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## **Naturalistic driving studies**

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Deliverable 2.1 - part 1 of 5

## **Review of current study methods for VRU safety**

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## Table of Contents

1.	Executive Summary .....	1
2.	Introduction .....	5
2.1.	Objective and scope .....	5
2.2.	InDeV questionnaire surveys .....	6
3.	Epidemiological studies based on accident data .....	8
3.1.	Description of epidemiological studies .....	8
3.2.	Overview of the method’s applications .....	10
3.2.1.	Types of traffic accident analysis reports .....	10
3.2.2.	General traffic safety report .....	10
3.2.3.	Black spot analysis .....	12
3.2.4.	Road network safety analysis .....	15
3.2.5.	Research-type epidemiological studies .....	16
3.3.	InDeV questionnaire survey on epidemiological studies .....	19
3.3.1.	Structure of the questionnaire .....	19
3.3.2.	General Traffic Safety Reports .....	19
3.3.3.	Black Spot Analysis .....	22
3.3.4.	Road Network Safety Analysis .....	24
3.4.	Best practice examples of epidemiological studies .....	25
3.5.	Summary .....	28
4.	Quality of accident data .....	30
4.1.	Problems with accident data quality .....	30
4.1.1.	Types of data problems .....	30
4.1.2.	Definition of a road accident .....	30
4.1.3.	Underreporting .....	31
4.1.4.	Incomplete and inaccurate data .....	32
4.2.	International accident data sources .....	33
4.2.1.	Community database on Accidents on the Roads in Europe CARE .....	33
4.2.2.	International Road Traffic and Accident Database IRTAD .....	34
4.2.3.	World Health Organisation .....	35
4.3.	InDeV questionnaire survey on data quality .....	35
4.4.	Survey results .....	36
4.4.1.	Summary tables .....	36
4.4.2.	Country notes and specific national conditions .....	39
4.5.	Summary and conclusions .....	44
5.	In-depth accident investigations .....	47
5.1.	Description of in-depth accident investigation .....	47
5.2.	Overview of the method’s applications .....	50
5.3.	Studies related to VRU safety performed in InDeV partner countries .....	51
5.3.1.	Fatal accident statistics .....	51
5.3.2.	Limited time studies addressing specific questions .....	52
5.3.3.	Permanent studies .....	58
5.4.	Best practice examples of in-depth studies .....	58
5.5.	Summary .....	59
6.	Naturalistic driving studies .....	60
6.1.	Description of the naturalistic driving study method .....	60

6.2.	Overview of the application of naturalistic studies.....	61
6.3.	Summary of a scoping review of literature on naturalistic driving studies .....	62
6.4.	Studies related to VRU safety performed in InDeV partner countries .....	63
6.5.	Best practice examples of naturalistic driving studies .....	64
6.6.	Summary .....	65
7.	Behavioural observations .....	66
7.1.	Description of road user behavioural observation studies .....	66
7.2.	Summary of a scoping review on the current practices in behavioural observations studies in scientific literature .....	67
7.3.	Studies related to VRU safety performed in InDeV partner countries .....	70
7.4.	Best practice example of a behavioural observation study.....	71
7.5.	Summary .....	72
8.	Traffic conflict studies .....	73
8.1.	Description of traffic conflict studies .....	73
8.2.	Overview of the method’s applications .....	74
8.3.	Summary of the scoping literature review on surrogate measures of safety in site-based traffic observations .....	75
8.4.	Studies related to VRU safety performed in InDeV partner countries .....	76
8.5.	Best practice examples of traffic conflict studies .....	77
8.6.	Summary .....	78
9.	Self-reported accidents .....	79
9.1.	Description of self-reported accidents .....	79
9.2.	Overview of the method’s applications .....	80
9.3.	Summary of a scoping review of literature on self-reported accidents .....	80
9.4.	Studies related to VRU safety performed in InDeV partner countries .....	81
9.5.	Best practice example of self-reported accident.....	83
9.6.	Summary .....	83
10.	Summary and Conclusions .....	84
10.1.	Summary of the review findings .....	84
10.2.	Integrated approach to safety assessment .....	88
10.3.	Recommendations for improving VRU safety assessment .....	89
10.4.	Future research needs .....	90
11.	Acknowledgements .....	91
12.	Literature .....	92
Appendix 1	.....	103
Questionnaire survey 1	.....	103
Appendix 2	.....	120
Questionnaire survey 2	.....	120
Appendix 3	.....	125
Scoping literature review method	.....	125

## List of Figures

Figure 3.1: Accident patterns with pedestrian fatalities in Israel, 2003-2006 .....	18
Figure 3.2: Most common PTW fatal accident configurations (PTWs shown in green) in France .....	18
Figure 3.3: Number of cyclist fatalities and percentage of all road fatalities, EU, 2004-2013 .....	26
Figure 3.4: Cyclist fatality rates per million population by country, 2004 and 2013 .....	26
Figure 3.5: Distribution of cyclists and all road fatalities by month, EU, 2013 .....	27
Figure 4.1: Road user collision matrix .....	32
Figure 7.1: The main goals of road user behaviour observation studies .....	67
Figure 8.1: “Safety pyramid” .....	73



## List of Tables

Table 2.1: Number of forms filled in by InDeV partner countries .....	7
Table 3.1: Criteria used to determine the severity of accident victims’ injuries .....	9
Table 3.2: Form A.1: Epidemiological studies based on accident data at the national level .....	20
Table 3.3: Form A.1: Epidemiological studies based on accident data at the regional/local level .....	21
Table 3.4: Black spot analysis.....	23
Table 3.5: Road network traffic safety analysis – regional level .....	24
Table 3.6: Form A.3: Road network traffic safety analysis – city and road/district level .....	25
Table 4.1: Accident data definitions and collection procedures .....	37
Table 4.2: Quality of road accident data.....	38
Table 5.1: Categories/levels of road traffic accident investigations .....	48
Table 5.2: Overview of in-depth databases worldwide .....	49
Table 5.3: Results of the InDeV questionnaire concerning in-depth investigations in partner countries .....	51
Table 6.1: Naturalistic driving studies of VRUs in partner countries.....	63
Table 7.1: A SWOT analysis on road user behavioural observation studies.....	68
Table 7.2: Behavioural observation studies reported by partner countries .....	71
Table 7.3: The topics of the behavioural observation studies reported by partner countries .....	71
Table 8.1: The status of use of traffic conflict studies among safety professionals in InDeV countries .....	77
Table 9.1: The number of self-reported studies in InDeV countries reported by the partners .....	81
Table 9.2: Studies performed in partner countries concerning VRUs.....	82
Table 10.1: Number of publications found and reviewed .....	86
Table 10.2: VRU safety assessment method complementarity table .....	88

## List of Abbreviations

AAU	- Aalborg University
AARU	- Audi Accident Research Unit
AIS	- Abbreviated Injury Scale
BAS	- Brake Assistance System
BASt	- Federal Highway Research Institute
BRON	- The National Road Crash Register Netherlands
BSM	- Black Spot Management
BVH	- Dutch registration system of road accidents
CARE	- Community database on Accidents on the Roads in Europe
CADaS	- Common Accident Dataset
CI	- Composite Indicator
CF	- Crash frequency
CR	- Crash rate
DALY	- Disability-adjusted life years
DEA	- Data Envelopment Analysis
DGV	- Traffic Directorate
DSS	- Decision Support System
EB	- Empirical Bayes estimate of total-crash frequency
EBs	- Empirical Bayes estimate of severe-crash frequency
EC	- European Commission
EDAVUL	- In-depth investigations of crashes involving light goods vehicles (Etude Détaillée d’Accidents impliquant des Véhicules Utilitaires Légers)
EUREF89	- European Terrestrial Reference System 1989
EPDO	- Equivalent Property Damage Only crash frequency
ETSC	- European Transport Safety Council
FARS	- Fatal Accident Reporting System (USA)
FAT	- Automotive Research Association (Germany)
GIDAS	- German In-Depth Accident Study
GIS	- Geographical Information System
GPS	- Global Positioning System
HSID	- various Hotspot Identification Methods
HU	- Hasselt University

ICD-10	- International Classification of Diseases – Revision 10
IFSSTAR	- French Institute of Science and Technology for Transport, Spatial Planning, Development and Networks
IGLAD	- Initiative for the Global Harmonization of Accident Data
InDeV	- In-Depth understanding of accident causation for Vulnerable road users
IRF	- International Road Federation
IRTAD	- International Road Traffic and Accident Database
ISS	- Injury Severity Score
LPR	- The National Hospital Discharge Registry (Landspatientregistret)
LU	- Lund University
MAIS	- Maximum Abbreviated Injury Scale
NISS	- New Injury Severity Score
NSM	- Network safety management
NWB	- National Road Database
OECD	- Organisation for Economic Co-operation and Development
OLS	- Ordinary least squares
PCM	- Pre-crash matrix
PET	- Post-Encroachment Time
PFI	- Potential for improvement
PTW	- Powered Two-Wheelers (motorcycles and mopeds)
RNSA	- Road Network Safety Analysis
SFA	- Stochastic Frontier Approach
STRADA	- Swedish Traffic Accident Data Acquisition
TCT	- Traffic Conflict Technique
TRID	- Transport Research International Documentation
TTC	- Time-to-Collision
UNECE	- UN Economic Commission for Europe
VRU	- Vulnerable Road User
VBB	- Vehicle Black Box
WGS84	- World Geodetic System 1984
WHO	- World Health Organization
WP	- Work Package
WUT	- Warsaw University of Technology

# 1. Executive Summary

This report presents the results of a review of the study methods related to vulnerable road user safety that are used today and aims to link accident causation factors to VRU accident risk. The review covered the following categories of study methods: epidemiological studies based on accident and injury data; in-depth accident investigations; naturalistic driving studies; behavioural observations; traffic conflict studies; and self-reported accident studies. The review consisted of two parts: a systematic literature review and a questionnaire survey. A scoping review of the available scientific literature was conducted that covered four types of safety-related studies: naturalistic driving studies, behavioural observations, traffic conflict studies and self-reported accidents – areas that have been the focus of most of the recent research effort. In total, over one thousand publications were included in the scoping reviews. Full reports on the results of the four reviews are published as separate parts of this report.

Questionnaires were sent out to all InDeV partners to obtain information and a critical appraisal of the currently used study methods related to VRU safety. The survey results show that epidemiological studies based on accident and injury records form the basis of traffic safety assessment in every partner country. General accident reports help identify the time trends of accident occurrence and to compare the safety situation among countries and cities. Benchmarking between countries can help monitor progress towards the targets for traffic safety improvement and to assess the relative importance of problems. While the exact causes of accidents cannot be determined, the contributing factors can often be deduced. Identification of dangerous locations is performed using black spot analysis and network safety analysis. Both are important and useful for VRU safety assessment – black spots identify dangerous intersections and road crossings and network analysis identifies dangerous road links. The exposure measures used should be appropriate for VRUs and include pedestrian and bicycle volumes in addition to motorised traffic volumes.

