between the amount of data captured and the level of false negatives. Research is underway in Sweden in the Semi-FOT2 project, exploring the utility of a classification of crash relevant events based on the analysis of continuous signals. This is highly innovative research that should be monitored during 2011 for consideration in DaCoTA activities.

2.4.2. Lane change, lane position and lane keeping

This is an interesting aspect of normal driving to study as lane position and lane keeping behaviour may be influenced by driver states such as inattention and fatigue. In addition, overtaking manoeuvres can add risk to the driving situation, especially where the vehicle crosses onto the opposite carriageway. The frequency and type of lane change manoeuvre in normal driving conditions is also of interest. Naturalistic Driving methods have been used to examine 'normal' lane change behaviour and how lane departure warning systems effect driver behaviour (e.g. LeBlanc et al 2006) as well as a measurement included in distraction or fatigue studies. For example, Lee et al. (2004) studied the lane change behaviour of 16 commuters. Of particular interest was the driver's eye glance behaviour and how often different types of lane changes occur. They found that the majority (91%) of lane changes were low in severity and urgency.

2.4.3. Aggressive driving: compliance with regulations

This category relates to other categories such as driving style, speed and acceleration and gap acceptance. Naturalistic Driving, especially where a drivers own vehicle is instrumented for a long period of time, could help identify the prevalence of aggressive or 'road rage' related behaviour such as gesturing, while travelling at speed in close proximity to another vehicle.

2.4.4. Learning

A number of studies have used Naturalistic Driving to monitor and provide feedback to novice drivers. Toledo et al (2008) reported on a data recording system aiming to assess when drivers performed high risk manoeuvres or actions e.g. harsh braking, entering a bend too quickly. McGehee et al (2007) conducted a study of young novice drivers (16-17 year olds). An event triggered recording system was used to capture 'risky' manoeuvres and the teenager's performance was fed back to their parents.

2.4.5. Decision making, errors, driving style/performance

This category was used in PROLOGUE to capture behaviour that was not covered more specifically in other categories. These behaviours relate to car handling e.g. signal and headlight use, and the traffic environment, e.g. overtaking and route choice. Driving style/performance could be observed using Naturalistic Driving by looking at the timing of, for example, gear changes and similar operational driving tasks. Decision making could be examined by observing the timing of manoeuvres and their consequences however the intention of the driver cannot be addressed though direct observation. Behaviours such as seatbelt use and seating position are also included in this category.

2.5. Driving Context

Chapter 1 identified a number of variables are necessary to collect meaningful data on the topics discussed within the context of specific methodologies (non Naturalistic Driving). Of course, knowing about the driving context is also essential in a Naturalistic Driving study to reach meaningful conclusions about the topics addressed. PROLOGUE (Sagberg and Backer-Grøndahl, 2010) identified several context factors that should be considered in Naturalistic Driving studies. These will be discussed below within 4 categories:

- Driver
- Vehicle
- Network
- Other contextual factors

Driver, vehicle and network are relatively permanent factors whereas those in the other contextual factors category are more transient and are likely to vary from one journey to the next.

2.5.1. Driver

Driver context factors describe the more permanent characteristics of the driver, for example: Driver age, gender and driver experience. Health problems or medical conditions also fall under this category. Knowledge of these background factors allow the identification of particular groups of drivers such as young or old which may be of interest.

2.5.2. Vehicle

The design of the vehicle is another important context factor. For example whether the vehicle has a manual gear box or automatic or fitted with advanced technologies such as Advanced Driver Assistance Systems (ADAS) and In-Vehicle Information Systems (IVIS) are likely to influence driving behaviour. To again take the example of speed, if the driver is warned when they travel over the speed limit then they may be less likely to speed compared to drivers who do not have this warning. The positioning of controls and the size of a car's 'blind spot' may also be interesting variables to consider.

2.5.3. Network

This refers to the roadway context of the driving activity. Characteristics such as the number of lanes, the width of the road and particular road layouts such as intersections could all influence the way individuals drive, for example speed choice. If it is important to understand the information drivers gain from the road environment then recording the presence of road markings and signs is important. Although the roads that the driver uses will vary for each journey, the characteristics of these roads are fixed so Network factors are also considered as relatively 'permanent'.

2.5.4. Other contextual factors

These factors are transient, i.e. can vary both within and between journeys. These 'other' factors include specific journey characteristics such as the presence of passengers, whether an in vehicle device is being used/triggered, weather conditions and interactions with other road users. Trip characteristics are variables that exist for the duration of a particular journey. An example of this is whether or not there are passengers in the vehicle. This could impact on the behaviour of for example younger drivers and add a potential additional distraction. Environmental factors such as adverse weather or road conditions are also important. For example wet weather or glare from the sun on a wet road is likely to affect driving behaviour.

Factors such as the amount of traffic which surrounds the driver are potentially important context variables. The driver is likely to behave differently on a busy road than when there are very few other vehicles on the road. If the interactions between road users are to be considered in a Naturalistic Driving study then knowledge about the presence for example of vulnerable road users or heavy vehicles is important.

2.6. General technical requirements of Naturalistic Driving studies

The variables collected in a Naturalistic Driving study relate directly to the research questions that the study seeks to answer. In turn the measurement methods depend on the specific variable, the level of detail required and the budget of the project. Specific sensors and pieces of technical equipment cannot be chosen in isolation from the other components that make up a Data Acquisition System (DAS). DAS can be relatively simple e.g. the DAS without video developed to detect the 'risky driving' behaviours of novice drivers in Israel (Toledo et al., 2008) or much more complex, for example the system used in the SeMiFOT project (SAFER, 2010).

A very basic DAS could comprise of a GPS device and accelerometers plus the ability to record the data. The majority of Naturalistic Driving studies use a more complex DAS comprising of a data logger that records information from a number of basic and more specialist sensors and video channels. The logger may also collect data from the Controller Area Network (CAN). Video can be internal e.g. of the driver and external to record the roadway environment. See Welsh et al. (2010) for a more comprehensive review.

The number of sensors and video cameras used differs according to the complexity of the study. SHRP2 plans to utilise sensors with high sensitivity and accuracy and wireless technology in order to build a DAS that is as unobtrusive as possible to the driver. Figure 3 shows the SHRP2 DAS system (cited in Welsh et al 2010).

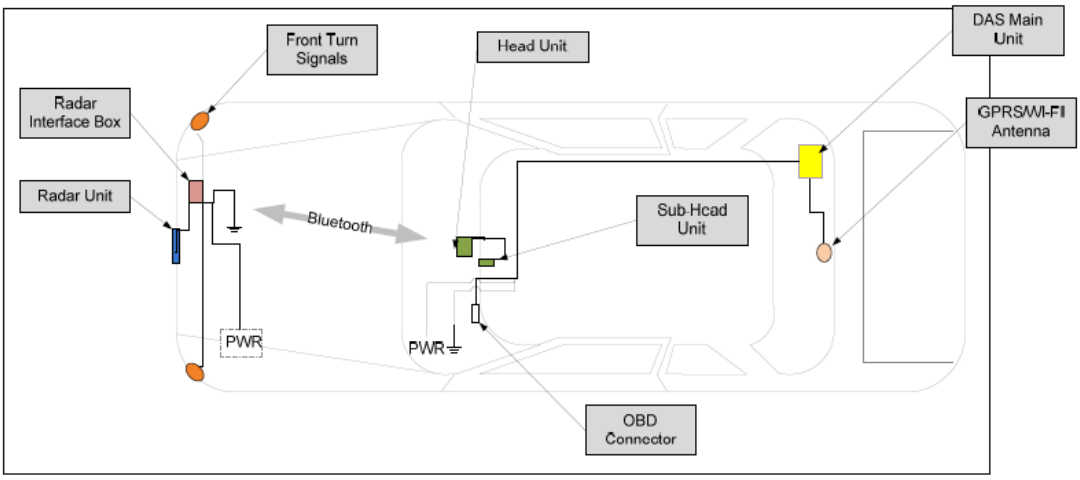

Figure 3 Planned SHARP2 DAS

The SHRP2 DAS includes internal and external video, GPS, accelerometers and forward facing radar. Bluetooth is used to remove the need for cables to be passed through the fire wall, meaning fewer alterations to the vehicle are needed to install the DAS.

There are a number of approaches to developing a DAS. Data logger packages bought from suppliers or a specific data logger can be developed using custom hardware and individual sensors. PROLOGUE (Welsh et al., 2010) suggests that using a mixture of these two approaches e.g. buying some 'off the shelf' devices and integrating them in a custom way, can avoid the potential limitations in terms of functionality of data logger packages and the need for the detailed technical knowledge required to achieve a purely custom DAS. SeMiFOT (SAFER, 2008) concluded that for their study, a solution using of the shelf hardware components was more successful than attempting a custom hardware solution. They experienced several issues with the implementation of the custom hardware leading to a greater focus on the off the shelf solution. A fear of using the off the self solution was that this would result in a significant amount of data loss as some components were not designed to be used in an automotive context. However this fear was proved to be unfounded.

DaCoTA aims to set out how road safety can be monitored through Naturalistic Driving Observations. It is envisaged that a large number of vehicles will be equipped with a DAS for a long period of time in a number of European countries. It is likely that there will be limited resources so, for such a large scale activity, a DAS with the complexity of the SHRP2 DAS is unlikely to be achievable. There are also specific issues relating to using CAN data, Map matching and video. These will be discussed in the following sections which are based on Welsh et al. (2010).

2.6.1. CAN Data

Access to the 'Controller Area Network' or CAN of a vehicle can provide detailed information about the electronic controls operating within the vehicle e.g. activation of safety systems or when the windscreen wipers are in use. However the protocols used within the CAN vary greatly between manufacturers and can often be regarded as proprietary data – especially that which relates to safety systems. Although a number of data logger manufacturers can provide access to some of the more basic variables this is limited and often it is necessary to enter into an agreement with the original equipment manufacturer (OEM) in order to gain access to the relevant data. This would be potentially problematic in a large scale activity as many different makes and models are likely to be included and therefore it would be necessary to gain agreements with multiple OEMs. Examples of variables that can be accessed without manufacturer assistant are 'Engine load' and 'Engine Speed'. These can be used to derive variables such as fuel consumption but may be of limited value when studying road safety.

2.6.2. Global navigation satellite systems

GPS, originally developed in the USA, is the global navigation satellite system (GNSS) most commonly used in Naturalistic Driving studies to record the position of the vehicles of interest at any given point of time. However Europe is currently developing its own GNSS in the form of Galileo. Galileo is being designed to work alongside GPS and the Russian equivalent and aims to greatly improve the accuracy of positioning data currently available through GPS. It will provide an open service which will be free for the user as well as a very accurate service that can be used in Safety Critical applications and will be commercially available for a fee. Future Naturalistic Driving studies will be able to take advantage of this additional accuracy once Galileo becomes operational in 2014.

GNSS do however have limitations in terms of accuracy, continuity and availability, therefore Satellite-based augmentation systems (SBAS) have been developed throughout the world. In simplistic terms, these systems work by boosting the satellite system through the use of a network of ground stations. Europe's system EGNOS, became operational in 2009 and enhances GPS within Europe. EGNOS was designed to be an open service and is therefore free to use and has an accuracy of up to 3 metres. As this service is currently available, any new Naturalistic Driving activity operating in Europe should consider using EGNOS.

2.6.3. Map Matching

Map Matching is the method for connecting GPS data with roadway data in order to generate network context variables, for example, which type of road the vehicle has travelled on. The number of network context variables that can be recorded is limited by the level of detail of available map related data e.g. speed limits, intersections etc. This map related data is commonly referred to as GIS data (Geographical Information System). Commonly available GIS data includes area type (urban/non urban) and road classification (4 classes from major to local roads).

The number of attributes available and the coverage of the maps can greatly vary depending on the provider and the price willing to pay. In most of the maps, geometrics information, as well as indications on the nature of the road (e.g. 2 lanes, presence of roundabout) and the city context (urban/rural) can be found. Some additional attributes are generally available, like mandatory speed limits. Some attributes can be added but are rarely available like road slope profile, curve characteristics, signs and priority rules. Some attributes can only be obtained through purchasing specific maps.

The availability of geographical data is the main limiting factor and this is likely to vary from country to country with some having detailed data and perhaps others having very little data available or none at all. Another potential issue is that geographical data for different countries – especially road classification - is likely to be recorded according to differing definitions therefore in order to aggregate data at a European level, common protocols will need to be developed or transformation rules applied.

Map matching can be performed either in real time during data collection, if the map is embedded in the DAS, or during post processing, once the data are retrieved from the vehicles. In this case algorithms are required that perform reverse geocoding – that is using raw GPS positions to match the position to the nearest relevant road element and to identify the necessary geographic attributes (see http://en.wikipedia.org/wiki/Reverse_geocoding).

Software is commercially available that provides access to map data and the tools to perform map matching. This can be gained directly from map producers (e.g. Navteq see http://www.nn4d.com/site/global/build/mobile_apis/maptp-c/maptp_cpp_intro.jsp) or from subcontractors who purchase maps to be used with their own software. (e.g. Benomad, see http://www.benomad.com/en/produits.html#sdk). The use of a commercially available development kit is a good solution to bring map functionalities into real time or post processing tools as this provides developers with built in reverse geocoding algorithms.

2.6.4. Video

The use of video is commonly used in Naturalistic Driving studies and FOT. There are many advantages of using video. Often this is the most reliable way of gaining information about what is happening outside of the vehicle and even something as basic as the ID of the driver. In previous Naturalistic Driving studies video data has been the key to understanding and interpreting the data gathered from other vehicle sensors. For example video was used extensively in analyses of the 100 car study data to identify whether or not the driver was distracted immediately before a ‘Near Crash’ or crash occurred (Klauer et al. 2006).

The number of cameras used effects the complexity of the system but there are a number of issues relating to data storage and analysis that need to be considered before the decision to use video in Naturalistic Driving Observations can be made. Video data requires the availability of a substantial storage facility both on the vehicle and when video data is transferred and stored for analysis. As a rough guide, 1 hour of video requires 1-3GB of data storage, depending upon the resolution of the video. Once this is scaled up to several months of driving data for several participants, the storage requirement is substantial. The amount of video data collected can be reduced by using ‘event triggered logging’ where video is ran continuously but is only a few seconds of video is actually stored when the data logger detects key parameters have been reached e.g. harsh braking. This in itself has disadvantages as the amount of exposure data that can be collected is limited and that data can be lost for events that do not meet the trigger requirements.

Another issue with video is that it cannot be analysed in its raw form. Therefore a certain amount of post data collection coding is required. This is usually referred to as data reduction and typically involves a person watching specific chunks of video and coding a defined set of variables depending upon the topic. This is particularly important in distraction studies to identify what distracted a driver at a given point in time. As Naturalistic Driving studies usually generate a considerable amount of video data the need for data reduction can result in a significant resource demand in terms of person-hours. Machine vision algorithms could be employed to detect certain aspects such as the driver ID or the status of traffic signals however this is likely to be costly. Although this technology is rapidly improving, it does not currently remove the need for a human to view video data and is unlikely to in the near future. Therefore the analysis demand of video in terms of person days is likely to remain high for the foreseeable future.