The European CARE accident database was set up with a comprehensive structure and scope of information as defined in the CADaS glossary. The advantage of using CARE for safety research is that it is a disaggregate database, i.e. detailed cross-classification analyses can be made. However, not all countries provide all data according to the guidelines. The possibilities of safety analysis would be greatly improved if the guidelines were followed by all countries.

The literature review and survey on accident data quality conducted among InDeV partners show that despite efforts to harmonise the definitions of injury road accidents and their severity at the European level, differences exist both in the definitions and their interpretation. Even in the case of the fundamental definition of “road accident/injury accident”, the definitions used by some countries differ slightly from the CARE database standard. Data on fatalities are quite comparable between the InDeV partner countries: the 30-day road accident fatality definition is used. CARE definitions of injury severity are applied in only 3 out of 7 countries. There are also considerable differences among countries in terms of accident data collection and data verification procedures, which results in varying levels of underreporting of the different accident categories. In all InDeV partner countries, accident data are collected on a paper form and transferred to a computer database. The information on injury severity is gathered from ambulances, hospitals or the road users involved in the accidents. This information is verified based

on hospital information after a period ranging between 30 days and one year. In Sweden, data verification is performed automatically via the STRADA database, which links the police database with hospital registries. In almost all InDeV partner countries, data quality control is carried out after the data is transferred to a computer database. Cross-checking for consistency of information is used in some countries.

The in-depth investigation study is a good tool to examine accident scenarios and to find accident/injury contributing factors. However, valid knowledge can be obtained only if the number of cases, the period of time and the number of variables are sufficient. The comparison of different in-depth databases is difficult due to the application of different investigation criteria. The drawbacks include the study's retrospective view (compared to video-documented crashes) and the introduction of uncertainties in the process of data collection and encoding due to interpretation. In general, in-depth investigations are time- and cost-consuming, but highly effective in terms of the knowledge that can be gained from the investigation of individual accidents.

A review of naturalistic studies shows that this method can provide important insights into the understanding of the causation factors of accidents with VRUs. These studies can also be used to identify the locations where vulnerable road users are involved in accidents. So far, naturalistic data from VRUs have mostly been collected via equipped motorcycles or bicycles. Accidents and critical situations were detected based on kinematic triggers such as acceleration, rotation, etc. only in few cases. The potential for such detection was shown through studies of falls among the elderly. In order to examine accident causation it is necessary to collect additional information from road users, e.g. via a questionnaire that is sent to them after the accident. Another limitation of naturalistic studies is that data is typically collected from only one of the road users involved in the accident.

Behavioural observation studies are an important tool to understand the causes of accidents that involve VRUs because such studies provide insight into the situational and behavioural processes that lead to an accident. The survey that was carried out among partner countries provides an overview of the behavioural observation studies conducted there and identifies the topics that were addressed. A review of about 600 publications on road user behavioural observation studies shows that these are mainly used to monitor traffic events and to evaluate safety improvement measures. Behavioural observations seem very useful to examine how road users interact with each other or navigate through a crossing. Most studies involving VRUs were found to take place at some kind of crossing. Many studies were not adequately documented with respect to the observation periods and sample size. Certain topics were found not to have been the subject of much research, for example powered two-wheelers.

Traffic conflict studies are a type of behavioural observations which focus on safety-critical traffic events. The observation and analysis of traffic conflicts as surrogates for accidents has two main advantages: conflicts occur more frequently than accidents and observing them allows better understanding of the processes that may lead to accidents. The basic theory behind the use of traffic conflicts for safety analysis is the assumption of continuity in the severity of all events that take place in a traffic environment. There is a relationship between the severity and frequency of events, i.e. injury accidents are rare, while normal interactions are frequent. As severe traffic conflicts are close to real accidents in terms of the process of their development, observations of these conflicts can be used to understand the mechanism of accident development. The scoping review of literature shows an increase in the use of traffic conflict studies, in particular those that

use video analysis tools. The review also shows that there is a considerable number of validation studies on the relationship between conflicts and accidents, although most of these are quite old. Recently, new indicators with high potential have been suggested and there is a clear need for new validation studies that use video analysis tools. Emerging technologies open up new possibilities for the wider use of site-based traffic conflict studies. Nevertheless, a combination of conflict studies with other types of behavioural observations and accident analyses provides better insight into road safety problems.

The self-reported accident study method is highly relevant as it allows to gain knowledge on accident causation as well as the events that led to the accident. This method allows to obtain information on accidents that are not reported to the police, thus making it possible to estimate the level of underreporting. A systematic literature review shows that the practice for collecting self-reported accidents varies and most studies focus on car accidents. Self-reported accidents are used to evaluate safety measures, estimate the total number of accidents and to identify accident causation factors. Self-reported accident data are typically collected via online or paper questionnaires where respondents are asked to recall their accidents from a period ranging from one month to 5 years. A survey among InDeV partners showed that the use of the self-reporting method is not very common in their countries. While the method has relevance and seems a promising way of gaining knowledge on accident causation factors, the level of underreporting and socioeconomic factors, it is still quite untested. Careful consideration of methodological challenges and issues is required before conclusions on underreporting can be drawn based on self-reports alone.

Based on the review of road safety analysis methods, several general recommendations for improving VRU safety assessment are put forward. The standard definition of injury accidents adopted by the EC (CARE database) covers virtually all traffic accidents involving VRUs with the exception of single pedestrian accidents (falls). It is recommendable to include this additional category in VRU safety assessment studies as well as in economic calculations of total accident costs.

There is no clear definition of what constitutes an “injury” suffered by the victims of a road accident. Since the occurrence of an “injury” is one of the preconditions for the classification of a collision as an accident, there is a grey area between “slight injury” and “property damage only” accidents. The term “injury” should be defined for the sake of consistency. The determination of injury severity in road accident victims poses considerable challenges. The EC’s current efforts have not yet produced a reliable system of reporting the numbers of the severely injured in different countries. The proposed criterion of serious injury based on MAIS3+ levels is difficult to implement and has its disadvantages.

There is a need to harmonise not just the definitions of injury and its severity but also the procedures for accident data collection and verification among the EU countries. A review of the current procedures should be conducted and common guidelines worked out. However, this type of study is beyond the scope of the InDeV project and should be undertaken by the EC.

One way of improving police accident data quality is to verify these data using hospital/medical records. When comparing police-reported numbers of traffic accident victims with hospital data, one should bear in mind the differences in definitions and the scope of available information. Guidelines for the integration of police and medical data based on best practices (e.g. the STRADA system in Sweden) would be very useful.

Overall, there is a lack of appropriate exposure measures for the calculation of safety indicators for VRUs. One way to solve this problem is to use the local population numbers as exposure for the calculation and comparison of fatality rates in cities and regions. When analysing and identifying black spots at intersections and road crossings, pedestrian and bicycle volumes should be used in addition to motorised traffic volumes.

In an effort to obtain improved results, an integrated approach to VRU safety assessment has been proposed. The study methods discussed in this report differ in terms of the approach, data collection method and the specific aims. The various methods often complement each other in terms of the results that can be achieved with a specific objective in mind. This complementarity is presented in the form of a matrix. Seven specific aims are listed against six assessment methods (see Table 10.2). The matrix should help to decide which combination of methods to use in order to achieve a specific objective. The use of a mix of different methods can often produce more accurate, more comprehensive and faster assessments.

## 2. Introduction

### 2.1. Objective and scope

The report entitled “Review of current study methods for VRU safety and recommendation for improvements” is the main deliverable of Work Package 2 (WP2) within the InDeV project. It is the product of Task 2.1 which addresses the following objectives of WP2: (a) to critically review the usefulness of the methods currently used in accident causation studies with relevance to vulnerable road users (VRUs) and (b) to assess the quality and availability of road accident data with relevance to VRU safety problems. The report also presents the results of Task 2.4, which aims to identify the gaps in the currently used methodology and data.

Task 2.1 first critically reviews the quality and usefulness of the methods used today (i.e. within the last ten years) in accident causation studies, with the aim of linking accident causation factors to VRU accident risk. The quality and availability of data with relevance to VRU safety problems are also documented and critically assessed. National and regional differences in both of the study methods used as well as in accident and injury datasets are given special attention. The following categories of the current study methods are included in the review and described in subsequent chapters:

- Epidemiological studies based on accident and injury data;
- In-depth accident investigations;
- Naturalistic driving studies;
- Behavioural observations;
- Traffic conflict studies;
- Self-reported accidents.

The review of the existing traffic safety study methods (objective a) was based on the following two activities which were carried out in parallel:

- A systematic and thorough review of the existing scientific literature (mainly peer-reviewed literature) which was conducted for each of the study method categories. The literature review identified when and how these methods were used, with an emphasis on their usefulness related to VRU safety.
- A questionnaire survey on the use of the existing study methods. Evaluation questionnaires were sent out to all InDeV partners in order to obtain information and a critical appraisal of the currently used study methods related to VRU safety. The main question was: to what extent can the existing methods help to identify the causes of accidents with VRUs?

A description of the state of the art (literature review, previous projects) and the summaries of the findings of the questionnaire survey in the respective study categories are presented in Chapter 3 and Chapters 5-9 of this report.

A second round of questionnaire surveys concerning the quality of accident data with relevance to VRU safety problems (objective b) was conducted in the later part of Task 2.1. As the accident data quality issues are closely related to epidemiological studies (Chapter 3), the survey results together with a review of accident data sources are presented in Chapter 4. The review examines international data sources (CARE, IRTAD, WHO) of accident and injury data, risk exposure data as well as safety performance



indicators. It builds on the results of previous projects (e.g. SafetyNet), focusing on the issues that are specific to VRUs. The main objectives of this review are:

- to determine the problems with VRU accident data and the gaps in the existing databases;
- to propose the possible measures to improve the quality of accident data that are important from the point of view of VRU safety.

## **2.2. InDeV questionnaire surveys**

As part of Task 2.1, questionnaires entitled “Review of the current accident study methods and data” were prepared and sent out to all InDeV partners. The complete questionnaire is attached as Appendix 1 of this report. The objective of the questionnaire survey was to critically review the usefulness of the methods currently used in accident causation studies with relevance to VRUs.

The questionnaire consisted of a set of forms, A to F, where each form corresponded to a different study category. The forms were meant to be filled out for each InDeV partner country and to present the situation in the entire country rather than to include only studies carried out by the InDeV partner institutions. The InDeV partner countries include: Belgium, Canada, Denmark, Germany, the Netherlands, Poland, Spain and Sweden. The forms were to be filled out by the InDeV partners with input by external experts, if necessary.

The questionnaire comprised the following forms:

- A.1 Epidemiological studies based on accident data – method assessment: GENERAL ACCIDENT REPORT
- A.2 Epidemiological studies based on accident data – method assessment: BLACK SPOT ANALYSIS
- A.3 Epidemiological studies based on accident data – method assessment: ROAD NETWORK SAFETY ANALYSIS
- B.1 In-depth accident investigations
- C.1 Naturalistic driving studies
- D.1 Behavioural observation studies
- E.1 Studies based on surrogate safety measures – method assessment
- E.2 Studies based on surrogate safety measures – publications
- F.1 Self-reported accidents

An instruction was provided to help in filling out the forms. If more than one method was used in a particular category in a particular country, the most useful one from the point of view of VRU safety was to be described. However, if more than one method per category was described, then the relevant forms were to be duplicated. If a certain type of study (e.g. self-reported accidents) had never been conducted in a country, “not applicable” was to be entered in the relevant form.

At the beginning of each part (A to F), detailed guidelines were provided as there might be differences between the parts concerning the number of studies/methods that were to be reported, the time period, etc.

The number of forms filled in by each InDeV partner country is presented in Table 2.1.

**Table 2.1: Number of forms filled in by InDeV partner countries**

Country	Survey responses (forms):								
	A.1	A.2	A.3	B.1	C.1	D.1	E.1	E.2	F.1
<b>Belgium (HU)</b>	3	1	1	1	0	0	1	4	0
<b>Canada (PM)</b>	1	1	1	0	0	0	0	0	0
<b>Denmark (AAU)</b>	1	2	3	2	1	3	3	11	3
<b>Germany (BAST)</b>	1	1	1	1	1	4	1	6	1
<b>The Netherlands (TNO)</b>	1	1	0	1	1	0	1	2	1
<b>Poland (WUT)</b>	2	1	1	1	0	1	2	2	0
<b>Spain (INTRA)</b>	6	2	1	3	1	6	0	1	2
<b>Sweden (LU)</b>	2	0	1	1	2	16	0	0	2

InDeV analyses of accident data conducted as part of other WP2 tasks indicate that the quality and reliability of traffic accident data varies across countries. Differences in fatality and injury rates between the countries are very difficult to explain and the proportions of victims killed, severely injured and slightly injured vary widely for no apparent reason. This limits the usefulness of accident data for the assessment of the safety of vulnerable road users.

A second questionnaire entitled “Quality of road accident data” was prepared and sent out to all InDeV partners. The complete questionnaire is attached as Appendix 2 to this report. The objective of this questionnaire survey was to critically review the scope and methods of road accident data collection and the methods of data verification. Hopefully, this will help to explain some of the differences and inconsistencies in VRU fatality and injury rates among countries.

## 3. Epidemiological studies based on accident data

### 3.1. Description of epidemiological studies

Epidemiological studies regard road accidents in the same way as diseases and investigate the distributions and frequencies of their occurrence. Epidemiological studies are based on information from national or regional accident databases. In most countries, road accident data are collected and maintained by the police, and in some countries also by hospitals (Denmark, the Netherlands, Greece, Sweden, Spain, Slovenia) or by governmental organizations (the Netherlands, Belgium, Portugal, Hungary) (ETSC, 2006). The Swedish GIS-based system, STRADA<sup>1</sup> (Swedish Traffic Accident Data Acquisition) contains information about accidents from both the police and hospitals. A data linkage project using data from various sources, such as emergency hospital and ambulance services, fire services, forensic services, mortality records, and information from insurance companies has been developed in the Netherlands (IRTAD, 2010).

There are several international accident databases:

- CARE (Community Road Accident Database for Europe)
- FARS (Fatal Accident Reporting System) – USA
- IRTAD (International Road Traffic and Accident Database)
- IRF (International Road Federation) World Road Statistics
- UNECE (Economic Commission for Europe)
- The WHO (World Health Organization) Mortality Database

CARE was created by the European Commission in 1993 with the aim of identifying road safety problems and improving road safety in the European road network. It is based on police accident records from EU countries<sup>2</sup>.

There are several problems with analyses based on international records. One of the most important barriers of such studies is the incompatibility of many definitions between countries, for example the levels of injury severity (slight, serious injury). In fact, only fatal injuries can be reliably compared between countries. The problem was thoroughly discussed in ETSC (2006). The definition criteria used for injured persons in European countries are given in Table 3.1.

Hospital databases use medical injury scales to define injury severity (IRTAD, 2010):

- *the Abbreviated Injury Scale (AIS) describes the severity of injury (1 Minor, 2 Moderate, 3 Serious, 4 Severe, 5 Critical, 6 Unsurvivable) for each of nine regions of the body: 1 Head, 2 Face, 3 Neck, 4 Thorax, 5 Abdomen, 6 Spine, 7 Upper Extremity, 8 Lower Extremity, 9 External and other.*
- *the Maximum Abbreviated Injury Scale (MAIS): the maximum of the AIS scores for each region of the body.*
- *Injury Severity Score (ISS): an overall score for patients with multiple injuries. Each injury is assigned an AIS and is allocated to one of six body regions (Head,*

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<sup>1</sup> The STRADA system does not cover all of Sweden, three counties have not joined it yet (IRTAD, 2010).

<sup>2</sup> CARE and other international accident databases are discussed further in Chapter 4.

*Face, Chest, Abdomen, Extremities (including Pelvis), External). Only the highest AIS score in each body region is used. The three most severely injured body regions have their score squared and added together to produce the ISS score. ISS was developed to predict mortality.*

- *New Injury Severity Score (NISS) is computed as the simple sum of squares of the three most severe AIS injuries, regardless of body region.*

**Table 3.1: Criteria used to determine the severity of accident victims’ injuries**

Countries	Definitions of seriously injured					Definitions of slightly injured					Criteria of injury degree
	Hospitalised	Hospitalised>24 hours	Hospitalised>7 days +serious injuries	Hospitalised+serious injuries	Serious injuries Disability>24 hours, or very serious injuries	Other than seriously injured	Slight injuries	Not hospitalised	Hospitalised<7 days +slight injuries	Not known	
Austria					✓					✓	Disability+injuries
Belgium		✓				✓					Hospitalisation
Cyprus		✓					✓				Hospitalisation
Czech Republic											-
Denmark				✓				✓			Hospitalisation+injuries
Finland											-
France		✓					✓				Hospitalisation
Germany		✓					✓				Hospitalisation
Greece		✓					✓				Hospitalisation
Hungary				✓				✓			Hospitalisation+injuries
Ireland				✓				✓			Hospitalisation+injuries
Italy				✓				✓			Hospitalisation+injuries
Latvia		✓					✓				Hospitalisation
Lithuania											-
Malta					✓			✓			Injuries
Netherlands		✓					✓				Hospitalisation
Poland			✓						✓		Hospitalisation+injuries
Portugal	✓								✓		Hospitalisation
Slovenia		✓						✓			Hospitalisation+injuries
Spain		✓					✓				Hospitalisation
Sweden	✓						✓				Hospitalisation
United Kingdom				✓				✓			Hospitalisation+injuries
Total	2	9	1	5	1	1	9	7	1	1	1

source: (ETSC, 2006)

IRTAD (2010) proposes to define a serious injury as one assessed at level 3 or more on the Maximum Abbreviated Injury Scale, i.e. MAIS3+. The disability-adjusted life year (DALY), expressed as the number of years lost due to ill-health, disability or early death could be used as an alternative to MAIS3+ because it conveys additional information about the influence of an accident on the future life of the person involved in the accident.

The lack of exposure data is another problem that limits the development of safety indicators. Exposure can be defined simply as the quantification of “being in a situation which has some risk of involvement in a road traffic accident” (Wolfe, 1982). Demographic information, such as population size or road network length, and exposure data, such as veh-km, person-km, as well as the travel shares of non-motorised modes are related to accident risk and therefore would be useful for calculating risk levels. These data are often difficult to gather, especially for VRU travel modes. Other factors used to interpret accident data include: average speed, traffic flow, congestion, road geometry, quality of infrastructure, age and gender of victims as well as the age and quality of the vehicle fleet. The attributes of the road as well as of the intersection may also be added to this list.

The relationship between accident risk and exposure was examined by Schepers et al. (2014b). The study presents a conceptual road safety framework that comprises the interacting factors of exposure to risk (volumes and distribution of traffic over time and space) and risk (crash and injury risk). The authors used the example of cycling to demonstrate the application of the model, linking cycling safety to land use and infrastructure.

## 3.2. Overview of the method’s applications

### 3.2.1. Types of traffic accident analysis reports

Analyses of traffic safety based on police records of traffic accidents and injuries can take many forms. Epidemiological studies aim to provide a diagnosis of the road safety situation of an area. If diagnostic reports are compiled on a regular basis (e.g. every year), the presumptive aim is to monitor the traffic safety situation. If, in addition to the safety assessment, safety improvements are proposed, then the report goes beyond diagnosis and becomes part of a safety management plan. However, this matter is outside of the scope of the InDeV project which focuses on the assessment of safety (and the causes of unsafety).

For the purpose of the current review, three types of analyses can be distinguished, according to the scope of the resulting report:

- **General road safety report** is defined as the result of any accident frequency analysis in a large spatial unit (country, region, city) that presents average accident statistics, charts, distributions, trends and traffic safety indicators without identifying high-risk locations.
- **Black spot analysis** is defined as a method of identifying high-risk accident locations (intersections or short road sections – less than 0.5 km long), i.e. locations with a high concentration of accidents. Black spot analysis can be a part of the Black Spot Management Programme.
- **Road network safety analysis** is defined as a method called “ranking of high accident concentration sections”. It is a method to identify, analyse and rank sections of the road network where a large number of accidents occurred in proportion to the traffic flow or road length. Road network safety analysis can be a part of the Road Network Safety Management process.

In addition to the studies listed above, a separate category of research-type epidemiological studies can also be distinguished. These involve statistical analyses and modelling using accident frequency data with the aim of investigating accident causation and identifying contributing factors and circumstances. These type of studies were covered in the literature review but not in the questionnaire survey.

### 3.2.2. General traffic safety report

General traffic safety reports are routinely prepared by road authorities or the police in most countries and regions at regular time intervals, typically every year. They provide an overview of the road safety situation in the area under consideration using descriptive statistics. The reports also identify time trends and specific problems, such as the situation of VRUs. These studies are based on police accident records and therefore the results are biased due to the well-known problems with police data, namely underreporting and inaccurate injury severity classification (see e.g. Elvik et al., 2009).