Some of these issues associated with the use of video were confirmed during the FOT-Net workshop with experts in naturalistic driving. While it was acknowledged that better metrics and event triggers are needed, it was also acknowledged that video analysis remains essential for event confirmation. That is, video analysis is used to qualitatively confirm that the triggered events (near crashes) do conform to the qualitative definition. External video can be used to validate aspects of the scenario, while internal video can be used to validate driver state and gaze direction. In essence, video confirmation can help to establish if the incidents observed are in face real near crashes. This is an important strategy to reduce the rate of false alarms (incidents classified as near crashes that are in fact not real crashes).

2.7. Specific variables and data collection methods

The following sections set out the specific variables that could be collected in order to explore the topics discussed in this chapter. A series of tables will set out the variable and the type of technical equipment required to collect these variables. Any potential issues will be highlighted in the ‘comments’ column. The selection of variables and collection methods suggested have been informed by a number of sources including PROLOGUE (Sagberg and Backer-Grøndahl, 2010; Welsh et al. 2010), draft material from SHRP2 S05, and the experience of the work package partners. The context variables will be addressed first as many of these are relevant to the study of multiple topics. Then any additional variables necessary to study the topics will be listed under the topic headings as described in section 2.3.

2.7.1. Driving Context Variables

The following sections list the variables and collection method for each context category described in section 2.5. For each variable, an indication is given of the technology necessary to collect the data and any issues related to this are also indicated.

2.7.1.1. Driver variables

Variable	Collection method	Comments
Age	Pre study Questionnaire	
Gender	Pre study Questionnaire	
Driving experience	Pre study Questionnaire	

Medical conditions	Pre study Questionnaire	
Driver attitudes e.g. risk taking	Assessment questionnaire e.g. sensation seeking	Possible but would increase induction time which may not be practical in a large scale study

Table 2 Driver variables

2.7.1.2. Vehicle variables

Variable	Collection method	Comments
Make	Pre study Questionnaire/recorded when DAS fitted	
Model	Pre study Questionnaire/recorded when DAS fitted	
Age	Pre study Questionnaire/recorded when DAS fitted	
In-vehicle technology fitted - basic driver assistance, advanced driver assistance, information	Pre study Questionnaire/recorded when DAS fitted	

Table 3 Vehicle variables

2.7.1.3. Network variables

Variable	Collection method	Comments
Intersection type (junction, roundabout etc)	GPS Road information database – map matching	Dependent on available geographical data
Road type (Urban, rural,)	GPS Road information database – map matching	Dependent on available geographical data
Road Classification	GPS Road information database – map matching	Dependent on available geographical data
Area: Urban/Rural/Mixed	GPS Road information database – map matching Video	Dependent on available geographical data
Road way geometry: Number of lanes Width of lanes Gradient Horizontal curve (bend)	GPS Road information database – map matching; Radar: line detection External video?	Dependent on available geographical data Specialist sensor
Road way signs	Machine vision sign	Dependent on available

	detection Road information database – map matching (speed limits)	geographical data
Road markings	Lane detection technology Radar/custom design machine vision; External Video	Specialist sensor
Traffic control (traffic lights, etc)	External video GPS Road information database – map matching	Dependent on available geographical data
Street lights, present – lit/not lit	External video	

Table 4 Network variables

2.7.1.4. Other contextual variables (transient)

Variable	**Collection method**	**Comments**
Traffic volume	Multiple external video cameras	
Traffic flow	Multiple external video cameras Headway sensor: Radar sensors or Machine vision technology Speed in relation to speed limit (approximate measure): GPS Road information database – map matching	 Specialist sensor – relatively high cost Dependent on available geographical data
Traffic composition – vehicles in vicinity of Naturalistic Driving vehicle	Multiple external video cameras	
Presence of Vulnerable Road Users	Multiple external video cameras	
Motivation for journey e.g. shopping, daily commute	Travel diary GPS	Unlikely to be completed continuously during Naturalistic Driving study – too onerous – will have implications in power of analysis. Common journeys such as daily commute could be identified through GPS data
Passenger present	Travel diary or internal	Video more reliable

	video Passenger seat belt sensor	method. Travel diary unlikely to be completed continuously during Naturalistic Driving study – too onerous – will have implications in power of analysis
Weather conditions	External video Monitor wiper switch electrics (CAN) Weather reports	Weather reports only give approximate data CAN data may need manufacturer assistance to access
Road conditions (wet / dry etc)	Infer from weather conditions External video	Video would be the best method as inferences from weather conditions is likely to be unreliable e.g. when you have sunny conditions but a wet road
Daytime / night-time	Sensor e.g.: Photodiode light detector Link with sunrise and sunset records for particular locations External video	Specialist sensor
Date and Time of day DD/MM/YY HH:MM:SS.FF	Data logger time stamp or GPS time.	The level of detail in the time stamp depends on the sampling rate necessary to collect data with a sufficient level of detail.
In-vehicle technology in use during journey	CAN data	Varies between manufactures – Could need manufacturer approval/assistance to access
Start of Journey	Sensor – ignition on linked with time stamp	
End of Journey	Sensor – ignition off linked with time stamp	
Length of journey (km)	Derived from Start and End of journey and GPS	
Duration of journey (time)	Derived from Start and End of journey and time stamp	

Table 5 Other context variables

2.7.2. Topic Variables

Each of the topics identified in section 2.3. is considered in turn in order to determine the additional data collection requirements beyond those listed as context variables.

The specific context variables required for each topic depends on the specific questions that will be asked of the data; whether this is calculating a specific SPI or additional questions. As this has not yet been determined, typical research questions for each topic are given by way of example, indicating the dependence of the contextual variables. These have been drawn from PROLOGUE, SHRP2 and the experience of the DaCoTA researchers. More comprehensive lists of possible research questions can be sourced in PROLOGUE and SHRP2. Multiple context variables are likely to be important in answering specific research questions; however for each example question essential context variables have been identified. This will give an idea of the type of equipment needed to answer specific questions.

2.7.2.1. Alcohol and Drugs

Example Research Questions	Essential Context Variable
Are young people more likely to drive intoxicated than older people?	Age

Table 6 Alcohol and Drugs – example research questions

Variable	Collection method	Comments
Under the influence of alcohol	Travel Diary Passive alcohol sensor	Unlikely to be completed accurately or continuously Specialist sensor
Driver Gaze (on road ahead)	Eyes forward sensor/Eye tracker Internal Video	Complex equipment – high cost
Driver action	Internal Video	
Under the influence of illegal drugs	Travel Diary	Unlikely to be completed accurately or continuously

Table 7 Alcohol and Drugs specific variables

2.7.2.2. Speed

Example Research Questions	Essential Context Variable
What factors influence a driver's choice of operating speed? (Roadway geometry, roadside features, intersections/driveways, weather, traffic volume, day versus night, etc) and how does the speed change?	Road environment variables etc
Do drivers travel at lower speeds and within what range when pedestrians (especially children) and cyclists are present?	Presence of vulnerable road users
How does operating speed impact deceleration at road junctions?	Intersection type
Is there a subset of drivers that are responsible for the majority of speeding or do all drivers speed occasionally?	Driver characteristics
How does operating speed compare to road speed limit?	Road way signs – speed limits

Table 8 Speed – example research questions

Specifically for speed, in addition to the contextual variables, the speed of the vehicle and its acceleration at any given point in time are required. It also important to have a DAS with sufficient Hz to accurately measure changes in speed and duration of speeding.

Variable	Collection method	Comments
Speed	GPS Or wheel speed sensor, optical road speed sensor or CAN	 CAN data may need manufacturer assistance to access
Acceleration (longitudinal, lateral and gyro)/Deceleration	Accelerometer	

Table 9 Speed specific variables

2.7.2.3. Protective Systems (seat belt and child restraint use) and Daytime Running Lights (DRL)

Example Research Questions	Essential Context Variable
Who is more likely not to use a seat belt and under what conditions?	Driver characteristics

Table 10 Protective Systems and DRL – example research questions

Variable	Collection method	Comments
Seat belt use	Internal video Seatbelt sensor	 Specialist sensor
Use of lights (on/off)	CAN/sensor	CAN data may need manufacturer assistance to access

Table 11 Protective Systems and DRL specific variables

2.7.2.4. Fatigue

Example Research Questions	Essential Context Variable
Is falling asleep at the wheel more likely on monotonous roads?	Road Type Road geometry
Do advanced driver support systems offer a safety benefit for impaired/drowsy drivers?	In-vehicle technology fitted In-vehicle technology in use

Table 12 Fatigue – example research questions

Variable	Collection method	Comments
Feeling tired	Travel Diary	Unlikely to be completed accurately or continuously
Time driven (journey so far)	Data logger time stamp; GPS; ignition on/off sensor	
Driver Gaze (on road ahead)	Eyes forward sensor/Eye tracker	Complex equipment – high cost

	Internal Video	
Blinking behaviour	Eye tracker/machine vision Internal video	Complex equipment – high cost
Driver action	Internal Video	
Steering wheel angle/movement	CAN Rotational potentiometer	CAN data may need manufacturer assistance to access Specialist sensor – relatively high cost
Lane departure	Lane detection: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost

Table 13 Fatigue specific variables

2.7.2.5. Distraction and Inattention

Example Research Questions	Essential Context Variable
What is the prevalence of distraction / inattention among different ages of drivers?	Age
What is the prevalence, as well as the type and frequency, of driver inattention in which drivers engage during their daily commuting?	Motivation for journey
Do IVIS cause additional distraction?	In vehicle technology in use during journey
Do passengers cause distraction / inattention?	Passenger present
To what extent do different types of distraction influence inattention at intersections?	Intersection type

Table 14 Distraction and Inattention – example research questions

Variable	Collection method	Comments
Driver action: driving task or secondary task	Internal Video	
Driver attention/gaze (specifically what looking at)	Eye tracker Internal Video	Complex equipment – high cost

Table 15 Distraction and Inattention specific variables

2.7.2.6. Headway

Example Research Questions	Essential Context Variable
What is the relationship between gap acceptance, own speed and speed of other vehicles?	Traffic composition Traffic volume
Do older drivers have higher thresholds for gap acceptance at intersections?	Age Intersection type
What is the relative contribution of aggressive driving to inappropriate gap acceptance?	Driver characteristics
Are headways appropriate for the travel speed?	Traffic composition

Table 16 Headway – example research questions

Variable	Collection method	Comments
Time Headway (Forward and rear)	Headway sensor: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost
Distance to vehicle in front/behind	Headway sensor: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost
Time to collision	Headway sensor: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost
Relative speed/position of surrounding vehicles	Multiple external video cameras Radar can be used to measure distance	Specialist sensor – relatively high cost

Table 17 Headway specific variables

2.7.2.7. Exposure measures

The exposure measures are derived from the context variables:

Exposure	Context variables	Comments
Vehicle km	Aggregated: Length of journey (km)	
Fuel consumption	Derived from CAN variables ‘engine load’ and ‘current engine speed’	These are ‘open access’ CAN variables so manufacturer assistance is not required
Person km	Driver ID plus Aggregate of: Length of journey (km)	
Number of Trips	Derived from Start and End of journey then aggregated	
Time in traffic	Aggregate of: Duration of journey (time)	

Table 18 Exposure measures specific variables

2.7.2.8. Near Crashes

In many respects the identification of ‘Near Crashes’ can be considered as the collection of an additional context variable as Near Crashes are usually studied as part of an examination of one of the main topics described here.

Example Research Questions	Essential Context Variable
What are the relevant lane changing behaviours of nearby vehicle that may have contributed to crash and near-crash events?	Traffic composition
How does driving behaviour and crash/near crash risk change when single/multiple passengers are present?	Passenger present

How does crash/near crash risk change when the driver is fatigued/distracted?	

Table 19 Near Crashes – example research questions

To identify Near Crashes it is important to develop relevant trigger values for key variables. Trigger values could either be established within a pilot phase or used in an iterative process to identify Near Crashes following data collection. Video data is necessary to verify whether the event should be classified as a Near Crash and to identify the circumstances surrounding the Near Crash event. The variables required are dependent on the Near Crash criteria and associated trigger thresholds, therefore the following table only gives examples of possible variables.

Variable	Collection method	Comments
Acceleration (longitudinal, lateral and yaw, roll, pitch)/Deceleration	Accelerometer	
Brake force	Brake force sensor	Specialist sensor
Swerve	Accelerometer and steering wheel position sensor/CAN	Specialist sensor
Near crash type	External video	
Driver action	Internal video	
Participant indicated event occurred	Event Button	Requires video for verification

Table 20 Near Crashes specific variables

2.7.2.9. Lane change, lane position and lane keeping

Example Research Questions	Essential Context Variable
What is the prevalence of lane departure?	Road Geometry (width)
Does the risk of lane departure vary with traffic volume and road type?	Traffic volume Road type
How do lane edge markings affect lane keeping?	Road Marking
How does overtaking behaviour vary with driver characteristics?	Driver characteristics

Table 21 Lane change, lane position and lane keeping – example research questions

Variable	Collection method	Comments
Lane Departure	Lane detection: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost
Lateral position	Lane detection: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost
Time to cross line (lane marker)	Lane detection: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost

Table 22 Lane change, lane position and lane keeping specific variables

2.7.2.10. Aggressive driving: compliance with regulations

Example Research Questions	Essential Context Variable

What is the level of compliance for drivers of different age categories to stop signs, traffic signals, advisory speeds on bends etc…?	Age Road signs
Does the type of vehicle influence the likelihood of aggressive driving?	Make/Model
What is the role of illegal manoeuvres in collision risk at intersections?	Intersection type

Table 23 Aggressive driving – example research questions

Variable	Collection method	Comments
Acceleration (longitudinal, lateral and gyro)/Deceleration	Accelerometer	Yes
Time Headway	Headway sensor: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost
Horn use	Horn sensor (on/off) CAN	CAN data may need manufacturer assistance to access
Light use (flashing)	Light sensor (on/off) CAN	CAN data may need manufacturer assistance to access
Driver gestures	Internal video	

Table 24 Aggressive driving specific variables

2.7.2.11. Learning

Example Research Questions	Essential Context Variable
How do drivers come to use and understand advanced in-vehicle safety systems?	In-vehicle technology fitted In-vehicle technology in use
How do visual search skills and attention to other road users develop during driver training and the first phase of solo driving?	Traffic Composition

Table 25 Learning – example research questions

The learning topic combines many of the variables used to measure the topics discussed above, so only a selection of variables will be listed here. If learning is the study focus then careful subject recruitment is going to be essential to ensure drivers have an appropriate level of experience.