However, general traffic safety reports provide an overview of the road safety situation and should form the basis of any safety assessment.

Analyses of road safety based on statistical data have been conducted for many years. Hagenzieker et al. (2014) described the development of such studies from the 1900s to 2010. The authors identified various trends in road safety research, such as the focus on a single cause of an accident (road user, vehicle, road) or on the combination of factors. From the 2000s, road accidents are considered to be the result of the entire road system: the researcher should take into account multiple factors that can contribute to the occurrence of an accident. Shen et al. (2015) emphasized the importance of comparing countries in terms of road safety. The authors also pointed to the limitations of benchmarking studies, such as those concerning the socioeconomic conditions, motorization level and road safety experiences which vary from country to country. According to Shen et al. (2015), benchmarking studies should be carried out only between similar countries that are at the same level of development.

As road unsafety is a major global problem, several international comparative studies have been completed recently. The IRTAD Road Safety Annual Report published by the International Traffic Safety Data is an international study on road safety that focuses on road traffic mortalities, e.g. IRTAD (2015). Other large-scale projects that address VRU traffic safety issues include:

- Road accident data in the enlarged European Union (ETSC, 2006)
- Country Reports on Road Safety Performance (OECD, 2006)
- WHO “Global status report on road safety 2013” (WHO, 2013)

The WHO 2013 report states that in view of increasing numbers of motorized vehicles, there should be higher awareness about the risk of pedestrian and PTW casualties and there is still a need for additional criteria to develop policies that ensure the safety of vulnerable road users. According to the WHO, pedestrians and cyclists are especially exposed to a higher risk of injury and fatality in road crashes because of excessive vehicle speeds. Speed is one of the main factors that contribute to pedestrian accidents. The New York City Department of Transportation studies of 2010 showed that speeding led to 21% of pedestrian accidents (WHO, 2013). The relationship of accident frequency and speed should be given particular attention in epidemiological studies.

Over the years, many epidemiological studies relating to VRU safety have been conducted. These are mostly based on national accident databases maintained by the police. Many of these studies pointed to the limitations of analyses of large accident databases, which usually do not contain detailed information about accidents and are only useful for analyses of the trends in road safety (Chung and Chang, 2015; Dubos et al., 2016; Muller and Haustein, 2016; Twisk and Reurings, 2013).

Several techniques and statistical tools are used for epidemiological analysis: tables and graphs, ratio analysis, multiple ratio analysis, statistical methods using ordinary least squares (OLS) (e.g. multiple regression), frontier analysis such as data envelopment analysis (DEA) and the stochastic frontier approach (SFA). A common safety indicator (CI – composite indicator or index) should be the output of the analysis. CI is a combination of a number of individual indicators (Shen et al., 2015). The idea of a composite road safety index is relatively new and has been developed by Al-haji (2007) and Hermans et al. (2008) in the SUNflowerNext study and by de Leur and Sayed (2002).

Within the framework of an EC-funded project called SaferBrain, described by Tripodi et al. (2012), a DSS (Decision Support System) application was developed to aid in the analysis of accidents involving VRUs. DSS is a GIS-based system aimed at improving VRU safety that helps to analyse databases and identify the causes of an accident. There are two possible approaches: the corrective and preventive approach. In the first case, the system identifies the countermeasures for the possible accident causes and provides suggestions for corrective actions aimed at reducing the likelihood of an accident. In the preventive approach, the system analyses the infrastructure and eliminates the factors that can contribute to an accident. The application uses photographic maps (e.g. Google Earth) to visualise information about crashes.

### 3.2.3. Black spot analysis

Black spot analysis (or more generally, black spot management, BSM) has a long tradition in traffic safety studies performed by road administration authorities. In most cases, the identification of black spot locations (or crash hotspot locations, high-risk locations) is the first and very important step of the safety management process (Qu and Meng, 2014). This type of analysis usually involves the identification, analysis and treatment of black spots (including before-and-after studies). However, both the current approaches and the quality of BSM differ from country to country. There is no single definition of a black spot and there is no single method of its treatment. Accident black spots are usually defined as road locations with a (relatively) high accident potential or locations with a higher expected number of accidents than other similar locations (intersections or short road sections – less than 0.5 km long).

Fuller definitions of black spots used in some European countries were presented in the Ripcord report (Elvik and Sørensen, 2007) – Best Practice Guidelines on Black Spot Management and Safety Analysis of Road Networks:

- Austria: A black spot is any location that satisfies one of the following two criteria:
  1. Three or more similar injury accidents within three years and a risk coefficient  $R_K$  of at least 0.8. The risk coefficient is calculated as follows:

$$R_K = \frac{U}{0.5 + 7 \times 10^{-5} \times AADT}, \text{ where:}$$

U = number of injury accidents during three years

AADT = Annual Average Daily Traffic

2. Five or more accidents (including property damage only) of similar type during one year. Property damage accidents have stopped being recorded since 1995, hence the identification of black spots relies primarily on the first definition. To identify black spots, a sliding window with a length of 250 metres is applied. The window is moved along the road and the risk coefficient is calculated for each of its positions.
- Denmark: “The identification of black spots relies on a fairly detailed classification of the road system into various types of road sections and various types of intersections (Vistisen 2002, Overgaard Madsen 2005 as cited in Ripcord-Iserest, 2005). To identify a black spot, a test based on the Poisson distribution is used. The minimum number of accidents for a site to be considered as black is four accidents recorded during a period of five years. The level of significance used in the statistical test is 5%. Thus, suppose the normal number of accidents for a location has been estimated as 2.8 during five years and that five accidents have been recorded. Applying the Poisson distribution, the probability of observing at least five accidents given that the mean number is 2.8 can be

calculated to 0.152, which means that this location would not be classified as black. As far as road sections are concerned, black sections are identified by means of a sliding window approach. The size of the window varies, depending on the normal number of accidents for a section.”

- Flanders: The following definition of a black spot is applied (Geurts, 2006 as cited in Ripcord-Iserest, 2005), based on police reports of accidents: Each site where in the last three years three or more accidents have occurred, is selected. Then, a site is considered to be black when its score for priority (S), calculated using the following formula, equals 15 or more:

$$S = LI + 3 \cdot SI + 5 \cdot DI, \text{ where}$$

LI = total number of slight injuries

SI = total number of serious injuries

DI = total number of fatal injuries

A sliding window with a length of 100 metres is applied to identify black spots.

- Hungary: Two definitions of black spots are used. Outside built-up areas, a black spot is defined as a location where at least four accidents have been recorded during three years on a road section no longer than 1000 metres. In built-up areas, a black spot is defined as a location where at least four accidents have been recorded in three years on a road section no longer than 100 metres. Black spots are searched for using the sliding window approach. The window is either 1000 metres or 100 metres wide.
- Norway: A black spot is any location with a length of not more than 100 metres where at least four injury accidents have been recorded in the last five years. A black section is any road section with a length of not more than 1000 metres where at least 10 injury accidents have been recorded during the last five years. The period used to identify black spots or black sections was recently extended from 4 to 5 years (Statens vegvesen, 2006 as cited in Ripcord-Iserest, 2005). Black spots and black sections are identified by applying a sliding window, which is fitted to the location of the accidents. Black sections will often consist of several black spots that are located near one another.
- Portugal: Two definitions of black spots are currently used in Portugal: one was developed by the Traffic Directorate (DGV) and the other was proposed by LNEC. According to DGV’s definition, a black spot is a road section with a maximum length of 200 metres, with five or more accidents and a severity indicator greater than 20, in the year of analysis. The severity index is calculated using the following weighted sum:  
 $100 \cdot \text{number of fatalities} + 10 \cdot \text{number of serious injuries} + \text{Number of slight injuries}.$

A sliding window that is moved along the road is used for detection.

- Switzerland: A black spot is defined as any location where the recorded number of accidents is “well above” the mean number of accidents at comparable sites. Comparable sites are defined by classifying the road system into various types of sections and intersections. For each group, accident rates are estimated. Based on the accident rates, critical values have been developed for the minimum recorded number of accidents during a period of two years for a site to be identified as a black spot.

BSM has been accepted for a long time as an effective way of preventing road accidents. However some researchers, e.g. Elvik (1997) and Rossi et al. (2004) showed that many simple before-and-after studies do not take account of any confounding factors that might



affect the number of accidents. The authors noted that it was difficult to prove that treating a black spot could really reduce the number of accidents at the black spot location and in the surrounding area. Boyle and Wright (1984) proposed the hypothesis that “where an accident black spot is treated, drivers will be subjected to fewer “near-misses” at that site, and consequently will be less aware of the need for caution. This reduced awareness may persist for some distance downstream, and consequently the risk of an accident in the area surrounding the blackspot may be increased”.

In some countries with the best traffic safety record (Finland, Sweden, Great Britain), the BSM has been replaced with Network Safety Management (NSM) because all black spots were identified and treated. In other countries such as Norway, Denmark and Germany, which have also used BSM for many years, the black spot analysis is supplemented by NSM. There are also some European countries that have only performed BSM for a few years or are planning to start performing BSM in the public road network (e.g. Italy, Greece).

Elvik (2007) described a state-of-the-art approach to road accident black spot management and proposed a theoretical definition of a black spot:

*A road accident black spot is any location that has a higher expected number of accidents than other similar locations as a result of a local risk factor.*

The main conclusions of this study included the following:

- Black spots should be identified in terms of the expected (not recorded) number of accidents and by reference to a clearly defined population of sites (whose members can in principle be enumerated).
- The use of a sliding window approach to identify black spots is discouraged as it artificially inflates variation in accident counts.
- To estimate the expected number of accidents, multivariate accident prediction models should be developed (combining the recorded number of accidents with the model estimated for the site produces the best estimate).
- The evaluation of the effects of black spot treatment should employ the empirical Bayes before-and-after design.

Montella (2010) used five years of crash data from the Italian A16 motorway and compared the performance of various hotspot identification (HSID) methods against four robust and informative quantitative evaluation criteria. The following HSID methods were compared:

- Crash frequency (CF),
- Equivalent property damage only (EPDO) crash frequency,
- Crash rate (CR),
- Proportion method (P),
- Empirical Bayes estimate of total-crash frequency (EB),
- Empirical Bayes estimate of severe-crash frequency (EBs),
- Potential for improvement (PFI).

These methods were compared using:

- The site consistency test,
- The method consistency test,
- The total rank differences test,

- The total score test.

The test results showed that EB is the most consistent and reliable method to identify priority investigation locations. The EB estimate of total crashes performed better than the EB estimate of severe crashes. The CF method performed better than other HSID methods. The PFI and EPDO methods were largely inconsistent. The proportion method (P) performed the worst in all of the tests. These results were consistent with the results of previous studies (Elvik, 2008, 2007), (Cheng and Washington, 2008; Persaud et al., 1999 as cited in Montella, 2010).

### 3.2.4. Road network safety analysis

In order to identify the safety deficits in a road network, it is necessary to perform section-specific accident analyses – also named as Network Safety Management (NSM). The EU prescribes Network Safety Management as part of a comprehensive system of road infrastructure safety management (*Directive 2008/96/EC of the European Parliament and of the Council, 2008*). These analyses form the basis for road safety improvements at all levels. However, the standards of road network safety analyses in particular EU countries differ considerably. Another problem is that an important part of the analyses do not take vulnerable road users into account.

In a review of international publications about NSM, Sørensen (2006) as cited in (Ripcord-Iserest (2005) counted more than 20 different terms. The terms used to rate road segments are divided into negative terms, e.g. hazardous road sections, dangerous roads or problem roads, more neutral terms, e.g. grey or red road sections, accident-prone locations, one-star roads or roads for safety investigation and finally some positive terms, e.g. roads with safety potential and promising roads. The most common and frequently used term for road sections identified in NSM was hazardous road section. A hazardous road section can be defined as any section at which the site-specific expected or the observed number of accidents is higher than for similar sections, due to local and section-based risk factors present at the site. In addition, this definition should include not only the number of accidents but also their severity.

Elvik (2008) compared five techniques of road network safety analysis:

- recording the number of accidents during a specific period,
- observing the accident rate (per million veh-kms) during a specific period,
- combining a critical count of accidents and an accident rate above normal,
- using the empirical Bayes estimate of the expected number of accidents,
- determining the size of the contribution of presumably local risk factors to the empirical Bayes estimate of the expected number of accidents at each location.

He concluded that hazardous road locations are most reliably identified by applying the empirical Bayes technique. This method combines the accident count at a specific site in the most recent years with an estimate of the expected annual number of accidents based on the accident history of similar sites.

The EuroRAP programme (Elvik and Sørensen, 2007; EuroRAP, 2015) has developed four standardised protocols for showing the safety level of a road, providing a common language that everyone can speak. In low- and middle-income countries, the EuroRAP methodology provides a structure to measure and manage road safety risk. The protocols include: Risk Mapping, Performance Tracking, Star Ratings and Safer Road Investment Plans. Risk Mapping is based on real crash and traffic flow data and therefore can be

considered a variation of network safety analysis. Colour-coded maps show the safety performance of each road by measuring and mapping accident density, i.e. the rate at which road users are being killed or seriously injured. The exposure measures used include: km of road length, km travelled, costs per road km and per km travelled, and the potential savings per road km and per km travelled. Risk is depicted in colour-coded bands from high (black), through medium-high (red), medium (orange), low-medium (yellow) to low (green). Performance Tracking uses the data compiled for consecutive risk maps to assess how risk on the network as a whole, or on individual road sections, has changed over time. It is a way of measuring success and the outcome of investment in safer roads and can be used as an objective measure by governments and funding agencies. Star Ratings are based on road inspection data and provide a simple and objective measure of the level of safety “built-in” to the roads for vehicle occupants, motorcyclists, pedestrians and bicyclists. 5-star roads (green) are the safest, and 1-star (black) are the least safe. Safer Road Investment Plans identify ways in which fatal and serious injuries can be improved in a cost-effective way. These plans are produced in three stages: (a) Fatality and injury estimation based on Star Ratings and traffic volumes, (b) Trigger Improvements, in which options for improvement for each road section are tested for their suitability and potential to reduce deaths and injuries and (c) Economic Analysis, in which each improvement is assessed against the project’s economic effectiveness criteria.

In accordance with the abovementioned definition of hazardous road sections used by NSP, i.e. “any section at which the site-specific expected or the observed number of accidents is higher than for similar sections”, it is worth noting that according to the EuroRAP classification this includes roads marked on Risk Maps as high (black) and medium-high risk (red).

There are also similar road assessment programs in other countries: usRAP (USA), CanRAP (Canada, feasibility study stage) and AusRAP (Australia). The methodologies applied are based on EuroRAP and are adjusted for local conditions. In the Netherlands, besides the application of EuroRAP, the ProMeV program has recently been developed: Measuring traffic safety proactively (Aarts et al., 2014). This method has been developed to prioritize location-specific traffic safety problems, without the need for accident statistics. This approach uses Safety Performance Indicators and has been developed to make policy choices for the layout of roads and the road network. ProMeV not only contains methods for the analysis of infrastructural problems, but also of hazardous traffic behaviour that is evoked by the design of the road or road network. At present, pilots are being performed based on this method.

### **3.2.5. Research-type epidemiological studies**

A review of road safety theories such as engineering theory (engineering, road design and vehicle-related factors), human theory (human behaviour-related factors), physiological theory, economic theory (the relationship between economic development and road safety performance) and public health theory (improvements in medical services and technology could improve road safety) was compiled by Wang et al. (2013). The impact of laws and legislations was examined by Bjørnskau and Elvik (1992). A game-theoretic model was used in their study to analyse the influence of traffic law enforcement on road user behaviour and the resulting number of road accidents. One of the conclusions was that stricter penalties did not affect road user behaviour and that

implementing automatic traffic surveillance techniques would be one example of better solutions to reduce the number of accidents.

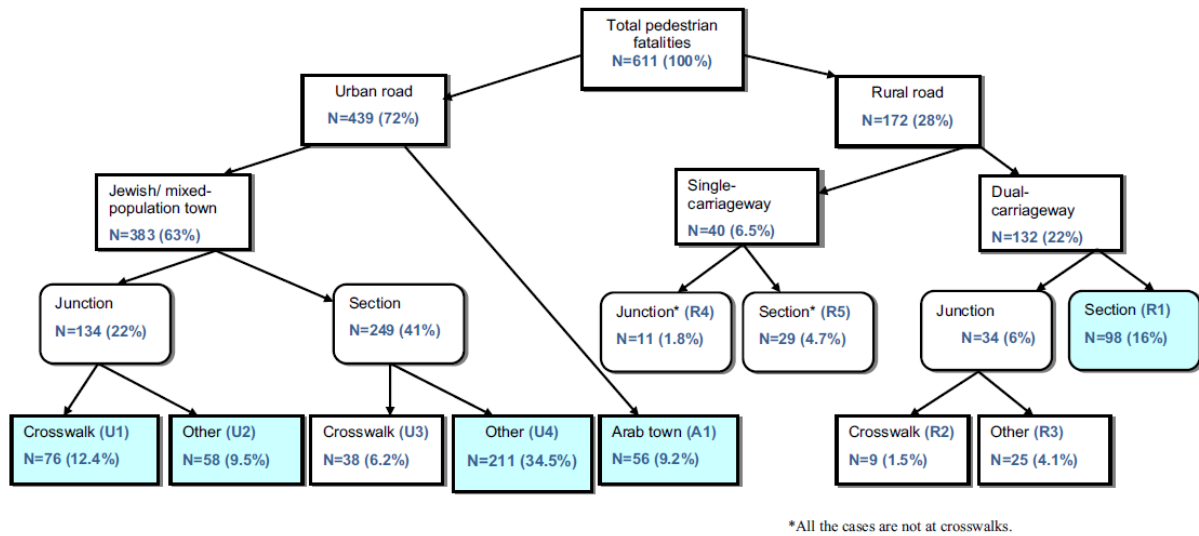
Lord and Mannering (2010) conducted a review of the methodological alternatives for the statistical analysis of crash frequency data with the aim of understanding various factors that affect the likelihood of an accident at a specific location. The authors identified the key issues associated with crash frequency data and presented the relative advantages of particular approaches used to address these problems. A similar review of methodological issues that focused on analyses of accident injury severity was presented by Savolainen et al. (2011). The paper summarised the evolution of the statistical methods used to analyse the effect that vehicle, roadway and human factors have on accident injury severity.

The literature on pedestrian accident causation was examined by Zegeer and Bushell (2012). The authors indicated several factors that affect the risk of an accident: those associated with pedestrians (behaviour, age, gender, disability), vehicles (speeding), infrastructure (type of area, number of lanes, midblock location, sidewalks, marked crosswalks, bus and tram stops, light condition, presence of signalisation, signal timings) and exposure (traffic volume, number of pedestrian crossings). The highest risk of a pedestrian accident occurs in low-income countries and in urban areas because of high traffic and pedestrian volume. The risk is higher for older people and for males. Male pedestrians are more likely to be involved in road traffic accidents than their female counterparts because of riskier behaviour. Tiwari et al. (2007) found that mean waiting times at traffic signals for males were lower than for females, which means that male pedestrians are more likely to cross on red. According to Zegeer and Bushell (2012), dart-out in the first half of the street (meaning: dashing out into the road) constitutes 4% of all pedestrian accidents and in the second part of the street, 10%. Intersection dash (13%) and midblock dart (8%) are other types of pedestrian crashes that are associated with pedestrian behaviour. Higher vehicle speeds significantly increase the risk of these types of crashes.

In most epidemiological studies based on national accident databases and relating to VRUs, the factors that contribute to accidents are categorized into three groups: factors related to the road and its surroundings, factors related to the vehicle and factors related to the users and their behaviour. This approach was proposed by e.g. Bjørnskau and Elvik (1992) and Muller and Haustein (2016).

Several studies investigated the factors that contribute to pedestrian accidents and found that the main risk factors were age and physical conditions (Al-Ghamdi, 2002; Chong et al., 2010; Fontaine and Gourlet, 1997; Harruff et al., 1998; Kim et al., 2010; Zegeer and Bushell, 2012; Zhang et al., 2014). In their analysis of a Chinese accident database, Zhang et al. (2014) introduced additional variables, such as pedestrian’s or driver’s fault in an accident (fault was determined by the police and recorded in the database) and a country-specific factor, *hukou*, which is a classification of a person’s region of residence and represents the status of a person who works in China. Generally, the *hukou* factor reflects differences in the educational, occupational and social status of the person involved in an accident. The determination of fault by the police could be controversial because of the possible unreliability and this issue requires further investigation.

More detailed epidemiological studies associated with pedestrian accidents have been conducted, for example, by Gitelman et al. (2012). A typology of 10 accident patterns (U1-U4, R1-R5, A1) that covers all pedestrian fatalities in Israel was created using an iterative classification process. The typology is shown in Figure 3.1.