Variable	Collection method	Comments
Acceleration (longitudinal, lateral and gyro)/Deceleration	Accelerometer	
Brake force	Brake force sensor	
Speed	GPS Or wheel speed sensor, optical road speed sensor or CAN	
Attention – eye gaze	Eye tracker Video	Complex equipment – high cost
Lane departure	Lane	Specialist sensor –

	departure/positioning: radar sensor or machine vision technology	relatively high cost
Time headway	Headway sensor: Radar sensors or Machine vision technology	Specialist sensor – relatively high cost
Driver action	Internal video	

Table 26 Learning specific variables

2.7.2.12. Decision making, errors, driving style/performance

Example Research Questions	**Essential Context Variable**
What is the driver reaction time and control input selection for safety critical events?	Traffic composition
How often do drivers misjudge acceleration/time available?	Roadway Geometry
Does the driver make appropriate signals in order for other road users to understand manoeuvre intentions?	Roadway Geometry
Who is more likely not to use a seat belt and under what conditions?	Driver characteristics

Table 27 Decision making, errors, driving style – example research questions

Variable	**Collection method**	**Comments**
Seat belt use	Internal video Seatbelt sensor	Specialist sensor
Signalling	Signal on/off sensor (Left/Right) Internal Video	Specialist sensor
Gear change	CAN Can be derived through Speed, RPM, and gear ratio Internal video	CAN data may need manufacturer assistance to access
Brake force	Brake force sensor	Specialist sensor
Acceleration (longitudinal, lateral and yaw, roll, pitch)/Deceleration	Accelerometer	
Use of lights (on/off)	CAN/sensor	CAN data may need manufacturer assistance to access
Mirror checks	Internal video Eye tracker	Complex equipment – high cost
Driver action	Internal video	

Table 28 Decision making, errors, driving style specific variables

3. DEFINITION OF VARIABLES TO MEASURE WITHIN ERSO BY NATURALISTIC DRIVING OBSERVATION

This chapter will draw on both Chapter 1 and Chapter 2 to consider the feasibility, desirability and practicability of measuring variables that can be used to monitor road safety with Naturalistic Driving Observations. This has to be achieved within the framework of conducting a large scale activity which will have additional technological and cost related considerations that have not yet been discussed. Therefore, this chapter will begin with a discussion of these considerations which will then inform the later evaluation of which road safety monitoring variables are most appropriate to be measured with Naturalistic Driving Observations.

3.1. Considerations of a large scale Naturalistic Driving activity

It is envisaged that the large scale activity will involve instrumenting a large number of passenger cars – perhaps 20,000 – within the EU27 countries. Such numbers necessitate a simple low cost device that is easy to fit. This will also result in a large amount of data being generated so another requirement is for the data to be automatically processed and analysed e.g. through the use of scripts etc. Exactly what continuous monitoring means in terms of participant recruitment and participation duration will be determined by task 6.2. However, as extended periods of monitoring are likely, then the equipment used should be unobtrusive and any methodologies adopted should require minimal input from the participants.

These factors all have implications about what kind of Data Acquisition System (DAS) is appropriate for the large scale activity and subsequently the variables that can be collected with Naturalistic Driving Observations. Chapter 2 demonstrated that it is possible to collect a large number of variables using Naturalistic Driving methods, however high costs are associated with some variables – particularly those reliant on video analysis – and if many different sensors are required then the DAS becomes very complex and potentially unreliable. It is necessary therefore to balance the cost and complexity of the DAS with the ability to collect meaningful data. Another factor that cannot be fully considered here is that although certain sensors might be expensive now, the prospect of supplying a very large number of sensors or systems may result in manufacturers lowering the cost or specifically adapting systems for the large scale activity to make them less complex and more cost effective.

As a result, DaCoTA intends to propose 2 scenarios. Scenario 1 would be a basic DAS that comprises of a GPS logger and accelerometer. This would be a relatively low cost system that utilises existing technology such as that that exists on Smart Phones (see section 3.3 for further discussion). This would allow the collection of certain variables directly e.g. vehicle speed, however 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 clearly a limiting factor here.

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. This is more of a tool box approach as it is not possible currently to measure certain variables due to cost (e.g. headway sensor), access (e.g. CAN) or availability of supplementary data (e.g. map detail) but maybe possible in the future. Scenario 2 will set out the benefits of measuring certain additional variables and the technological requirements but it should not be viewed as a single DAS alternative to Scenario 1. Instead it should be seen as a set of options that could be implemented depending upon future advances and data acquisition agreements. The use of video is costly and currently very time consuming to analyse therefore variables that that rely heavily on video will not be considered as part of Scenario 2 in this deliverable. However this does not preclude the future consideration of video – especially if as part of a large scale activity it is recommended that more sophisticated equipment is installed in a subset of vehicles thus allowing a greater number of variables to be collected.

3.2. Monitoring road safety with Naturalistic Driving Observations

3.2.1. SafetyNet RED

As reported in Chapter 1, SafetyNet recommended that the following Risk Exposure Data (RED) should be collected in any future pan-European (exposure) data collection system:

- Vehicle km
- Person km
- Number of trips
- Time in traffic

A fifth RED, Fuel consumption, was also discussed in Chapter 1, however SafetyNet regarded this as very low priority as it is considered to be an indirect indicator of traffic volume and used only when other indicators are not available, particularly as an alternative to Vehicle km.

Apart from Vehicle km, data on these RED were not found to be widely available in Europe or compatible with European databases (CARE, EUROSTAT). Traditional data collection methods for these are surveys which although able to give an indication of mobility, may not be entirely accurate as they rely on individuals' accounts and estimations of their journeys.

It is possible to collect data on the 4 priority RED using Naturalistic Driving Observation although their definition may be narrower than that which SafetyNet envisaged. For example 'Person km', 'Number of trips' and 'Time in traffic' in SafetyNet included all journeys with any type of transport including pedestrian journeys. However DaCoTA focuses only on passenger cars and the 'person' will be the driver(s) of the vehicle equipped with the DAS. It will only be possible to record RED for the drivers' journeys in their specific vehicles excluding any additional journeys that a person may take in other passenger cars. Although possible to measure Fuel consumption using Naturalistic Driving Observations it is unnecessary to do so as recording data on 'Vehicle km' would give more accurate data and is a much better RED measure.

Within a tightened definition, measuring variables associated with these RED with Naturalistic Driving in a large scale activity would have several advantages. For example data will be collected in a harmonised way and therefore will be comparable between vehicles and countries. Naturalistic Driving Observation also allows a more accurate recording of behaviour than more traditional methods such as surveys. For example the number of km travelled and duration of the journey is recorded accurately. It is possible to measure the 4 priority RED with a Scenario 1 DAS, as long as it is possible to identify the driver.

As discussed previously, Naturalistic Driving Observations can provide valuable data that can be used to calculate the relative risk of behaviours (e.g. distraction) or person states (e.g. fatigue) resulting in an accident. This is because Naturalistic Driving can provide data about how often specific behaviour takes place within 'normal' driving, i.e. the driver's exposure to a risk factor. The large scale activity that will be proposed by DaCoTA focuses on monitoring road safety factors rather than calculating relative risk, however a large scale activity can provide valuable exposure data that can be used to interpret accident data such as that stored within the CARE database. As reported in Chapter 1, SafetyNet identified a number of variables that should be collected if aiming to record exposure data that are useful for analysis of the CARE database. These variables relate to the context of driving so the feasibility of recording them during a large scale activity will be discussed within the context variable sections of this chapter (section 3.2.5).

In order to generate data to calculate the 4 priority RED, the following variables are required: Time (Day, month, year, hh:mm:ss), km travelled, Driver ID, start of trip, end of trip

SafetyNet also recommended additional variables to be measured in order to collect more meaningful exposure data. In the context of DaCoTA these are:

Vehicle type, vehicle age, engine size, road type, area type, driver age, gender, driving experience, nationality.

3.2.2. SafetyNet SPI and additional topics

3.2.2.1. Speed

Speed can be considered in behavioural terms in two ways – 1) Excessive speed, where the driver exceeds the legal speed limit and 2) Inappropriate speed where the driver travels faster than appropriate for the road geometry or conditions. Both have been associated with increased risk of accidents and therefore are important to be monitored by ERSO. However speed data that is available from established methodologies such as speed surveys and used to calculate SPI focuses on excessive speed only. Also, as discussed previously, this data is rarely comparable between countries due to differences in methodologies. Naturalistic Driving Observations have the potential to complement the excessive speed data provided by more traditional methodologies. For example aspects of excessive speed could be measured through Naturalistic Driving Observation by examining how far drivers drive when travelling over the speed limit and average speeds per journey or per road type. Naturalistic Driving Observation also allows speed related data to be linked with driver characteristics such as age and gender, aspects that are not measured in roadside speed surveys.

Excessive speed could be measured using a Scenario 1 DAS in countries where maps are available that provide data on legal speed limits. The availability of data to utilise in map matching will determine the context variables that can be measured and therefore the amount of information that can be collected on Excessive speed. Naturalistic Driving Observation also has potential to explore inappropriate speed by examining drivers' speed adaption behaviour in relation to environmental factors such as road layout and weather conditions. However this is again dependent on the detail available in maps in order to perform map matching and additional sensors such as windscreen wiper on/off and temperature. It is unlikely to be possible to gather data on inappropriate speed with a Scenario 1 DAS but it may be possible to gather some data using a Scenario 2 DAS. Measuring Inappropriate speed is dependent on the available context variables so the possibilities of collecting data on the roadway geometry and weather will be discussed in the context variable sections below (section 3.2.5).

As monitoring speed is a road safety priority and Naturalistic Driving methodologies could provide additional insights into speeding behaviour, the collection of speed and associated context variables should be a priority for an ERSO Naturalistic Driving Observation activity.

The large scale activity should seek to record the following variables in relation to Excessive Speed:

Speed, Speed limit, Date/Time (DD,MM,YY; HH,MM,SS), Driver ID, plus as many other context variables as possible

If Inappropriate Speed is considered, the following additional variables would be of interest: windscreen wiper on/off, temperature, as much detail on roadway geometry as possible.

3.2.2.2. Alcohol and drugs

Addressing the issue of driving under the influence of alcohol and/or illegal drugs continues to be a high priority for road safety policy makers. In support of this, ‘Alcohol’ was considered to be a high policy priority for the majority of the National Experts surveyed (see section 1.5). Focus has also been on driving while taking prescription medicines. The ideal would be to have an estimate of the number of people who fall into these categories during routine driving rather than just those who have been involved in an accident. It is however difficult to record the use of alcohol and drugs using Naturalistic Driving Observation. Participants would be unlikely to record in a tool such as a travel diary if they have been drinking/taken drugs and in any case this recording method is likely to be too onerous for a large scale activity. Alcohol sensors have been developed that can unobtrusively measure the presence of alcohol in the air of a vehicle however this would not record whether it was the driver or a passenger who had drunk the alcohol and again it is likely to be impractical in a large scale activity. In light of these considerations DaCoTA will not recommend that alcohol and drugs are included in the large scale activity.

3.2.2.3. Protective systems (seat belt and child restraint)

The use of seatbelts and child restraints remains a key road safety issue and data requirement within ERSO. The relevant protective systems SPI focus on the use of seatbelts by the front (including driver) and rear seat passengers and the use of child restraints for children under 12 during the daytime. The method for recording the use of restraints in the general driving population is roadside Observation surveys however the availability of data in different countries is greater for the driver and front seat passenger than for the rear seat. Child restraint use data was collected routinely in much fewer countries. Roadside Observation surveys are a more cost effective way of collecting such data than Naturalistic Driving Observation. This is because Naturalistic Driving would use either video or individual seatbelt sensors to record whether the driver or passenger(s) was wearing their seatbelt. Video of the rear seats would be necessary to record the use of child restraints as the adult seat belt is only one component of such systems and many employ Isofix which does not require the use of an adult belt. The need for video therefore precludes the collection of data on child restraint use in the large scale activity. The one advantage Naturalistic Driving has over observational surveys is that seat belt data could be collected any time of the day and does not need to be restricted to daytime due to visibility restrictions.

The additional sensors required to measure seatbelt use mean that this is not a variable that can be measured with a Scenario 1 DAS. However there may be an argument for adding seatbelt sensors as part of a Scenario 2 DAS either to a specific group of participants' vehicles e.g. young drivers or just a driver seatbelt sensor to all participants' vehicles. This is because roadside observational surveys cannot give information about who (age, gender etc) do not wear seatbelts or the circumstances when seatbelts are not worn e.g. short journeys, certain roads. Such surveys also do not give information as to how often individuals wear their seatbelt when driving. Data collected by SafetyNet show that in the best performing countries in terms of road safety, seat belt use is high at 90+% for drivers and front seat passengers of cars and vans < 3.5 tonnes (Vis and Van Gent, 2007). For fatal single vehicle accidents included in the SafetyNet Fatal Accident database, the seatbelt wearing rate was only 67% for drivers and 50% for passengers (Reed and Morris, 2009). Although these figures are not directly comparable there appears still to be an overrepresentation of non-seatbelt wearing in fatal accidents. As seatbelt wearing is still a high priority among policy makers, data which gives information about how to target those who still do not wear seatbelts would be valuable.

If Seat belt wearing is considered in the large scale activity, the following variables should be recorded:

Seatbelt worn? Yes/No for driver, [plus front seat passenger or rear seat passenger depending on resources], Road type (at least motorway, urban, rural); Driver ID, age, gender, plus any other context variables that are possible to record.

3.2.2.4. Daytime Running Lights

The use of daytime running lights has generally been of low policy priority in recent years. The survey of National Experts shows that for the majority of countries this is only a medium or low policy priority. This is probably due to the fact that the northern European countries already have a DRL law that has a high rate of compliance and that the southern countries see no need for such measures. Following the introduction of the European directive (Directive 2008/89/EC) that states a mandatory requirement for all new cars to be fitted with dedicated DRL from 2011, it is likely that the priority given to DRL further reduces – especially as these lights are designed to automatically illuminate when the engine is started thus removing the human behaviour element. Information about DRL can be gained from roadside observational surveys and it would appear that there is little value of attempting to measure DRL with Naturalistic Driving Observation. A Scenario 1 DAS would not record whether lights were illuminated. If however access to CAN information was achieved in order to record other variables, there would be no reason not to record light use information as part of Scenario 2 – especially if the vehicle is not fitted with automatic DRL. However this really relates to light use behaviour more generally rather than the use of DRL (see 3.2.3.5). Given the policy priority of DRL, it is not recommended that data on this SPI is collected in the large scale activity.

3.2.2.5. Fatigue

As discussed in chapter 1, fatigue has been found to be associated with greater crash risk by a number of studies and is therefore considered to be an important factor in road safety. The majority of National Experts stated that fatigue was a high or medium priority for their country but less of a priority than speed alcohol and seatbelt use. However the SafetyNet webtext (SafetyNet, 2009) suggests that determining the extent of the problem of driving while fatigued is of lesser importance than establishing more clearly the risk imposed by fatigue. Previous studies have also already identified the groups that are most likely to drive while fatigued for example professional drivers and young males.

Measuring fatigue can be difficult but within a Naturalistic Driving study certain behaviours that give an indication of fatigue can be monitored such as head movements, blinking behaviour, steering wheel movements, and lane keeping behaviour. The technology required to measure such behaviour however is relatively complex and therefore costly. Equipment such as an eye tracker and/or video and/or radar systems that measure lane departure would be necessary. Again, the cost of purchase and time consuming nature of the analysis of the resulting data realistically precludes the collection of data on fatigue within the type of large scale activity proposed by DaCoTA. In addition, as DaCoTA is concerned with road safety monitoring, fatigue is perhaps not as high a priority as other factors and it may be more appropriate to study fatigue within a research study such as PROLOGUE.

3.2.2.6. Distraction and Inattention

Driver distraction and inattention has gained increased attention in recent years and many studies have focused on elements of distraction and inattention in relation to road safety. Around half of the National Experts surveyed indicated that distraction and inattention is a high policy priority. Concerns about distractions while driving, such as mobile phone use, have lead to changes in legislation in some countries. In addition a number of European projects are currently using Naturalistic Driving methodologies to explore the impact on driving of using various technologies and driver aids such as personal navigation devices e.g. TeleFOT[11].

Naturalistic Driving allows distraction and inattention to be studied within a real world driving context and therefore has advantages over other methodologies such as experimental and crash studies. A large scale Naturalistic Driving study has the potential to provide objective and representative data on inattention and distraction, for example, the proportion of time drivers drive while distracted. Many Naturalistic Driving studies have focused on distraction and inattention and have raised awareness about their potential crash risk e.g. 100 car study. However to measure whether the driver is distracted or has lost concentration (inattention), it is necessary to record detailed information about where the driver is looking, what the driver is doing and what is happening outside of the vehicle. This involves the use of video or a combination of video and eye trackers. The type of technology required to measure distraction and inattention is beyond a Scenario 1 DAS (Scenario 1) and the cost involved in using and analysing data from equipment such as eye trackers and video is also likely to prohibit the use of such equipment, even with a Scenario 2 DAS. It would therefore be inappropriate to recommend that the large scale activity explores distraction and inattention.

3.2.2.7. Headway

Travelling too close to the car in front is considered to increase the risk of rear end collisions if an emergency situation was to arise. However there is currently little data available on actual following distances. Section 1.4.3.3. suggested that studying headway using instrumented vehicles is one of the most effective ways of studying following behaviour and that the long term monitoring of headway can give valuable information about driving styles. Therefore including headway measures in Naturalistic Driving Observations is likely to be valuable. The priority of such data for

[11] See http://www.telefot.eu/ for further details

policy makers is less clear – 'Gap acceptance' was not considered a particularly high priority by respondents of the survey of National Experts. However with the increasing development and availability of in-vehicle technologies, for example Active Cruise Control, the safety benefits of such technologies are likely to receive increased focus in the future both from the vehicle industry and policy makers.

Specific equipment is required to measure headway – the distance and time gap between the lead and following vehicle continually changes and requires recalculation. Devices that typically measure headway use either radar or machine vision and can be expensive. The measurement of headway would not be possible using a Scenario 1 DAS; however, as the technology develops and prices reduce it may become possible to add a headway sensor to a Scenario 2 DAS. The type and usefulness of data that can be gained by measuring headway also very much depends upon information about the driving context that is possible to record alongside headway data. The ideal would be to have forward facing video showing the road in front and the surrounding vehicles however this is not practical for a large scale activity in the short and medium term.

Useful information about gap choice could be gained if certain context variables such as basic road type (urban, rural, motorway) were collected alongside driver characteristics such as age gender and additional data on driving style that can be measured using an accelerometer. These context variables should all be possible to be measured using a Scenario 1 DAS and therefore well within the capabilities of a Scenario 2 DAS. Additional information could be collected by adding a sensor to the Scenario 2 DAS that measures the use of turn signals or by gaining access to CAN information. Depending on the headway system capabilities and associated cost, information could also be collected on the gap between the instrumented vehicle and the vehicle behind as well as vehicles in front. This could give some indication of congestion in terms of traffic flow as well as the behaviour of additional drivers, although the characteristics of these drivers would be unknown.

If Headway is considered in the large scale activity, the following variables should be recorded:

Time Headway, Distance to vehicle in front (and possibly rear), Time to collision, speed, acceleration, road type (min. urban, rural, motorway), driver age, gender, plus as many other context variables that are possible to record.

3.2.3. Topics from Naturalistic Driving

As Chapter 1 and Chapter 2 had differing starting points – Chapter 1 focused on the data needs of ERSO and Chapter 2 focused on data that has or could be collected using Naturalistic Driving Observations, a number of topics were discussed in Chapter 2 that were not directly addressed in Chapter 1:

- Near Crashes
- Lane change, lane position and lane keeping
- Aggressive driving: compliance with regulations
- Learning
- Decision making, errors, driving style/performance

The first of these, 'Near Crashes' although within the scope of DaCoTA, was deliberately only discussed in Chapter 2 as the majority of the literature regarding Near Crashes relates to Naturalistic Driving methodologies. The following sections will discuss these topics in relation to the feasibility of collecting variables in a large scale activity and the benefit of collecting them in terms of road safety monitoring.

3.2.3.1. Near Crashes

The study of Near Crashes within the context of monitoring road safety involves assessing the number and circumstances of Near Crash events that occur. As previously discussed (see section 2.4.1) the value of collecting data on Near Crashes relates to the value of Near Crashes as a proxy measure for crashes. This relationship has not been firmly established and the value of such data for road safety policy making is unknown. This is reflected in the priority assigned to Near Crashes in the survey of national policy makers(see section 1.5) where only 1 National Expert considered Near Crashes to be a high priority. Around half the National Experts indicated that it was a medium priority.

Measuring Near Crashes can be problematic. However when PROLOGUE carried out a survey of potential users of Naturalistic Driving data, they found that the majority of respondents considered ‘pre-crash’ and ‘crash avoidance’ behaviour as important or very important to be studied with Naturalistic Driving methodologies. Certain ‘trigger values’ can be used to identify when a Near Crash may have occurred, e.g. detecting harsh braking or swerve manoeuvres. The large variation in braking and acceleration amongst car drivers (non professional) makes it difficult to set trigger values that will identify Near Crashes accurately so that the actual occurrence of a Near Crash (as defined by the specific study) usually has to be established using video data.

It is likely that the limits of the vehicle capacity are influenced by its mass. Also road and tyre conditions, such as roughness, will play a role in the assessment to classify a triggered event as a near crash. In the choice of any trigger value to indicate e.g. harsh braking, this needs to be considered. Especially for the large DaCoTA sample this could become important, as the sample is very heterogeneous.

The context of a Near Crash event is also very important. It is necessary for example to establish the circumstances surrounding the Near Crash, for example whether it occurred at an intersection and whether it was related to actions of another road user. Again the most effective way of assessing this is through the use of video. A Scenario 1 DAS would not give sufficient information to identify whether a Near Crash had occurred and it is unlikely that equipment appropriate to a Scenario 2 DAS would be more successful. It may be possible to use pre-defined trigger values set at a very high level – with the aim of excluding false positives – in the large scale activity, however it is likely that only limited context data would be available. The task of establishing appropriate trigger values is a complex one and is beyond the scope of DaCoTA, therefore any adopted trigger values would have to have been established by another project/study.

However, a large scale activity using a Scenario 1 DAS to collect data on thousands of different drivers could contribute data about patterns of acceleration in the general driver population and in this way contribute to the knowledge base on Near Crashes. The addition of a brake sensor that records when and how strong the brake pedal is depressed could be added in a Scenario 2 DAS and thus patterns of braking and acceleration could be measured. If agreements were made with manufacturers so that CAN data could be accessed, a Scenario 2 DAS would be able to record data about when vehicle technology aimed to avoid crashes (safety systems), e.g. ESC, are activated. Of course this depends on the age of the countries vehicle fleet, as represented by the sample, as only newer vehicles are equipped with advanced safety systems. Although not identifying Near Crashes in the way that they have been previously studied, this type of data could provide valuable information to policy makers.

If elements relating to Near Crashes are considered in the large scale activity, the following variables should be recorded:

Scenario 1: acceleration/decelerations, vehicle information e.g. mass.

Scenario 2: in-vehicle safety technology in use, plus as much detail about the network as possible, Windscreen wipers activated, Temperature.

As mentioned previously, the definition of event trigger values is beyond the scope of DaCoTA. It should be noted, however, that for either scenario it may not be necessary to prescribe all event triggers in great detail. It is possible that with modern data loggers, with high sampling frequencies, that data be logged continuously. Researchers would then be in a position to apply different event trigger models to the data afterwards and to then examine the influence on the number and type of near-crashes captured in the analysis.

Earlier the importance of having video data was discussed, the primary reason being its importance to the verification of near crash events. The inclusion of video also supports the analysis of light conditions, road type, and so on. Again, these data would be made available for researchers outside DaCoTA to analyse.

3.2.3.2. Lane change, lane position and lane keeping

Measuring lane related behaviour can assist in the assessment of other topics that were discussed in Chapter 1, e.g. distraction and fatigue. Lane changing and overtaking are both variables that would be of interest in terms of gathering exposure data in relation to accident data (CARE). Similarly to the measurement of headway, measuring lane related behaviour requires the use of specialist sensors such as radar or machine vision therefore is not a topic that can be studied using a Scenario 1 DAS. The context of lane changes and positioning is also important and without video, the data gathered will always be limited. E.g. information about the surrounding vehicles, traffic flow and the number of lanes available are important context variables. However it may still be desirable to measure lane behaviour using a Scenario 2 DAS. The value of this would be when headway is already being measured and the information from lane departure sensors could complement headway information and provide information about overtaking behaviour.

3.2.3.3. Aggressive driving: compliance with regulations

Aggressive driving' was not discussed in detail in Chapter 1 as it was considered to be covered in other topics such as speed and headway. Drivers' compliance with regulations is clearly an important topic for policy makers as 'Alcohol/drug use', 'Speed' and 'Seatbelt wearing' continue to be rated as very high priority (cf Expert Survey, section 1.5). In terms of a large scale study, the most appropriate way of monitoring aggressive driving would be by identifying drivers who persistently break speed limits or drive very fast in low speed limit zones with a Scenario 1 DAS or by looking at those who persistently drive very close to the vehicle in front with a Scenario 2 DAS (Headway).

3.2.3.4. Learning

'Learning' could be regarded as a specialist topic involving a particular group of drivers and therefore may be more appropriate to examine through a specific Naturalistic Driving study or Field Operational Trial rather than the large scale activity aimed at monitoring road safety. For example the study of the effect of instruction on drivers' competence would not be regarded as a road safety monitoring issue. This topic does not require additional variables to those discussed previously, but does depend upon the sample of drivers with instrumented cars. If inexperienced drivers were included in the large scale activity then a Scenario 1 DAS would allow individuals' driving behaviour in terms of braking, acceleration and speed to be recorded over a long period of time and the identification of any consistent changes in these behaviours. This would only give an indication of how behaviour changes with increased exposure to driving. It could not lead to any specific conclusions about learning beyond this.

3.2.3.5. Decision making, errors, driving style/performance

This category was suggested by PROLOGUE to capture 'normal' driving behaviour and anything that does not fit into a specific topic category. Patterns of acceleration behaviour could be studied using a Scenario 1 DAS, however the level interpretation of such data is dependent upon the context variables that can be measured (see section 3.2.5). With a Scenario 2 DAS, braking behaviour could also be studied if an additional sensor(s) was added to show when the brake pedal is used and/or the braking force being applied. If access to CAN data was achieved using a Scenario 2 DAS, behaviours such as signal or light use could be studied although again this is dependent upon the availability of information on the road network such as that discussed below.

Other variables that were thought to be important for examining exposure data in relation to accident statistics (CARE see 1.4) include 'stopping' 'driving straight ahead', 'turning' and 'U-turn' fit into this topic. These manoeuvres could be detected using a Scenario 1 DAS, however to be able to confidently identify them, a certain amount of context information is necessary. For example without detailed map information, it would not be possible to identify whether a turn was at a junction, onto a major road or off a major road. It would also be easy to mistake a U-turn with a round-a-bout manoeuvre. The availability of map data that can be used in map matching will be discussed in relation to the context variables in section 3.2.5. Another aspect of driving that falls into this category and was suggested to be of interest in the survey of National Experts is blind spot identification. However reliable data in a Naturalistic Driving study could only be obtained through the use of video and therefore is not something that can be measured in the large scale activity.

3.2.4. Topics recommended to be investigated in the large scale activity

The following table (Table 29) summarises the processes of deciding which topics can be investigated in the large scale activity. The ERSO priority is taken from the discussion in Chapter 1. 'Collect with Naturalistic Driving' is marked as 'yes' when it is technically possible to collect data related to the topic with Naturalistic Driving methodologies as discussed in Chapter 2. 'Enhance existing methods' refers to whether studying the topic through Naturalistic Driving Observations could give better or additional data than the traditional methods as discussed in Chapter 1 or those methods known to the partners. If it is considered difficult to explore the topic with traditional methods and Naturalistic Driving, then 'Enhance existing methods' will be marked as 'no'. 'National Expert priority' refers to the results of the survey of National Experts discussed in section 1.5. N/A is used here when the topic was not given as an option within that survey. 'Recommended for Large Scale activity' summarises the results of the discussion within this chapter and is divided as to whether it is possible to explore the topic with both a Scenario 1 and 2 DAS, just a Scenario 2 DAS or not within the Large Scale Activity at all.

Topic	ERSO Priority	Collect with Naturalistic Driving?	Enhance existing methods	National Expert priority	Recommend for Large Scale activity	
					Scenario1 DAS	**Scenario2 DAS**
Vehicle Km	High	Yes	Yes	N/A	Yes	Yes
Fuel Consumption	Low	Yes	No	N/A	No	No
Person Km	High	Yes	Yes	N/A	Yes	Yes
Number of Trips	High	Yes	Yes	N/A	Yes	Yes
Time in Traffic	High	Yes	Yes	N/A	Yes	Yes
Alcohol	High	Yes[12]	No	High	No	No
Drugs	High	No	No	N/A[13]	No	No
Speed – excessive	High	Yes	Yes	High	Yes	Yes
Speed - inappropriate	High	Yes	Yes	High	No	Yes
Seatbelt Use	High	Yes	Yes	High	No	Yes
Child Restraint Use	High	Yes	No	N/A	No	No
DRL	Low	Yes	Yes	Low	No	No
Fatigue	Medium	Yes	Yes	Medium	No	No
Distraction and Inattention	Medium	Yes	Yes	Medium	No	No
Headway	Medium	Yes	Yes	Low	No	Yes
Near Crashes	N/A	Yes	Yes	Low	No	No
Vehicle Technology: Safety Systems	N/A	Yes	Yes[14]	Medium	No	Yes
Lane Behaviour	N/A	Yes	Yes	N/A	No	Yes
Learning	N/A	Yes	Yes	N/A	No[15]	No

[12] But not reliably

[13] However a number of Experts commented that drug use was another priority in their country (see section **Error! Reference source not found.**).