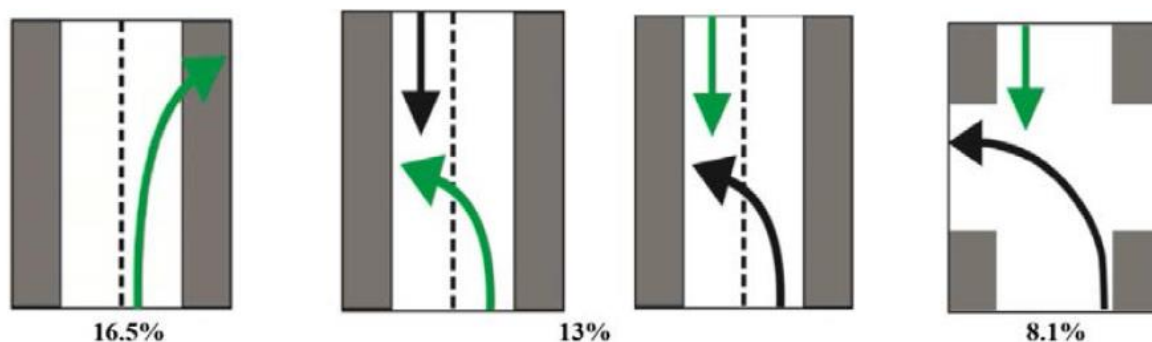


**Figure 3.1: Accident patterns with pedestrian fatalities in Israel, 2003-2006**

Source: (Gitelman et al., 2012)

While the problem of pedestrian safety has been studied extensively for many years, there is a relative lack of epidemiological studies on PTW users (Muller and Haustein, 2016). According to Muller and Haustein (2016), moped riders are exposed to a higher risk of injury and death in road crashes. Studies by Brems and Munch (2008) showed that the risk of being injured is 13 times higher for moped riders than cyclists (as cited in Muller and Haustein, 2016).

In France, the VOIESUR project was conducted to fill the information gaps in police accident records (Dubos et al., 2016). The study used statistical analysis of data based on road traffic accident reports for 2011. The objective was to examine injury and fatal accidents involving powered two-wheelers. About 8 500 accident reports were coded and analysed with the aim of using variables that are normally not included in police databases, e.g. vehicle speed before the accident and at the moment of impact. The speed was estimated based on accident sketches with vehicle positions, information on the road and surface conditions, photos and witness reports. Other variables were also considered, including: built-up/non-built-up area, type of road, manoeuvre, alcohol use, exceeded speed limit, existence of a driving license, and type of vehicle. The results of the study provided detailed information about PTW accident rates in France and the identification of the most dangerous locations and situations for PTW safety. The most common fatal accident configurations for PTWs are shown in Figure 3.2.



**Figure 3.2: Most common PTW fatal accident configurations (PTWs shown in green) in France**

Source: (Dubos et al., 2016)

### 3.3. InDeV questionnaire survey on epidemiological studies

#### 3.3.1. Structure of the questionnaire

This part of the questionnaire dealt with reports on the road safety situation of an area, based on police records of traffic accidents and injuries. Three forms were provided according to the type of report (see Appendix 1). The definitions of the three reports are as listed in section 3.2.1:

- **General road safety report** (Form A.1) is an analysis of accident frequency in an area where accident statistics, charts, distributions, trends and traffic safety indicators are presented.
- **Black spot analysis** report (Form A.2) identifies and presents high-risk accident locations (intersections or short road sections – less than 0.5 km long), i.e. locations with a high concentration of accidents.
- **Road network safety analysis** (Form A.3) is a method to identify, analyse and rank sections of the road network where a large number of accidents occurred in proportion to the traffic flow or road length.

Similar questions were asked in all three forms. They concerned the geographical coverage and frequency of the described reports, the content with respect to VRU accidents and the details of the included tabulations. A specific question was asked about the existence of procedures to identify the factors that contribute to accidents and the risk level. Another question dealt with the exposure measures used to calculate safety indicators. The final question was about the usefulness of the report for the InDeV project.

#### 3.3.2. General Traffic Safety Reports

The summarised results of the questionnaires are presented in Table 3.2 and Table 3.3. Form A.1 refers to general traffic safety reports that are the basic tool to assess the traffic safety situation in an area. These reports are used in every partner country and published every year. National reports (Table 3.2) seem to contain full information regarding VRUs (except for Poland, where information on motorcycle and moped accidents is not singled out and Canada where these two categories are combined). The level of detail of information varies, but national reports generally provide tabulations showing where and when VRU accidents occur.

Reports showing the safety situation at the regional level (Table 3.3) are less detailed and contain only selected information on VRU accidents. The Swedish national report is the only one marked as “useful for the InDeV project”. This report can be considered an example of best practice. The exposure measures commonly used in general traffic safety reports are: veh-km travelled, road length and population. The first two are useful for the assessment of the safety situation of motorcyclists, moped riders and to some extent, cyclists. For pedestrians, only population size can be used as a measure of their exposure, unless we have information on pedestrian flows moving along the road and crossing the road.

Only few of the general traffic safety reports contained sufficient information to identify the factors that contributed to VRU accidents: one at the national level and one at the regional/local level. The risk level was specified in only one case in Sweden. Spain and Sweden described these studies as useful for the InDeV project both at the national and regional/local level. In Spain, the regional report is considered useful only for assessing the safety of pedestrians and cyclists.

Table 3.2: Form A.1: Epidemiological studies based on accident data at the national level

GENERAL TRAFFIC SAFETY REPORT	Belgium	Canada	Denmark	Germany	Netherlands	Poland	Spain	Sweden
<b>Form A.1 - National level</b>								
· Frequency of report:	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly
<b>Content with respect to VRU victims:</b>								
· Pedestrians	X	X	X	X	X	X	X	X
· Cyclists	X	X	X	X	X	X	X	X
· Motorcyclists	X	X**	X	X	X		X	X
· Moped riders	X		X	X	X		X	X
<b>Tabulation of accidents by VRU category for:</b>								
· Urban area	X			X	X	X	X	X
· Junction type	X		X	X	X	X	X	X
· Junction control				X		X		
· Carriageway type							X	
· Pedestrian crossing				X	X	X	X	
· Timing (month, day, hour)	X			X	X	X	X	X
· Weather conditions					X		X	X
· Light conditions				X	X	X	X*	X
· Injury severity of VRU		X		X	X	X	X	X
· Victim's age (distribution)	X		X	X	X		X	X
· Other (please describe):							X*, ***	
<b>Analysis procedure for identifying:</b>								
· contributing factors?	No	No	No	No	Yes/No	No	No	No
· risk level?	No	No	No	No	No	No	No	Yes
Exposure type used		2	1,2,4	1,2,3		2	1	1,2
Usefulness of the method for InDeV:	Low	Low	Low	Low	Low	Low	Low/High*	High

\* only urban areas

\*\* includes moped riders

\*\*\* gender

1 – veh-km

2 – population

3 – road length

4 – licensed drivers

Table 3.3: Form A.1: Epidemiological studies based on accident data at the regional/local level

GENERAL TRAFFIC SAFETY REPORT Form A.1 - Regional/local level	Catalonia (Spain)	Swedish Regions	Masovian district (Poland)	Warsaw (Poland)	Barcelona (Spain)	regional roads (Spain)	Canadian provinces
· Frequency of report:	Yearly		Irregular	Yearly	Yearly		Yearly
<b>Content with respect to VRU victims:</b>							
· Pedestrians	X	X	X	X	X	X	X
· Cyclists		X	X		X	X	X
· Motorcyclists	X	X	X		X		X
· Moped riders	X	X			X		
<b>Tabulation of accidents by VRU category for:</b>							
· Urban area	X						
· Junction type				X		X	
· Junction control						X	
· Carriageway type						X	
· Pedestrian crossing							
· Timing (month, day, hour)						X	
· Weather conditions						X	
· Light conditions						X	
· Injury severity of VRU	X		X	X		X	X
· Victim's age (distribution)				X		X	
· Other (please describe):							
<b>Analysis procedure for identifying:</b>							
· contributing factors?	No	No	No	No		Yes	No
· risk level?	No	No	No	No		No	No
Exposure level used	1,2		2				
Usefulness of the method for InDeV:		Low	Low	Low	High*	Low	Low

\* only for pedestrians and cyclists

1 – veh-km

2 – population



### 3.3.3. Black Spot Analysis

The summarised results of A.2 questionnaires are presented in Table 3.4. One general remark can be made after analysing the questionnaires – the definition of a black spot differs from country to country:

- Belgium: Location where in the period of 3 years at least 3 injury crashes occurred and had a “priority score” of 15 or higher (score = 5\* # fatal victims + 3\* # serious injury victims + 1\* # slight injury victims);
- Denmark: The observed number of accidents is significantly higher than the expected number of accidents. The expected numbers of accidents are estimated using accident models. In addition, there is a demand for a minimum of 4-5 accidents over a period of 5 years to call a location a black spot;
- Germany: Different definitions are used for black spot analysis depending on the location and road category:
  - In urban areas: 5 accidents of the same type during one year or 5 accidents with personal injury during three years.
  - Outside urban areas: The number of accidents with serious personal injury (death or serious injury) is multiplied by factor 5 and accidents with slight injury, by factor 3. An accident black spot is identified on road sections (max. 300 metres on rural roads and max. 1000 metres on motorways) or junctions where a limit value of 15 is reached during three years;
- Netherlands: Unsafe traffic situations can be detected and analysed with the official AVOC method (black spot approach). These locations are defined as those at which more than ten accidents or more than five accidents with common characteristics (for example cyclist accidents) have been registered over a period of 3-5 years. The method is still in use but not always according to the manual. Because of the decrease in the number of accidents and the deteriorating registration of accidents, the number of locations suitable for this method is drastically decreasing;
- Poland: No clear definition; especially high number of accidents and collisions;
- Spain: Dangerous index >300 or No. of accidents\* traffic flow;
- Canada: Based on the calculation of a relative risk;
- Sweden: it is not practiced.

The geographical coverage and scale of analysis are very diverse (region, road/district or city), with most black spot analyses performed yearly and including information on VRU victims. Detailed collision diagrams are made in Denmark, Germany and the Netherlands and in those countries (as well as in Belgium) there is a well-defined analysis procedure for the identification of contributing factors. Thus, in almost half of the black spot studies reported, there was sufficient information to identify the factors that contribute to VRU accidents. The risk level was specified in only one black spot analysis in Spain. Germany and Spain (1 analysis each) described their analyses as useful for the InDeV project.