[14] This type of data is important for the vehicle industry and usually collected using instrumented vehicles.

[15] Learning would be possible to be measured with a Scenario 1 or 2 DAS however it is not recommended to be studied in a large scale activity as Naturalistic Driving methods are thought to be more appropriate to provide feedback to learners rather than in the context of monitoring road safety

Driving Style: Acceleration	N/A	Yes	Yes	N/A	Yes	Yes
Driving Style: Braking, signal/light use	N/A	Yes	Yes	N/A	No	Yes

Table 29 Summary of recommended topics to be included in the large scale activity and decision making process

3.2.5. Context variables

In order to draw meaningful conclusions about data collected through Naturalistic Driving Observations, it is necessary to collect information about the driving context. Chapter 1 identified a minimum set of context variables that need to be collected to generate SPI and RED data as well as a set of desirable variables that would enhance that type of data. However as Naturalistic Driving is a very different methodology than those traditionally employed to collect SPI and RED data, collecting all of the context variables suggested might not be feasible. It may also be possible to collect additional context variables, as listed in Chapter 2. In addition, a number of variables were mentioned in Chapter 1 that would be useful in providing exposure data in relation to CARE. The feasibility of collecting the minimum, desirable, additional and CARE context variables will be discussed in the following sections: Driver, Vehicle, Network and Other context variables which are those that are transient. An indication will be given of which variables are recommended as they can be collected using a Scenario 1 DAS and those which are possible using a Scenario 2 DAS but optional depending on the exact nature of the large scale activity. Where variables can be collected independently from a DAS e.g. through questionnaire data, recommended variables are those which can be easily collected and optional are those which would add value but are less easy to collect due to time considerations or other factors e.g. ethical concerns. Variables that are suggested in Chapter 1 but relate to topics that are not recommended for the large scale activity will not be addressed.

3.2.5.1. Driver context variables

The minimum set of driver variables are age and gender. Driver context variables are collected in pre study questionnaire(s) and so are not dependent on available equipment. The minimum driver variables would all be easily collected in a large scale activity. Desirable context variables include country of residence[16], driving experience, level of education, occupation[17], prior traffic offences and personal characteristics (attitudes, risk taking, perceptual skills and limitations). The first 4 could be collected within a routine questionnaire however there are ethical considerations to be taken into account if collecting prior traffic offences. Participants may be reluctant to disclose such information which might affect participant recruitment. In addition, administering questionnaires that deal with driver characteristics such as driver attitudes may be time consuming and therefore inappropriate for the large scale activity. The only additional driver context variable

[16] This replaces ‘Nationality’ as suggested in Chapter 1. Knowing where the driver lives and therefore most likely to drive was thought to be of greater importance than their country of origin

[17] This additional socio-economic variable is included as its value as a sampling criteria is currently being considered

mentioned in Chapter 2 was 'Medical conditions'. Again this information can be collected however there are ethical considerations to take into account when collecting information on medical conditions when it is the participant's driving that is being studied. With regards to CARE variables, most of the priority variables are included and the remainder relate to the use of alcohol, drugs and driver state (e.g. fatigue) which have been covered in the previous sections.

Recommended variables: age, gender, country of residence, driving experience, level of education, occupation

Optional variables: personal characteristics (attitudes, risk taking, perceptual skills and limitations)

3.2.5.2. Vehicle context variables

The minimum context variables related to the vehicle are vehicle type and vehicle age. Desirable variables include engine size and specific type of car. Again this type of vehicle information would be collected in a pre-study questionnaire or when DAS equipment is fitted to the vehicle. As the vehicle type is always going to be passenger car, the more useful information to collect would be make, model, perhaps variant and vehicle style e.g. hatchback, MPV etc. Any in-vehicle safety e.g. ESC or Advanced Driver Assistance technologies that are fitted could also be recorded. These latter variables were all suggested in Chapter 2. There are no additional relevant priority CARE variables.

Recommended variables: Vehicle Make, Vehicle Model, vehicle age, vehicle style, In-vehicle technology fitted

Optional: Model variant, Engine size

3.2.5.3. Network context variables

Network variables are more difficult to collect than the driver and vehicle context variables discussed above. This is because, although generally the road infrastructure does not change physically from journey to journey, the roads that are driven on at a particular point in time change. It is necessary therefore to know exactly where the vehicle is at a given point in time and to have information about the road and immediate environment (excluding transient factors such as weather conditions). A Scenario 1 DAS would be able to give information about where the vehicle is using GPS but the availability of information about the road infrastructure is dependent on the map data detail that is available so that map matching can be performed.

The minimum network context variables are Road Type and Area Type. SafetyNet specified that Road Type should be at least Urban, Rural and Motorway however the ideal would be to have more detail about the classification of the road. As discussed in section 2.6.3, these variables are likely to be readily available in GIS. However there remains the issue about compatibility of definition of variables, particularly specific road class, between countries and in some case within countries. Definitions would have to be harmonised to allow more specific data collection about the type of road.

Additional CARE priority variables include speed limits, junction control, road markings, junction type, number of lanes and carriageway type. As previously discussed, speed limit data is available for some countries and some information may be available on certain junctions e.g. those of a particular size. However junction control, road markings, number of lanes and carriageway type is likely to be far more detailed information than the currently available map data is able to provide.

Video would be necessary to record these variables thus precluding their collection in the large scale activity.

Intersection information or curve information, which would be useful for studying Near Crashes or inappropriate speed could be obtained through real time/post processed algorithms (map matching) from basic data, but require some specific developments for example in the accuracy of available positioning data. This may be possible in the future once Galileo is operational. However, the more complex the information required, the more costly gaining the map data is likely to be.

Recommended variables: Road type (urban, rural, motorway), Area Type, Speed limit

Optional variables: Road class, junction type

3.2.5.4. Other context variables (transient)

The transient context variables can relate to the driver, vehicle or road network but require either constant assessment or assessing for each journey or journey section.

The minimum set of 'transient' variables include those necessary to collect the RED data as discussed previously (Start, End, duration and length of journey) and year, month, day, hour. These can all be collected using a Scenario 1 DAS as the data logger time stamp will record the date and time at intervals of at least every second. It is also necessary to identify the driver so the variable 'Driver ID' is also important. However recording Driver ID has its own challenges as the easiest way of achieving this is through the use of video. Although a reliance on video has ruled out inclusion of other variables Driver ID could be an exception as only very small sections of video are necessary. Recording Driver ID can be achieved by recording a few seconds of video of the driver as the vehicle sets off (following a prolonged stationary period). Traditionally the Driver ID would be matched with the logging data by manual viewing of the video although advances in technology mean that Driver ID could be identified automatically with machine vision technology. This latter solution would however be expensive and not appropriate for a Scenario 1 DAS but future technological advances might allow the use of video in this way in a Scenario 2 DAS. More realistic alternatives that could be used alongside a Scenario 1 DAS are issuing each driver with a swipe card which they would have to use at the beginning of each journey or an RFID tag with a receiver in the vehicle that could register the driver ID. Neither are 100% reliable as they depend upon the drivers carrying a device with them and in the case of the swipe card using it every time they drive.

Desirable variables included Driving purpose: professional or private, traffic density (volume), traffic composition and passenger age and gender (seatbelt use). It is theoretically possible to collect these variables using Naturalistic Driving Observations, but not necessarily practical in a large scale activity. Information on the purpose of a journey can only realistically be collected using a travel diary. Travel diaries tend not to be filled in consistently and would add too large a burden to the driver and make analysis time consuming if filled in for each journey. However it may be possible in a large scale study to record whether the journey is work related or not by generalising. For example if for some drivers journeys during certain hours on weekdays are all work related then only when there is an exception e.g. the driver is on holiday, requires recording. Alternatively whether the journey is work related could be handled through sampling by selecting a group of cars that are owned by companies and only used for work journeys and others that are privately owned and only used for private journeys or commuting. This however is a compromise and may not produce robust enough data for road safety monitoring and/or collecting exposure data.

Similar issues apply to collecting passenger age and gender and indeed whether or not a passenger is present. Passenger age and gender information would have to be recorded in a travel log which is unlikely to be filled in reliably. The presence of a passenger could be measured using a sensor on the seat (e.g. pressure sensor) but this would only be possible with a Scenario 2 DAS. However in the context of the large scale activity, collecting passenger related variables is only relevant if the large scale study examines seat belt use among passengers with a Scenario 2 DAS and this has not yet been determined. It is unlikely that the remaining desirable variables could be collected in a large scale study. Traffic density and composition requires the use of video which is beyond the scope of even a Scenario 2 DAS. However, it may be possible to collect data on another related variable, traffic flow. Certain organisations such as satellite navigation providers may record information about transient variables such as traffic flow for certain roads. It may be possible to negotiate access to such data. Headway sensors may also give some information about traffic flow (see section 3.2.2.7 ‘Headway’).

Chapter 1 recorded additional CARE priority variables that have not been mentioned above, namely, road surface conditions, lighting conditions, seasonality and weather conditions. With the exception of ‘seasonality’, these are difficult to record without the use of video. It may be possible to get some idea of the light conditions either by matching time stamp data to records of sunset or sunrise or by using a specialist light sensor (e.g. Photodiode) however this would not provide accurate information about whether street lamps were present and lit/unlit. Realistically, light condition data could only be collected using a Scenario 2 DAS. It may also be possible to record some weather conditions with the use of a Scenario 2 DAS. For example if access to the CAN is achieved then information on windscreen wiper use could give an idea of precipitation and adding a temperature sensor or accessing the vehicle’s own temperature gage if available would give an idea about the potential for icy conditions on the road. In contrast, which season it is can be derived from the time stamp data and therefore be recorded using a Scenario 1 DAS.

The only additional variable not mentioned in Chapter 1 is ‘in-vehicle technology in use during journey’. As discussed previously, it is possible to record when in-vehicle safety systems are in use but only if access to the CAN is secured therefore data is likely to be only available for certain makes/models and possible only with a Scenario 2 DAS.

Recommended variables: Time (Day, month, year, hh:mm:ss.ff), Kilometres travelled, Driver ID, start of trip, end of trip, Seasonality.

Optional variables: professional or private journey purpose, traffic flow, road surface conditions (temperature as proxy for ice), lighting conditions (natural light levels), weather conditions (precipitation), in-vehicle technology in use (safety systems), passenger present.

3.2.6. Summary of context variables

The following tables summarise the recommended and optional context variables to be collected in the large scale activity.

Driver	**Vehicle**	**Network**	**Other (transient)**
Age	Make	Road type (urban, rural, motorway)	Time (Day, Month, year, HH:MM:SS.FF)
Gender	Model	Area Type	Kilometres

			travelled
Country of residence	Vehicle Age	Speed limit	Start of trip
Driving Experience	Style (e.g. hatchback)		End of trip
Level of education	In-vehicle technology fitted		Trip km (derived)
Occupation			Trip time (derived)
			Driver ID

Table 30 Summary of recommended Scenario 1 context variables

Driver	**Vehicle**	**Network**	**Other (transient)**
Personal characteristics (attitudes, risk taking, perceptual skills etc)	Model Variant	Road Class	Journey purpose (private/professional)
	Engine Size	Junction type	Traffic flow
			Temperature
			Road surface conditions (Icy - derived from temperature)
			Lighting conditions (natural light levels)
			Weather conditions (precipitation)
			In-vehicle technology in use (safety systems)

Table 31 Summary of optional and Scenario 2 context variables

3.3. Scenario 1 DAS specification/technical needs

As stated in Table 29, it is recommended 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

The following sections will discuss the technical requirements in terms of equipment, data storage and data analysis for collecting these topics and the context variables listed in Table 30 using a Scenario 1 DAS.

3.3.1. DAS equipment

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 Driver ID (e.g. RFID tag/magnetic swipe card). Ideally the GPS device should be compatible for use with EGNOS (see section 2.6.2) as this will maximise its accuracy and reliability. This will also help 'future proof' the DAS by allowing it to access the Galileo system once this becomes operational. The DAS 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 as natural a way as possible.

It is not the aim of this deliverable to recommend specific devices or manufacturers to be used in the large scale activity as the exact requirements of this activity have not been fully determined and technology is advancing at such a rate that recommendations would be out of date before the end of the DaCoTA project and certainly before the commencement of any large scale activity. However it is possible to discuss the options and considerations when choosing and fitting devices.

The following discussion has been informed by the information gathered by PROLOGUE (Welsh et al. 2010) and the experience of the work package partners. There are 3 main types of data acquisition systems – 'off the shelf' systems which can be bought directly from a manufacturer and fitted without modification; custom built 'in house' design, where the system components are purchased and the DAS is build according to the specific study needs; or a hybrid system, which is a mixture of the 2 where for example additional components are added to an 'off the shelf' solution according to the study needs.

A well developed tried and tested 'off the shelf' solution is most likely to achieve the robustness required. As the Scenario 1 DAS is relatively simple, there are already a number of 'off the shelf' systems available which include the necessary components. As many devices are required for a large scale study it may also be possible to negotiate certain alterations/additions with specific manufacturers so that a low cost 'bespoke' system that meets the large scale activity needs is created so a hybrid system may also be appropriate.

One potential 'off the shelf' solution would be using SMART phones. Some SMART phones are already equipped with GPS and an accelerometer and could be used as data loggers – or adapted to this use. However SMART phones are portable devices and there is no guarantee that participants are going to remember to install them in their car every time they drive. A more reliable system would be for the DAS to be installed in such a way that it can remain in the vehicle for the duration of the data collection period. It is currently possible to purchase devices which are as small as a cigarette packet and can be fitted into the vehicle in such a way as to be invisible to the vehicle occupants thus also meeting the unobtrusive requirement.

A reliable power source is also necessary to avoid loss of data and this is often achieved by using the vehicle's power supply. This however, may require buffering however to reduce any effects of power spikes created by the vehicle. The placement of the DAS in the vehicle is also important because excessive vibration, penetration of dirt or water and interference from electronic devices integral to the vehicle can all lead to loss of data or reduced data quality.

3.3.1.1. Sampling rate

Another important consideration for data collection is the sampling rate at which data from the GPS and accelerometer is recorded. This depends very much on the sensitivity of the GPS and accelerometer and type of research questions that are being addressed. 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 SafetyNet (see section 1.2and 1.3.3respectively) then there is no need for a high sampling rate. Recording data once every 10 seconds or even less frequently would be adequate. If more detailed information is required about speeding or acceleration behaviour e.g. when drivers adjust their speed around speed limit signs, greater detail would be necessary. It is unlikely that a sampling rate of greater than once per second (1Hz) is required for Scenario 1 DAS unless very detailed acceleration data is required. If the latter is the case, then a higher sampling rate of e.g. 25Hz may be required and this in turn would have an impact on the data storage requirements discussed in the following sections.