Table 3.4: Black spot analysis

Form A.2 Epidemiological studies based on accident data - method assessment																	
BLACK SPOT ANALYSIS	Belgium		Canada		Denmark		Germany		Netherlands		Poland		Spain		Sweden		
	Region	Road/District	Road/District	Road/District	Road/District	Road/District	Road/District	Region, City, Road/District	Region, City, Road/District	Region, City, Road/District	Region	Region	Region	Region	City		
Geographical coverage /scale:		50 intersections in 2009	50 intersections in 2009	Municipality roads	Municipality roads	Municipality roads	yes				Spain	Catalunya				Black spot analysis is not done in Sweden anymore as those have been eliminated	
• Applications so far for:		Unknown (linked to the transportation plan, done every 10 years)	Unknown (linked to the transportation plan, done every 10 years)	From annual to every 4th or 5th year	From annual to every 4th or 5th year	From annual to every 4th or 5th year	At least yearly	The most recent description method since 1992			Annual	Annual					
• Frequency of report:	One time only	2 pilot projects	2 pilot projects	Annual	Annual	Annual					Annual	Annual					
<b>Content with respect to VRU victims:</b>																	
• Pedestrians		X	X	X	X	X	X	X	X	X				X	X		
• Cyclists		X	X	X	X	X	X	X	X	X				X	X		
• Motorcyclists		X	X	X	X	X	X	X	X	X				X	X		
• Moped riders		X	X	X	X	X	X	X	X	X				X	X		
• VRU injury severity	X																
• Road users involved		X	X	X	X	X	X	X	X	X				X	X		
• Manoeuvres of vehicles		X	X	X	X	X	X	X	X	X							
• Other (please describe):							Contributing factors										
Detailed collision diagrams				X	X	X	X	X	X	X							
Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:																	
• contributing factors?	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
• risk level?	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Usefulness for project in Dev:	Low	Low	Low	Low	Low	Low	High	Low	Low	Low	Low	Low	Low	Low	High	High	High

### 3.3.4. Road Network Safety Analysis

Table 3.5 presents a summary of Form A.3 of the questionnaire (road network safety analysis) for the regional level and Table 3.6, for the city and road/district levels. The level of detail of information and frequency of reports vary among the countries. In almost half of the countries such reports have never been prepared. The situation is even worse regarding the content with respect to VRU victims: the availability of such data regarding pedestrians and cyclists was reported only by three countries and with regard to motorcyclists and moped riders – by only two. The reported exposure levels are generally not suitable for VRU analysis. The usefulness of this method was assessed as low by all respondents.

Surprisingly, only 5 countries reported performing network safety analyses at the regional level and 6 countries at the district level. It seems then that some of the countries involved in InDeV (e.g. Denmark) do not participate in the EuroRAP programme or do not consider it as a network safety analysis tool.

It should be noted that some of the countries use safety indicators of accidents per km of road which are not suitable for pedestrian safety analyses.

In only two of the road network safety analyses reported (one at the regional level and one at the district level) there was sufficient information to identify the factors that contribute to VRU accidents. The risk level was specified in almost half of the NSM studies (two answers at the regional level and two at the city/district level). None of the studies were described as useful for the InDeV project.

**Table 3.5: Road network traffic safety analysis – regional level**

<b>ROAD NETWORK SAFETY ANALYSIS</b>							
<b>Form A.3 - Regional level</b>	Belgium	Denmark	Germany	Netherlands	Poland	Spain	Sweden
· Applications so far for:	Yes			Yes	Yes	Yes	Yes
· Frequency of report:	3 Year				Yearly	Yearly	
<b>Content with respect to VRU victims:</b>							
· Pedestrians					X		X
· Cyclists					X		X
· Motorcyclists					X	X	X
· Moped riders							X
Exposure type used	1,3			1,3	1,3	1,3	1
<b>Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:</b>							
· contributing factors?	No			No	No	No	Yes
· risk level?	No			No	Yes	No	Yes
Usefulness of the method for InDeV:	Low			Low	Low		Low

1 – veh-km

2 – population

3 – road length

**Table 3.6: Form A.3: Road network traffic safety analysis – city and road/district level**

ROAD NETWORK SAFETY ANALYSIS	Belgium	Canada	Denmark City	Denmark Road Districts	Germany	Netherlands	Poland	Spain	Sweden City	Sweden Road Districts
<b>Form A.3 - City and road/district level</b>										
· Applications so far for:		Yes	Yes	Yes	Yes				Yes	Yes
· Frequency of report:		Once	Yearly	Once	2-3Years					
<b>Content with respect to VRU victims:</b>										
· Pedestrians			X						X	X
· Cyclists			X						X	X
· Motorcyclists									X	X
· Moped riders									X	X
Exposure type used		4		1,3	1,3					1
<b>Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:</b>										
· contributing factors?		No	No	Yes/No	No					
· risk level?		No	No	Yes	Yes					
Usefulness of the method for InDeV:		Low	Low	Low	Low				Low	Low

1 – veh-km

2 – population

3 – road length

4 – traffic volume

### 3.4. Best practice examples of epidemiological studies

#### *European Union level*

The European Road Safety Observatory publishes yearly reports (ERSO, 2015) that present general traffic safety facts in EU countries concerning various road transport modes and user groups. Three of these reports focus on VRU user groups: pedestrians, cyclists and motorcycle/moped (PTW) riders. These reports are produced based on the analysis of the CARE database and are very good examples of epidemiological studies. They show the trends in the numbers of fatalities and the fatality rates in EU countries over the last ten years (Figure 3.3 shows an example of a trend chart of cyclist fatalities and Figure 3.4 a comparison of changes in cyclist fatality rates across Europe). It seems that although the numbers of traffic fatalities are generally falling in all countries and for all VRU categories, motorcycle, bicycle and pedestrian fatality numbers are not decreasing as fast as the average for all accidents. This means that expressed as the percentage share of all traffic fatalities, the proportion of cyclist, pedestrian and motorcycle deaths is actually increasing in Europe as a whole, especially in some countries (e.g. Belgium, Denmark, Spain for cyclists, Poland for PTW riders).

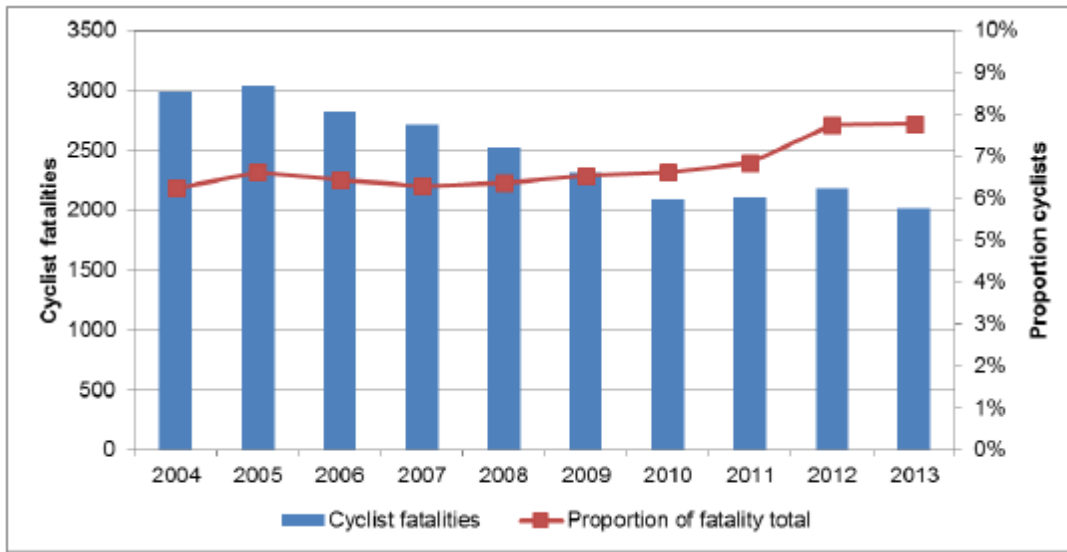


Figure 3.3: Number of cyclist fatalities and percentage of all road fatalities, EU, 2004-2013

Source: (ERSO, 2015)

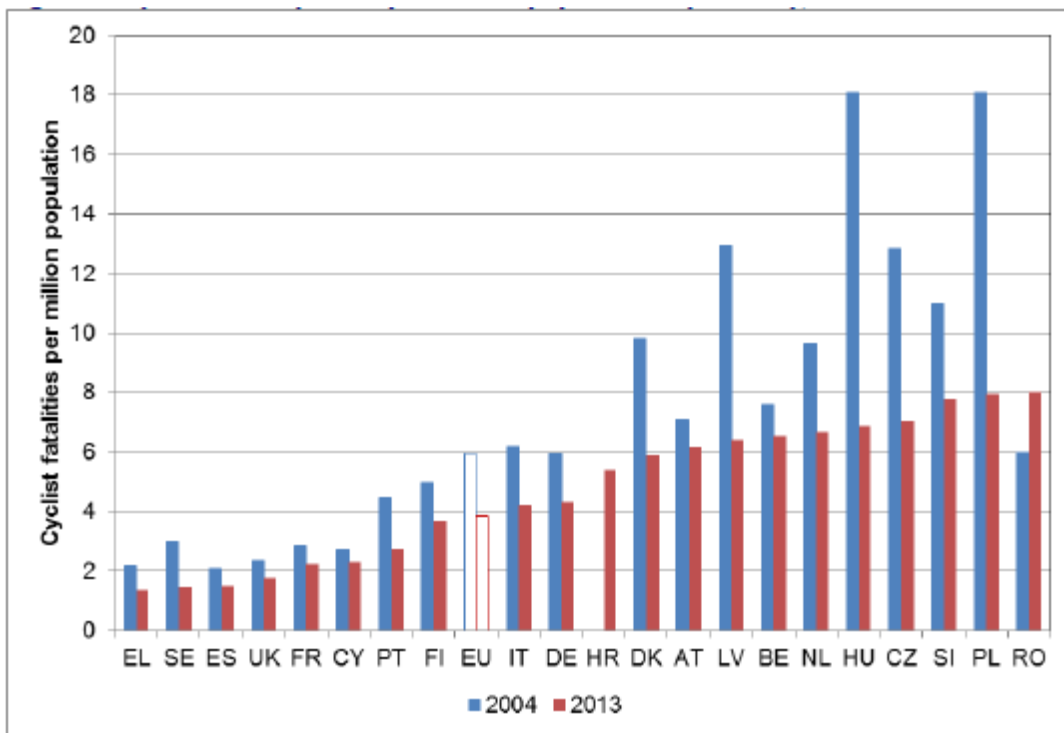
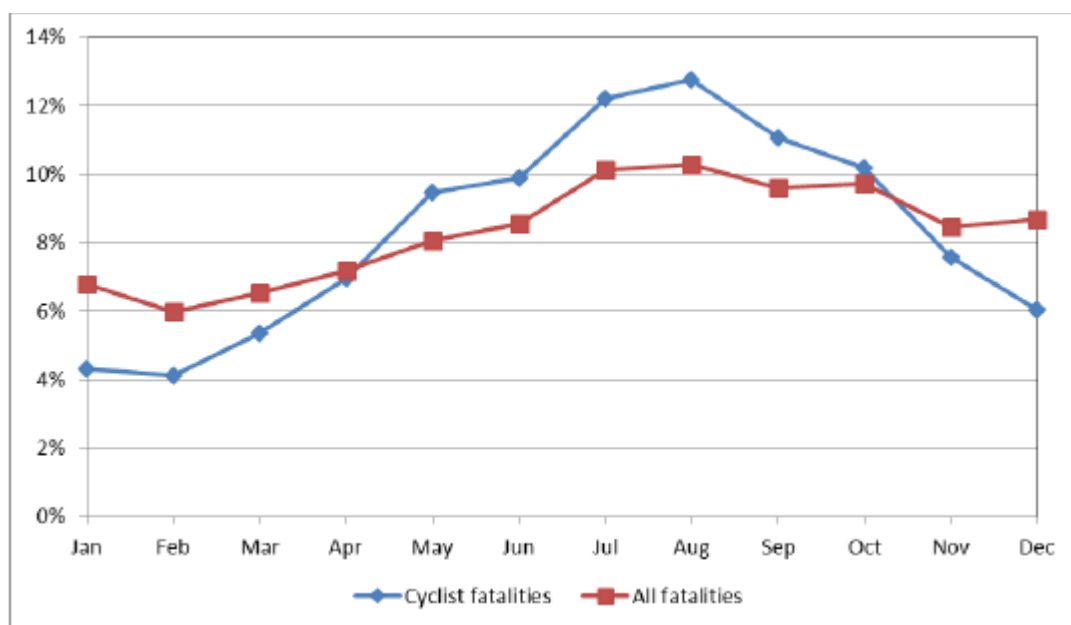