It is difficult to recommend an exact sampling rate to be used in the large scale activity at this stage of the DaCoTA project. The small scale pilots should give an insight into appropriate sampling rates, for example the pilot taking place in Israel plans to sample data every 30 seconds.

3.3.2. Data storage and transfer

3.3.2.1. In-vehicle storage

There are also a number of solutions for retrieving data from the vehicle. All DAS will need the capability to store a certain amount of data before it can be uploaded to a central storage facility or database. The amount of storage necessary will depend upon the method of upload. One way is to stream data onto some form of solid state storage device then either remove this from the vehicle and copy the data onto the central storage facility or plug a device into the car to upload data. Various previous studies have used this method. SemiFOT used USB hard drives to store data which were replaced regularly (SAFER, 2008). The 100 car study reported in Dingus et al. (2006), used 'chase cars' which travelled to the location of the cars and plugged a data transfer cable directly into the car to upload the data. For a large scale activity it is likely to be impractical to travel to vehicles to retrieve data due to the large number of cars involved. An alternative is to use the postal system to retrieve data. For example an Australian FOT used Flash cards that were sent to participants who replaced them and sent the used cards back to the researchers (Regan et al, 2006). This however puts a burden upon the participants which may affect recruitment or result in some loss of data.

An alternative method is to use 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. Both methods have been used in past studies. In a study looking at teenage driving, data from the participants' cars were retrieved via a secure wireless network when the cars were parked in the school car park (McGehee et al 2007). This method is only practical however if the participants routinely travel to the 'hub' site as part of their usual driving patterns. Otherwise the necessity of uploading data will influence where the participants drive and therefore affect the Naturalistic Driving data collected. This should be avoided in the large scale activity where exposure data such as Vehicle Km is the focus.

Automatic uploading of data using GPRS was employed by a Belgium study that recorded CAN data (Beusen et al, 2009). Data was stored using a memory card within the DAS and transmitted to the central server every day. This type of upload would be ideal for a large scale study however there may be cost implications as service providers charge for the transfer of data. In a large scale study, it may be possible to come to an agreement with the service provider(s).

3.3.2.2. Central storage and database creation

Two factors influence the amount of data storage capacity that is needed within the DAS – the sampling rate and the frequency of upload. It is essential to have a big enough storage capacity as data corruption can occur when the storage device approaches its capacity. Therefore in-vehicle storage should be overestimated to avoid loss of data.

The requirements for central data storage are very difficult to discuss at this stage of the project as they are dependent upon whether individual countries manage their own data and provide aggregate data to a European database or whether all data is uploaded to a central database. They are also dependent on the period of data collection and the sampling rate. These issues will be discussed in D6.2 which is due to be published in December 2011.

To produce adequate RED and SPI data, the minimum requirement is that the data collected in each country is stored centrally. There are various aspects that need to be considered when creating any database including data quality, backup and security with regards to data security laws. These aspects however have been discussed extensively elsewhere. PROLOGUE reviewed how previous studies handled data storage issues (Welsh et al., 2010) and the FESTA handbook provides a very comprehensive overview of the requirements of FOTs which have very similar data storage requirements to Naturalistic Driving studies (see FESTA, 2008).

3.3.3. Data analysis

It is difficult to specify data analysis requirements at this stage however some general considerations can be discussed. There will be a need for a certain amount of data preparation before research questions can be answered. Map related data requires matching to GPS data to create many of the context variables and various scripts will be required to create other derived variables. Map matching software can be purchased along with the map data itself (see section 2.6.3 for further details). Alternatively a custom solution would need to be developed. The key requirement is that the process of map matching and deriving variables is automatic in order to handle the large quantities of data produced.

Any Naturalistic Driving Observation activity produces large volumes of data; therefore analysis software has to be capable of handling such quantities. MATLAB has been used by some Naturalistic Driving studies such as SEMIFOT (SAFER 2008).

Again more information about the general requirements for data analysis can be found in the PROLOGUE deliverable Welsh et al. 2010 and the FESTA Handbook (FESTA, 2008).

3.4. Scenario 2 DAS – additional requirements

As previously discussed, 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. It may be decided that from the start of the large scale activity an additional sensor be added to collect some additional data or additions could be made once the activity is established. Also any such addition could initially be made in a subset of countries rather than all. Where it is the availability of map data that is the issue additions to the system this may be an ideal solution to gather the maximum number of variables as more detailed map information becomes available.

As stated in Table 29, the following topics would be of interest using a Scenario 2 DAS:

- Inappropriate Speed
- Seatbelt Use
- Headway
- Braking
- Vehicle Technology: Safety Systems
- Lane behaviour
- Signal Use
- Light Use

The following sections will discuss the additional technological considerations for collecting data relating to the above topics and Scenario 2 context variables listed in Table 31.

3.4.1. DAS equipment

To measure aspects of Inappropriate Speed (Windscreen wiper use and Temperature), Seatbelt use, Braking, Signal use or Light use additional sensors or access to the vehicle CAN is required. Individually these sensors are relatively basic and with the exception of temperature, then there is only a need to record a yes/no verdict as to whether the equipment is in use at a particular point in time. This need also simplifies the access necessary to CAN information. In contrast, data on Safety Systems requires a much greater level of access to CAN data and information on how to decode this data. Also Headway and Lane Behaviour require the addition of more sophisticated radar or machine vision sensors to detect the vehicle in front/behind and lane markings respectively, and this will have a number of parameters that require setting and integrating with other elements of the DAS.

Adding sensors or accessing the CAN leads to a more complex DAS with a greater likelihood of reliability errors and data loss. The need for ongoing maintenance of the DAS system is therefore also increased. This is minimised with the more basic sensors/CAN access but as the level of complexity rises, so the need for testing the DAS on individual vehicles is increased and the fitting of DAS becomes more costly.

As discussed previously (section 3.2.5.4), limited use of video in with a Scenario 2 DAS would allow the recording of Driver ID with more accuracy. Again however this would add a further layer of complexity to the system and therefore increase the cost.

It is unlikely that an ‘off the shelf’ DAS would be appropriate for Scenario 2. Some kind of hybrid or bespoke system would be required.

3.4.1.1. Sampling rate

Any sampling rate used for a Scenario 1 DAS is likely to also be appropriate for recording Temperature, Seatbelt use, Light use and Windscreen wiper use. Braking and Signal use is likely to require a higher sampling rate depending on the research question. The upper Scenario 1 rate of once per second could be adequate to know when braking and signal use occurred but if the exact timing of these is needed then a higher sampling rate is necessary. The measurement of Headway, Lane behaviour and Safety systems all require a much higher sampling rate – probably a minimum of every 1/10 of a second.

3.4.2. Data storage

The more variables that are collected directly from the DAS and the higher the sample rate, the more storage is needed in the car. It might also be necessary to upload data more often. Data storage needs are going to be much greater if data relating to headway, lane departure, safety systems and/or video Driver ID is collected than if a selection of the other topics is focused upon.

Of course the data storage needs for a central storage facility will also be greater especially if many more derived variables are required as well as the variables recorded directly from the DAS.

3.4.3. 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.

4. SUMMARY AND CONCLUSIONS

This deliverable reports the outcome of the first task of DaCoTA WP6, which was to generate an inventory of variables and measurement tools necessary to monitor road safety through Naturalistic Driving Observations. This was achieved by performing the following activities:

1. Generating an inventory of relevant variables to monitor road safety within ERSO (Chapter 1)
2. Generating an inventory of relevant variables to monitor through naturalistic driving observation (Chapter 2)
3. Combining 1 and 2 to define the variables to be measured within ERSO by naturalistic driving observation (Chapter 3)

The road safety topics considered relevant for monitoring road safety within ERSO were:

- Alcohol and Drugs
- Speed
- Protective Systems (seat belt and child restraint use)
- Daytime Running Lights (DRL)
- Fatigue
- Distraction and inattention
- Headway
- Exposure measures:
  - Vehicle km
  - Fuel consumption
  - Person km
  - Number of trips
  - Time in traffic

The following topics were addressed in Chapter 2 as additional topics that can be studied using Naturalistic Driving Observations:

- Near Crashes
- Lane change, lane position and lane keeping,
- Aggressive driving: compliance with regulations,
- Learning
- Decision making, errors, driving style/performance

The feasibility, desirability and practicability of measuring the variables associated with the above topics, which can be used to monitor road safety within a large scale Naturalistic Driving Observation activity, was assessed. This was considered within the framework of a Basic Data Acquisition System (DAS) (Scenario 1 DAS) and additional options that would add complexity to the DAS but increase the number of variables that could be collected (Scenario 2 DAS). It was proposed that a Scenario 1 DAS would comprise of a GPS logger and accelerometer. This would be a relatively low cost system that utilises existing technology such as that which exists on Smart Phones. Scenario 2 would supplement the Scenario 1 DAS with additional sensors or capability. This is more of a tool box approach as it is not possible currently to measure certain variables due to cost (e.g. headway sensor), access (e.g. CAN) or availability of supplementary data (e.g. map detail) but maybe possible in the future. Video was not considered as part of Scenario 2 at this stage as it is currently considered to be too expensive to implement in the large scale activity. However this does not preclude the consideration of video at a later stage of the DaCoTA project.

Topics that rely heavily on the use of video are Fatigue, Distraction/Inattention, the Child Restraint component of Protective systems and Near Crashes. These were therefore excluded from consideration although it may be possible to measure some elements of Near Crashes with a Scenario 2 DAS. The topic Alcohol and Drugs was excluded as currently there is no reliable way of measuring whether drivers have drunk alcohol or taken illegal or medicinal drugs within a Naturalistic Driving study. The exposure measure Fuel consumption was suggested by SafetyNet as a proxy measure for Vehicle km and was only recommended to be considered if it was not possible to measure Vehicle km directly. As Naturalistic Driving allows the accurate recording of Vehicle km, Fuel consumption was not further considered. The final topic to be excluded was Learning. Although this could be seen as a policy priority, it was thought that learning would be best studied in a more detailed Naturalistic Driving study and that there would be little added value for including it in a long term monitoring activity beyond taking account of drivers' gained experience.

The following topics were therefore considered, at least in part, to be valuable for examination in a large scale road safety monitoring activity:

- Speed (excessive and inappropriate)
- Protective Systems (seat belt use only)
- Daytime Running Lights (DRL)
- Headway
- Exposure measures:
  - Vehicle km
  - Person km
  - Number of trips
  - Time in traffic
- Lane change, lane position and lane keeping,
- Aggressive driving: compliance with regulations,
- Decision making, errors, driving style/performance

The variables necessary to collect data on the above topics were identified in Chapter 3 and the necessary technical equipment and associated data storage and analysis needs were discussed. There are also many context factors that should be considered when using Naturalistic Driving Observations. These form four categories:

- Driver
- Vehicle
- Network
- Other contextual factors

Driver, vehicle and network are relatively permanent factors whereas those in the other contextual factors category are more transient and are likely to vary from one journey to the next. A number of context variables were suggested in Chapter 1 and

2 and the feasibility of collecting these within the context of the Scenario 1 and 2 DAS were also considered within Chapter 3.

The recommended topic specific and context variables are summarised in the following sections.

4.1. Variables recommended by DaCoTA to be collected in a large scale Naturalistic Driving activity

The following tables summarise the variables that have been recommended for collection with a Scenario 1 and Scenario 2 DAS and the equipment/resources necessary. This is based on assessments of the current feasibility of collecting variables given the technology available now or in the immediate future. However this does not preclude the consideration of collecting additional variables within a large scale activity in the future if technology advances make this more practical. For example once Galileo is operational it may be possible to collect more accurate data that would allow the assessment of variables such as bend severity. As technology advances, the storage and analysis of video data may become less costly and it may be possible to consider collecting additional variables that rely heavily on the use of video (e.g. distraction).

4.1.1. Scenario 1 variables

Variable	Topic	Equipment/resources
Vehicle km	RED	Derived from aggregate trip km: GPS and trip start/end
Person km	RED	Derived from aggregate trip km and Driver ID
Number of trips	RED	Derived from trip start and end
Time in traffic	RED	Derived from aggregate time at trip start and end
Speed	Speed	GPS
Acceleration	Driving Style	Accelerometer

Table 32 topic specific variables and required equipment

Variable	Equipment/resources
Driver	
Age	Pre study Questionnaire
Gender	Pre study Questionnaire
Country of residence	Pre study Questionnaire
Driving Experience	Pre study Questionnaire
Level of education	Pre study Questionnaire

Occupation	Pre study Questionnaire
Vehicle	
Make	Pre study Questionnaire/recorded when DAS fitted
Model	Pre study Questionnaire/recorded when DAS fitted
Vehicle Age	Pre study Questionnaire/recorded when DAS fitted
Style (e.g. hatchback)	Pre study Questionnaire/recorded when DAS fitted
In-vehicle technology fitted	Pre study Questionnaire/recorded when DAS fitted
Network	
Road type (urban, rural, motorway)	GPS Road information database – map matching
Area Type	GPS Road information database – map matching
Speed limit	GPS Road information database – map matching
Other (transient)	
Time (DD, MM, YY, HH:MM:SS)	Data logger time stamp or GPS time.
Kilometres travelled	GPS
Start of trip	Sensor – ignition on linked with time stamp
End of trip	Sensor – ignition off linked with time stamp
Trip km (derived)	Derived from Start and End of journey and GPS
Trip time (derived)	Derived from Start and End of journey and time stamp
Driver ID	RFID or magnetic swipe card

Table 33 Scenario 1 context variables and necessary equipment/resources

4.1.2. Scenario 2 variables

Variable	**Topic**	**Equipment/resources**
Seatbelt worn (yes/no)	Seatbelt use	Sensor/CAN
Time Headway	Headway	Headway sensor: Radar/Machine vision
Distance to vehicle in front	Headway	Headway sensor:

		Radar/Machine vision
Time to collision	Headway	Headway sensor: Radar/Machine vision
Lane Departure	Lane Behaviour	Lane detection: Radar sensors or machine vision technology
Lateral position	Lane Behaviour	Lane detection: Radar sensors or machine vision technology
Time to cross line (lane marker)	Lane Behaviour	Lane detection: Radar sensors or machine vision technology

Table 34 Scenario 2 topic specific variables and required equipment

Variable	**Equipment/resources**
Driver	
Personal characteristics (attitudes, risk taking, perceptual skills etc)	Pre study Assessment questionnaire e.g. sensation seeking
Vehicle	
Model Variant	Pre study Questionnaire/recorded when DAS fitted
Engine Size	Pre study Questionnaire/recorded when DAS fitted
Network	
Road Class	GPS Road information database – map matching
Junction type	GPS Road information database – map matching
Other (transient)	
Driver ID	Video
Journey purpose (private/professional)	Pre study Questionnaire (whether used for work and between which times) and logged time. Travel diary
Traffic flow	3rd party traffic data Headway sensor: Radar sensors or Machine vision technology Speed in relation to speed limit (approximate measure): GPS

	Road information database – map matching
Temperature	Sensor/CAN
Road surface conditions (Icy - derived from temperature)	If temperature for e.g. is less than 5 degrees centigrade
Lighting conditions (natural light levels)	Sensor e.g.: Photodiode light detector Link with sunrise and sunset records for particular locations
Weather conditions (precipitation): Windscreen wiper on/off	Sensor or Monitor wiper switch electrics (CAN) Weather reports
In-vehicle technology in use (safety systems)	CAN
Braking (yes/no)	Sensor e.g. pressure sensor on brake pad
Light Use	Sensor/CAN
Signal Use	Sensor/CAN

Table 35 Optional and Scenario 2 context variables plus necessary equipment/resources

4.2. Additional added value of a large scale pan-European Naturalistic Driving Observation activity

As DaCoTA WP6 was tasked with defining which variables should be collected in a large scale Naturalistic Driving activity with the aim of monitoring Road Safety, the wider benefits of conducting such an activity have not been discussed. However if such a large scale activity was established, there may be benefits beyond road safety. For example, although excluded in this document as a measure of mobility or exposure to risk, Fuel consumption is relatively easy to measure and could provide valuable environmental and 'eco-driving' data.

Data collected for safety purposes could also be used for mobility studies and traffic monitoring. Data on Person km and where drivers actually travelled as recorded using GPS or Galileo data would also be useful for those studying mobility or traffic flow – especially if a concentration of vehicles equipped with a basic DAS was established in a particular country. Speed data could also allow the development of digital maps that indicate both the average and extreme speeds at which cars travel on specific road types or classifications. As information on the time of day would also be available this would allow the identification of traffic hot spots. Although such data already exists in some countries, this is achieved through speed traps which only show speeds at 1 point of a road. Naturalistic Driving allows speeds to be recorded for the whole time the vehicle is travelling on a particular road.

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Project Websites

DRUID	Driving under the Influence of Drugs, Alcohol and Medicines: http://www.druid-project.eu/
ERSO	European Road Safety Observatory: www.erso.eu
FOT-Net	Networking Platform for Field Operational Tests: www.fot-net.eu/
PROLOGUE	Promoting real life observations for gaining understanding of road user behaviour in Europe: http://www.prologue-eu.eu/
SafetyNet:	http://ec.europa.eu/transport/wcm/road_safety/erso/safetynet/content/safetynet.htm
SeMiFOT	Sweden Michigan Naturalistic Field Operational Test: https://www.chalmers.se/safer/EN/projects/traffic-safety-analysis/semifot
SHRP2	Strategic Highway Research Program 2: http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Blank2.aspx
TeleFOT	Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles: http://www.telefot.eu/

APPENDIX: SUPPLEMENTARY INFORMATION ON RED AND SPI

Vehicle kilometres

Vehicle kilometres data are regarded as generally available within the EU (Lejeune et al., 2007): 18 out of 26 countries have vehicle kilometres data at least partially available.

This RED can also be available in a high level of disaggregation, but the actual availability and level of disaggregation varies strongly and depends on the type and features of the methods used in each country.

Vehicle type (mostly by surveys and traffic counts, secondarily by statistical models and combinations of methods) and road type (motorway - non motorway) (via traffic counts) come out as the most commonly used variables. Year, month and area type were furthermore only available in a very small number of countries (Duchamp et al., 2008; Yannis et al., 2008a).

The SafetyNet EU needs' analysis showed that for vehicle kilometres there is an overall high need from countries for data on vehicle type, age, engine size, and road type for vehicle-oriented traffic risk analyses; while for network-oriented traffic risk analyses most countries think data per vehicle type, road type, area type and year are necessary. Furthermore, vehicle kilometre data is considered a high priority need (Yannis et al., 2008a).

The SafetyNet derived priorities in data harmonization with regard to the vehicle-kilometres variables are: vehicle type and age, road type, area type and year. An additional variable identified as important in this scope but not as a priority is vehicle engine size (Yannis et al., 2008a; Duchamp et al., 2008).

Since the provided data on vehicle kilometres are also regarded as being compatible to EUROSTAT/CARE, this RED is considered to be usable for EU-wide country comparison (Lejeune et al., 2007).

The overall comparability across countries is still low though because of significant differences in variables and values (Duchamp et al., 2008), e.g. (Lejeune et al., 2007):

- the exact definition of included vehicles (all vehicles or only motor vehicles); as only very few countries include bicycles kilometres, this poses no big problem for the comparability at the moment;
- the exact definition of traffic volume (related to national vehicle or traffic within national borders); more and more countries started to use odometer readings from periodic vehicle inspections to estimate vehicle kilometres which includes an unknown percentage of travels carried out abroad; this method needs to be complemented by others to avoid biased traffic volume;
- the frequent restriction of the data on vehicle kilometres to some specific road types.

Besides the differences in definitions, the comparability of vehicle kilometres is also jeopardised by differences in national collection methods (Duchamp et al., 2008). Most countries use travel surveys and traffic counts to estimate vehicle kilometres, either in a separated or in conjunction manner. These are the only methods that can produce detailed vehicle-kilometres estimates (Thomas et al., 2009), but as both are sampling methods, they are subject to various types of errors (Duchamp et al., 2008).

Travel surveys have the advantage of being more flexible in their design, which might enable a higher level of disaggregation for person and vehicle units. On the other hand, the advantage of traffic counts is that they can provide continuous measurement over time. Consequently, the SafetyNet experts conclude that a common exposure data collection system should be established, including both travel survey and traffic count elements (Duchamp et al., 2008).

They indicate that traffic counts at the European level would provide continuous traffic measurements over time, which could be used for monitoring exposure. “Guidelines for a European traffic counts systems should be elaborated. The system could be initially implemented on the Trans-European Road Network (TERN) and expanded gradually to lower level roads (Duchamp et al., 2008 p. 17-18)”.

Besides this, the use of odometers is regarded as having high potential in future data collection of traffic volume. Its clear advantage is the uniform data collection, which allows a high comparability of the data in the different countries. This requires though finding a uniform way of estimating traffic carried out abroad (Thomas et al., 2009).

The collection methods of vehicle kilometres of international data files vary according to the type of data and the responsible authority collecting these. Thus, this data should be used with caution (Duchamp et al., 2008).

Fuel consumption

Current practice and recommendations (SafetyNet outcomes)

Fuel consumption data are regarded as generally available within the EU. Almost all the countries (23 out of 26) collect data on fuel consumption: all on fossil fuels, 4 also on electricity. Nevertheless, most of this data is not compatible with CARE, mainly due to the fact that transport use, not to mention different transport modes, cannot be filtered out (Lejeune et al., 2007).

Fuel consumption is thus currently not considered to be a usable indicator for EU road safety comparisons. It could become usable though if data could be disaggregated by transport use and transferred into an estimate of vehicle kilometres (Lejeune et al., 2007 p. 33). On the other hand, its usefulness is also questioned due to other important limitations (Yannis et al., 2008a). There are several biases, which can be expected to be systematic (e.g. fuel sold in one country may be consumed in another), which make it an unreliable road traffic indicator, and it seems difficult to find solutions to overcome these problems (Lejeune et al., 2007).

Because of its low usability for road safety analysis, fuel consumption was not included in the SafetyNet survey on RED needs and priorities; it was thus also not mentioned in the final recommendations on RED within ERSO (Duchamp et al., 2008).

Nevertheless, many countries currently do use fuel consumption data in combination with other data sources to estimate road traffic volumes or vehicle kilometres (Lejeune et al., 2007; Yannis et al., 2005).

Fuel sales are probably best used at an aggregated level, possibly national and annual. However, when comparing countries additional parameters should be taken into account, such as fuel efficiency of motor vehicles, pricing differences etc.

Person kilometres

Current practice and recommendations (SafetyNet outcomes)

The SafetyNet investigation revealed that data on person kilometres are at least partly available in 11 out of 26 countries; they are thus not regarded as generally available within the EU. Consequently no further investigation on the compatibility with CARE/EUROSTAT of this data in the scope of its EU wide usability took place. Although this RED is seen as one of the most useful exposure indicators, it is unusable for EU-wide comparisons. (Lejeune et al., 2007)

The EU data needs' investigation indicated that person-kilometres per person class, age, gender, nationality, driving experience and year are necessary for person-oriented traffic risk analyses for most countries (Yannis et al., 2008a). Taking into account the priority needs within the EU, person kilometres per person class, age, gender and year come out as prioritised variables to be harmonised among European countries, while nationality and experience are considered important additional data (Duchamp et al., 2008).

Country comparison indicates that person kilometres data can be available for numerous person, vehicle and road characteristics, but the variables as well as their compatibility to the respective CARE variables varies significantly between countries (Yannis et al., 2008a).

The SafetyNet recommendations focus mainly on the methodology of collecting this and the other traffic and mobility RED, and more specifically on the use of surveys. Although more collection methods are available, surveys are preferred because they give most detailed (disaggregate) data. As a sampling method though, it is subject to all kinds of errors (e.g. sampling, measurement, response etc.), which can make it challenging to obtain representative data for the risk calculation (Duchamp et al., 2008).

The most common variables in surveys to estimate person kilometre data are: person class, age and gender; and to a lesser extent vehicle type and year. Person kilometres by a combination of methods traffic counts (travel surveys, statistical models, as well as other official traffic data) are in general less usable than by surveys, and can hardly be considered as usable for the establishment of a common framework (Yannis et al., 2008a).

Like for vehicle kilometres, SafetyNet indicates that only through establishment of a future pan-European data collection system comparable exposure data on these indicators can be achieved. A pan-European survey would provide disaggregate person-kilometres, cross-tabulated per person, vehicle and road characteristics (Duchamp et al., 2008).

Number of trips

<u>Current practice and recommendations (SafetyNet outcomes)</u>

The SafetyNet investigation concludes that number of trips is still seldom collected. Only nine out of 26 countries have at least partly available data on number of trips. In most countries data were only partly available because not all age groups were included (no young persons). No further investigation regarding data compatibility with CARE/EUROSTAT was thus performed. As this RED is not generally available, it is not regarded as usable for EU comparisons (Lejeune et al., 2007).

Furthermore, unlike for person or vehicle kilometres, none of the international data files (EUROSTAT, IRF, IRTAD, UNECE, ECMT) contain data on the number of trips made in each country (Duchamp et al., 2008).

The SafetyNet data needs analysis among EU Members States revealed that time in traffic per person class, age and gender are necessary for both health and person-oriented traffic risk analyses for most countries, whereas a few countries indicated that this indicator is also necessary per vehicle and network characteristics (Yannis et al., 2008a).

It was not ranked as a priority by more than three countries (Yannis et al., 2008a), so number of trips per person class, age and gender, and per vehicle type are included in the SafetyNet list of important additional data needs to be tackled after consideration of the data harmonising priorities (regarding for instance vehicle and person kilometres) (Duchamp et al., 2008).

With regard to the method to collect data on number of trips, reference can be made to the survey related information and recommendations for person kilometres (see chapter before). It was summarised that number of trips data collection suffers several important limitations, besides its lacking availability (Yannis et al., 2008a).

A main SafetyNet recommendation for this RED is to use a unique definition of a trip, and to collect all data regardless of the length or duration. In order to make respondents remember small trips, interviewers should actively encourage them to include all kinds of trips in their responses (Duchamp et al., 2008).

Time in traffic

Current practice and recommendations (SafetyNet outcomes)

Time in traffic data are very rare (Duchamp et al., 2008). Only nine out of 26 countries have at least partly available data on time in traffic. The other countries replied that they do not collect these data (Lejeune et al., 2007). No further investigation on compatibility with CARE/EUROSTAT was thus carried out. SafetyNet experts concluded that data on time in traffic are at the moment not usable for the EU country comparison on road safety (Lejeune et al., 2007).

Furthermore, like number of trips, none of the international data files (EUROSTAT, IRF, IRTAD, UNECE, ECMT) contain data on time spent in traffic in each country (Duchamp et al., 2008).

The SafetyNet analysis on data needs revealed a high need though for time in traffic per person class, age and gender for both health and person-oriented traffic risk analyses for most countries, whereas fewer countries indicated that this indicator is also necessary per vehicle and network characteristics. But like number of trips, time in traffic was also not ranked as a priority RED by more than three countries (Yannis et al., 2008a).

Like the two previous mobility and traffic RED, time in traffic is basically collected through surveys, which are mainly carried out for mobility research rather than for risk exposure purpose. Mobility surveys have some drawbacks though, e.g. focussing only on specific trips, or on a selection of traffic modes (Duchamp et al., 2008).

As it considers the same method, reference can be made to the survey related information and recommendations for person kilometres (see chapter on person kilometres). It was summarised though that current time in traffic data collection suffers important methodological limitations, besides the lacking availability (Yannis et al., 2008a).

Survey collected data are mostly available for various road user characteristics and more specifically, for person class, age, gender and nationality. However, the definitions of variables and values used differ. Difficulties may thus be encountered in the disaggregation of time spent in traffic, especially for comparisons between different road users or different age groups. Together with the national methodological survey features, this makes the current survey data not usable in a common framework (Yannis et al., 2008a; Duchamp et al., 2008).

SafetyNet experts recommend that a harmonised European travel survey, which focuses on the whole population, all trips (daily or holiday trips) and all types of road users or transport means, could solve the difficulties of this RED. In such a kind of survey, all countries should use the same definitions and they could work with data of the same year. This could enable braking down time in traffic by national/regional level, date and time, vehicle type, transport mode, motorway/no motorway, rural/urban area, age and gender (Duchamp et al., 2008).

Alcohol and drugs

General concept

Driving under the influence of alcohol and drugs is one of the most important factors increasing the risk of (severe) road accidents. As a result, most countries ban the use of these psycho-active substances among drivers, or set low legal limits for blood alcohol and drug concentrations. However, drink and drug driving is involved in a high proportion of fatal accidents in most countries (Vis et al., 2005; Hakkert and Gitelman, 2007; Thomas et al., 2009).

About 25% of all road fatalities in Europe are alcohol related whereas about 1% of all kilometres driven in Europe are driven by drivers with 0.5 g/l alcohol in their blood or more. As the blood alcohol concentration (BAC) in the driver increases, the crash rate rises progressively.

Impaired driving may strongly vary by road type, period of the year, day of the week and time of the day. Moreover, driver variables like age, gender and Driving Under the Influence (DUI) offences history also seem to strongly influence driving under influence (Hakkert et al., 2007; European Commission Road Safety, 2010b; Boets et al., 2008).

Policy makers need to be informed on the state of this problem in their country. Data on the prevalence of alcohol and drugs among road users help the understanding of crash risk and the need for countermeasures, such as legislation, enforcement, and information (Vis et al., 2005; Hakkert and Gitelman, 2007; Thomas et al., 2009).

Development of SPI

Theoretically the "ideal" SPI on alcohol and drugs should be the prevalence and concentration of impairing substances among the general road user population. There are, however, major methodological problems related to such SPI, because of either judicial impediments (e.g. in some countries: no random testing by police allowed, only mandatory tests if suspected impairment) or methodological obstacles (e.g. sample representativeness).

Extreme difficulties are thus foreseen when all EU countries would have to agree on a common sampling and testing protocol on this topic, so this SPI for alcohol and drugs has been rejected (Hakkert et al., 2007).

As the "ideal" SPI is not feasible, the following more practicable SPI, based on crash data, have been proposed by SafetyNet (Hakkert et al., 2007):

- number and percentage of severe and fatal injuries resulting from road accidents involving at least one active road user impaired by psychoactive substance (concentration above a predetermined impairment threshold);
- percentage of fatalities resulting from accidents involving at least one driver impaired by alcohol;
- percentage of fatalities resulting from accidents involving at least one driver impaired by drugs other than alcohol.

In case the first one is not feasible, the other two are proposed as alternatives.

Current practice of defined SPI

After investigation of data availability, usability and quality, SafetyNet selected the following alcohol and drugs SPI for more comprehensive country comparisons:

- alcohol: percentage of fatalities resulting from accidents involving at least one driver impaired by alcohol
- drugs: percentage of fatalities resulting from accidents involving at least one driver impaired by drugs other than alcohol

Most countries (26 of 29) provide data on alcohol which can be used for the calculation of the SPI. Only six countries provide data for drugs other than alcohol, but some state that these data are unreliable because the number of tested drivers is very low.

The analysis of comparability of the alcohol SPI showed several difficulties though:

- In most countries the data depend on the legal limit (0.0 up to 0.9 g/l BAC), as only data for drivers above the legal limit are provided.
- The percentage of drivers involved in fatal accidents who are actually tested for alcohol and/or drugs varies. Thus, it remains unclear whether the fatal accidents with alcohol-positive drivers should be related to the number of fatal accidents with drivers tested or to the total number of fatal accidents.
- In some countries only data from fatal accidents “caused” by impaired drivers were presented. This concept of cause leads to difficulties and SafetyNet recommends that all fatal accidents should be included in the data collection.
- In small countries the number of fatal accidents is small and therefore subject to random variation. Consequently the experts suggest computing the SPI based on data for several years, rather than for one year.

These difficulties led to the advice not to compare the results across countries, before definitions, data collection and data analysis methods are harmonized (Thomas et al., 2009).

Data for drugs is a more complex topic. The number of drugs in use is very large and varies by country. Furthermore, drugs vary from medical drugs in prescribed doses, to medical drugs in abuse doses and to illicit drugs in varying doses and can be combined with each other or with alcohol. All this makes common definitions and approaches on the topic almost impossible.

The SafetyNet experts concluded that considerable effort in harmonising definitions, data collection and data analysis methods, will still be needed in order to do reliable and valid country comparisons on alcohol and drugs SPI. “The most important aspect is likely to be the number of drivers involved in fatal accidents, who are actually tested for alcohol and/or drugs. Each country should report the number of tested and untested drivers involved in fatal accidents in addition to the total number of fatalities and the number of fatalities resulting from accidents with at least one driver impaired by alcohol or drugs (Vis and Van Gent, 2007a p. 13)”.

Speed

General concept

Vehicle speed is one of the main causes of accidents and has direct influence on accident severity. In fact, it is the core of the road safety problem, as speed is involved in all accidents: no speed, no accidents. In about 10% of all accidents and 30% of fatal accidents speed has been found to be a major contributing factor (Transportation Research Board, 1998 IN: Hakkert and Gitelman, 2007; Thomas et al., 2009).

Both excessive (i.e. exceeding the posted speed limit) and inappropriate (i.e. faster than the prevailing conditions allow) speed are important accident causation factors, and very common phenomena. “Typically, 40-50% of the drivers travel faster than the speed limit; 10-20% exceeds the speed limit by more than 10 km/h. In addition, drivers often insufficiently adapt their speed to the prevailing local and temporary conditions related to traffic and weather. Speed choice is related to the drivers' motives, attitudes, risk perception and risk acceptance, and affected by characteristics of the road, the road environment and the vehicle (SafetyNet 2009 p. 3)”.

The high prevalence numbers underline the high safety potential of managing drivers’ excessive or inappropriate speed. Although speed data are initially often collected by other motives than road safety (e.g. traffic management and planning) it can help policy makers to monitor safety interventions on specific road types and to make specific comparisons on factors relevant to safety (Vis et al., 2005; Hakkert and Gitelman, 2007; SafetyNet 2009).

Specific driver related variables have been found to influence speeding behaviour (e.g. age, gender, attitudes, personality characteristics like risk taking, perceptual skills and limitations). On the level of the vehicle, aspects like the size of the engine power and specific types of cars (e.g. landrover-types) may also increase the chance of speeding. Other relevant variables are related to the road (e.g. road and area type) or to transient characteristics (e.g. professional or private driving purpose, traffic density, traffic composition, level of enforcement). (European Commission Road Safety, 2010d, 2010e; Hakkert et al., 2007).

Development of SPI

According to the theoretical framework, excessive and inappropriate speed are both important accident causation factors, and both should thus be considered within the development of SPI. But while excessive speed data can be collected on a large scale, this is considered impossible (too expensive) for inappropriate speed, as this is a more complex problem requiring information on the specific road, weather and traffic conditions and thus has to be studied case by case (Hakkert and Gitelman, 2007).

The developed speed SPI and recommendations within SafetyNet therefore concentrate only on excessive speed. They summarise that (Hakkert et al., 2007 p. 153f):

“The speeds that are most relevant for safety purposes are spot speeds measured at various locations on the road network during periods when traffic can be considered free flowing, i.e. not during periods of congestion when speeds are severely restricted.

The selected relevant SPI for road safety are:

- mean speed;
- standard deviation;
- 85th percentile speed;
- percentage of drivers exceeding the speed limit (later specified into (1) over speed limit and (2) 10 km/h over speed limit).

These indicators should be disaggregated by road type, vehicle type, period of day (day-night time) and period of the week (week-days and weekends)".

The SafetyNet Manual indicates the minimum set of indicators: each developed SPI disaggregated by day versus night time for light vehicles (Hakkert and Gitelman, 2007).

SafetyNet stresses that country comparisons can only be carried out for roads of similar category and for which similar methods of speed data collection are used (Thomas et al., 2009). For road types it is suggested to adopt the classification developed in the roads task (See: Hakkert et al., 2007 p. 99-126).

Current practice of defined SPI

After investigation of data availability, usability and quality, the following speed SPI were selected for comprehensive country comparison (Vis and Van Gent, 2007a):

- Average speed either during daytime or during the night
- Percentage of speed limit offenders.

Speed data from large-scale speed surveys can be provided by most countries and most of them are able to compute the proposed speed SPI. Nevertheless, due to the large variability in the conduction of the surveys, international country comparisons for speed SPI are -at present- almost impossible (Thomas et al., 2009).

The SafetyNet experts point out the following main difficulties, and provide some recommendations (Vis and Van Gent, 2007a):

- Representativeness of measuring locations. Only 8 of the 18 countries that provided speed data use a sampling procedure to select the measuring locations. Some countries cannot produce aggregate data on national level, as speed surveys are conducted by regional organisations.
- Traffic conditions. Due to the fact that traffic conditions have a significant impact on speed, the experts of SafetyNet recommend only comparing speed measurements that were carried out in similar non-congested traffic conditions. The criteria for traffic conditions under which the measurement is considered to be valid, vary between countries.
- Comparability of roads. The SafetyNet analysis found that road classifications and speed limits vary between countries and that at the moment it is impossible to find even one corresponding road in each country for each SafetyNet road category. The three most common road types were: motorways (AAA), single carriageways A-level road (A) and urban single carriageway distributor roads (D). Most surveys only conduct speed measurements on free flowing traffic and straight roads.
- Period of measurement. The length of time of speed measurement varies across countries. In cases of a measurement of a few hours this is usually carried out during daytime. The first country comparison carried out by SafetyNet supports the idea that speeds differ between day and night, which leads to the conclusions, that day and night speeds should be considered separately and not be combined into one speed SPI. Other time distinctions, such as weekday versus weekend or time of the year, are so far not common.

- Vehicle types. Speed indicators should not be aggregated over all vehicle types, as for example differences in vehicle fleet may influence the country comparison. The SafetyNet experts recommend comparing indicators for one vehicle type only (e.g. cars).
- Accuracy of data. At the moment it is impossible to determine whether any two values are significantly different or not. This is due to many sources of uncertainties in speed data, which make it impossible to calculate the margin of error. The experts of SafetyNet point out that in general, it is more accurate to compare trends of speed data than absolute values because internal country methodologies usually remain consistent in time.

Regardless of all the difficulties though, comparison of speeds on motorways was indicated as feasible, accounting for relative similarity of road and traffic conditions on these road types across Europe (Thomas et al., 2009).

Protective systems

General concept

Seat belts and child restraints are standard protective systems saving the most vulnerable parts of the human body from harm during crashes. Other protective systems in regard to motorised vehicles are for example airbags or head restraints (Hakkert et al., 2007).

Seat belts are considered the easiest and cheapest way to avoid injury (at least 40% decrease of death rate, ETSC, 2001), they do not require any special technology and have been mandatorily fitted in front and back seats for a long time. Since 2006, the use of seatbelts is mandatory in all EU countries. Not using a seat belt is the second biggest cause of road deaths, after speeding and ahead of drink driving (Hakkert et al., 2007; EC, 2010).

Generally, the availability and appropriate use of protective systems as a whole are fundamental items in the development of SPI. Furthermore, SPI on seat belts in particular should rather concentrate on use rates than on the presence of seat belts itself (Hakkert et al., 2007).

Characteristics of the road user, such as age, gender and other socio-economical characteristics, have a significant influence on the use rates of protective systems in general. Therefore, it is important to distinguish different road user groups in order to understand the problem better and find out the general rate for the whole population. Furthermore, disaggregated information is necessary in order to plan and evaluate (sub) target group specific information and education, and enforcement activities (Vis et al., 2005). Besides driver variables, road related characteristics may also affect seat belt use, like the speed limit (e.g. lower seat belt use in low speed zones) (Via Secura, 2008).

Development of SPI

The SafetyNet experts defined as direct indicator “the day-time use (wearing) rate of protective systems in traffic” and as indirect indicators based on which the direct indicator could be derived: (1) ”the use of protective systems by fatally injured accident participants recorded by police” and (2) “the presence of the systems, or their availability in general” (Hakkert et al., 2007).

Based on the literature and practical availability of data, the experts of SafetyNet propose the following SPI on protective systems for passenger cars (extracted from Hakkert et al., 2007):

- daytime wearing rates of seat belts in front seats (passenger cars)
- daytime wearing rates of seat belts in rear seats (passenger cars)
- daytime wearing rates by children under 12 years old (restraint systems use in passenger cars)

The data should be at least disaggregated by main road types (motorways, other rural roads and urban roads) (Hakkert and Gitelman, 2007). Moreover, characteristics of the road users, such as age, gender and other socio-economical variables might be of interest as they have a significant influence of the on the use rates of protective systems (Vis et al., 2005). SafetyNet recommends using data from independent observational surveys carried out on an annual basis (Hakkert et al., 2007).

Current practice of defined SPI

The three proposed SPI on seat belt and child restraint use in passenger cars were subject of the SafetyNet analysis on country comparability.

The information on the availability and comparability of the observational survey data on protective systems SPI can be summarized as follows (Vis and Van Gent, 2007a):

Daytime wearing rates of seat belts in front seats of passenger cars (whether driver only, or also front passenger) are assessed in 22 out of 27 countries. Among the available data the calculated rates of six countries were not considered valid and fully comparable, in most cases because they were not representative for the entire road network due to a limited number of observation sites (one/two road types only).

In most countries disaggregated data are only available for the driver and front seat passenger (Vis and Van Gent, 2007a).

Daytime wearing rates of seat belts in rear seats of passenger cars are assessed in 18 out of 27 countries among which the data for 3 countries are not considered to be valid and fully comparable.

Daytime usage rates of restraint systems in passenger cars by children under the age of 12 are regularly assessed in nine out of 27 countries. Furthermore, two countries assess the daytime usage rates of restraint systems in passenger cars for children under a certain body length.

Daytime running lights (DRL)

General concept

Vehicle visibility is one of the contributing factors to the number of road accidents. A lot of traffic accidents occur because road users do not see each other (not in time or not at all). This happens not only in the dark but also in daylight.

The level of use of DRL can be considered as an indirect indicator for vehicle-visibility, as visibility cannot be measured directly.

DRL helps road users to better and earlier detect, recognise and identify vehicles and helps to estimate the distance, speed and moving direction of vehicles. The relation between the level of use of DRL and the size of the effect on safety serves as basic idea for developing an SPI.

According to SafetyNet (Hakkert and Gitelman, 2007) and the Directorate-General for Energy and Transport of the European Commission (DG TREN, 2006), DRL has a high potential to increase road safety (SafetyNet, 2005).

Development of SPI

SafetyNet suggests as SPI for DRL:

- percentage of vehicles using daytime running lights.

This suggestion is based on a literature review and the current practices (Hakkert et al., 2007).

With an increase of vehicles with automatic DRL option, usage rates will lose their importance as a behavioural SPI (Hakkert et al., 2007).

This general indicator can be estimated for the whole sample of vehicles, which were observed in the country. Similar values can be calculated for different road categories and for different vehicle types.

“The road categories to be considered are: motorways, rural roads, urban roads, and DRL-roads, where the term “DRL roads” implies the road categories where the usage of DRL is obligatory. The vehicle types to be considered are: cars, heavy good vehicles (including vans), motorcycles and mopeds (also in Hakkert and Gitelman, 2007 p. 12)”.

Current practice of defined SPI

The experts of SafetyNet used the following DRL SPI for their analysis on country comparability (Vis and Van Gent, 2007a):

- total usage rate of DRL;
- usage rate of DRL per road type (four road types[18]);
- usage rate of DRL per vehicle type (four vehicle types).

Eight countries delivered national observation survey data on the usage rate of DRL per road type, only one country on the usage rate of DRL per vehicle type and no country could provide data on the total usage rate of DRL.

The data of the eight countries on usage rate of DRL per road type can be compared but some differences can be explained also through differences in the country

[18] Motorways, Rural roads, Urban roads, DRL roads

characteristics. Above all the DRL legislation (obligatory, recommended or none of both), might have an influence on the usage rates but also characteristics such as latitude of the country (as closer to the equator the less the effect of DRL). Furthermore, the prevalence of automatic switch-on of lights in vehicles is a relevant factor.