Figure 3.4: Cyclist fatality rates per million population by country, 2004 and 2013

Source: (ERSO, 2015)

The distributions of fatalities by age show that improvements occur mostly for younger user groups and not for the elderly. This is especially visible in the case of pedestrians – 44% of pedestrian fatalities are people older than 64 years. In some EU countries (e.g. Spain, Italy, Finland) this percentage is as high as 60%. ERSO reports also show the distributions of fatalities by area (urban, non-urban), location (junction, not at junction), junction type, light conditions, month and time of day. It has been observed that for VRU,

a higher than average proportion of accidents occurs at junctions. Most cycle and PTW fatal accidents occur during the summer months (see Figure 3.5 as an example; this fact can be partly explained by higher exposure, i.e. more frequent cycling in the summer) but the opposite is true for pedestrians – in their case, higher numbers of fatalities occur during the autumn and winter months. There are also clear differences regarding the light conditions: half of pedestrian fatalities occur during the dark hours, whereas for cyclists this number is only 26%. The reports also present the consequences of accidents in terms of hospitalization rates as well as the length of hospital stay. The percentage of accident victims admitted to hospitals is higher than average for pedestrians and PTW riders and lower for cyclists. The same trend can be observed for the length of hospital stay: it is longer than average for pedestrians and PTW users.



**Figure 3.5: Distribution of cyclists and all road fatalities by month, EU, 2013**

Source: (ERSO, 2015)

### **Country/national level**

The Swedish General Traffic Safety Report (Melkersson, 2015), published by the Swedish government agency for transport policy analysis, Transport Analysis (Trafikanalys) is a good example of a country-level statistical report. Transport Analysis produces annual reports on road traffic injuries based on official police statistics.

These reports cover the statistics of road users killed and injured in road traffic, and contain information about the accidents and the circumstances concerning fatalities, including vulnerable road users, such as:

- All VRU categories:
  - Pedestrians
  - Motorcyclists
  - Cyclists
  - Moped riders
- VRU victim characteristics:
  - Age
  - Gender

- Blood alcohol concentration
- Injury severity (killed, serious, slight injury)
- Location of the fatal accident:
  - Type of area
  - Pedestrian crossing
  - Type of road and speed limit
  - Type of junction
- Timing (distribution by month, day of the week, hour)
- Weather conditions
- Light conditions
- Road conditions
- Risks in road transport

The Swedish General Traffic Safety Report doesn't contain information about junction control, carriageway type and exposure level. Nevertheless, together with exposure data from travel surveys or cities' own traffic counts, STRADA (data from the police and hospitals) could be very useful for the statistical analysis of VRU safety.

### **3.5. Summary**

Epidemiological studies based on accident and injury records form the basis of traffic safety assessment. General traffic safety reports help to identify the time trends of accident occurrence and to compare the safety situation among countries and/or regions and cities. Benchmarking between countries can help monitor progress towards the goals set as targets for traffic safety improvement. This is important especially when exceptions from the generally positive trends occur. For example, two worrying trends are currently observed in Europe: while the overall traffic safety situation is improving from year to year, the proportion of accidents with vulnerable road users among all traffic accidents is rising which means that VRU safety problems are gaining importance. The second trend is the increasing proportion of the elderly among all VRU victims of road accidents. Comparing the situation among different countries can also help to assess the relative importance of problems that contribute to poor safety performance. While the exact causes of accidents cannot be determined, the contributing factors can often be deduced.

Comparing traffic accident and injury data among countries is challenging due to the inconsistency in definitions. Although common definitions of what a “traffic accident” is and how to count fatalities have been worked out as part of the common CARE database, there is no common definition of severe injury and slight injury. This means that in practice only the numbers of fatalities and fatality rates are fully comparable. The EuroRAP programme in which all of the InDeV partner countries (except Denmark) participate is a good example of international benchmarking. A common methodology has been worked out to rate the safety of road segments based on exposure, e.g. road length and vehicle-kilometres travelled. However, these exposure measures are not suitable for pedestrian accidents.

The following conclusions concerning epidemiological studies can be formulated based on the literature review and InDeV questionnaire responses:

- A general traffic safety report is the basic method to present traffic accident data that is useful for the assessment of the road safety situation in an area, for benchmarking and monitoring time trends. A comprehensive general traffic safety report should highlight VRU problems. Although most respondents do not

consider it useful for the InDeV project, it should nevertheless be the basic reference for VRU safety assessment.

- Black spot analysis is useful for the identification of dangerous intersections and pedestrian/cyclist mid-block crossings and therefore is very important for pedestrian and cyclist safety assessment. Network safety management is replacing black spot management in several countries, however, both are needed for comprehensive VRU safety analysis.
- Network safety analysis involves the safety assessment of road links and therefore is more applicable to assess the safety of VRUs who move along the roads, i.e. cyclists and PTW riders. The standards of road network safety analyses in particular EU countries differ considerably. An important part of NSM analyses do not take vulnerable road users into account.
- The most common and frequently used term for road sections identified in NSM is hazardous road section, defined as any section at which the site-specific expected or the observed number of accidents is higher than for similar sections, due to local and section-based risk factors present at the site. This definition should include not only the number of accidents but also their severity.
- Lack of exposure data is a serious problem for VRU safety assessment. Commonly used exposure measures such as road length and vehicle-kms are suitable for bicycle, motorcycle and moped rider accidents but not for pedestrians. Pedestrian and cyclist traffic volumes can be used in combination with crossing motor traffic volumes for the purpose of identifying black spots (intersections and road crossings). The local population can be used to determine exposure when comparing fatality and injury rates in cities and regions.



## 4. Quality of accident data

### 4.1. Problems with accident data quality

#### 4.1.1. Types of data problems

It is a basic fact that high-quality information on road accidents, fatalities and injuries is a prerequisite for safety assessment and the development of effective safety improvement programmes. Yet the quality of accident data poses multiple problems which have been reported and analysed in many studies (Chisvert et al., 2007; WHO, 2013, 2010).

Virtually every country or territory collects data on road accidents from reports recorded by the police. Over the years, the systems of data collection and processing developed in each country independently and hence the major differences between these systems. According to a report on the SAU project (*Urban Accident Analysis System*) (Chisvert et al., 2007), the differences in the numbers and types of accidents included in different national databases stem from the differences in the following aspects:

- Traffic accident definitions assumed by the national/local administration,
- Normative criteria used for including accidents in the database and classifying them by type,
- Real practice of the persons in charge of data recording and processing.

The three issues listed above contribute to the following problems with data quality and reliability in national road accident databases:

- Underreporting of accidents by the police,
- Misclassification of injury severity,
- Inaccurate or erroneous data,
- Incomplete or missing data.

In its working policy document (EC, 2013), the EC states that the total number of people seriously injured in road traffic is likely to be substantially higher than currently reported. The reason for this is that transport databases lack relevant and comparable data on serious injuries. There are two main problems: the lack of common definitions and the widespread underreporting and misreporting. In road safety data, the severity of an injury is sometimes defined on the basis of medical classifications and sometimes in terms of the long-term effects of the injury. Often, it is defined by the length of hospital stay.

#### 4.1.2. Definition of a road accident

The definition of an Injury Road Accident that has commonly been adopted in Europe (IDABC, 2004) is that it is an incident on a public road that involves at least one moving vehicle and at least one casualty (person injured or killed). Thus, property damage only crashes are not considered “accidents” and in some countries are not recorded by the police. However, there is no clear definition of what constitutes an “injury” – the local criteria and practice may differ on whether minor scratches and bruises classify as an injury or not.

Luoma and Sivak (2007) compared fatal road accident databases from 20 countries and their availability. Although the 30-day fatality definition is commonly used, other criteria for the inclusion of fatalities in the database differ from country to country. For example,

accidents on private roads that are open to the public are included in some but not all countries. Similarly, fatalities due to suicide or disease may or may not be included. The inclusion of accidents with trains, trams and animal-drawn vehicles also varies among different countries.

Ever since the definition of a fatal road accident was adopted by the Vienna Convention in 1968<sup>3</sup>, efforts have been made to harmonise the definitions and criteria used to classify accidents and injury severity. This task became more urgent with the creation of an international road accident databases which combines data from many countries. As noted in a WHO report (WHO, 2013), significant progress has been made: 92 countries (out of 182) used the 30-day fatality definition in 2011. However, there are still major differences in how the numbers of injured accident victims are calculated and classified.

Does the commonly adopted CARE definition of a road accident include all VRU accidents? Figure 9.1 shows the possible combinations of road users involved in an accident in the form of a collision matrix. The last row represents single-user accidents. VRU accidents are shown in green and cases consistent with the CARE definition are within the red frame. The definition requires that at least one moving vehicle should be involved in an accident so all of the combinations are covered except for single pedestrian accidents. These additional accidents (pedestrian falls) can be included in VRU safety assessment and economic evaluation. The other two conditions, i.e. location on a public road and at least one injured person should still apply. A broad definition of public roads can be used to include private roads open to the public.

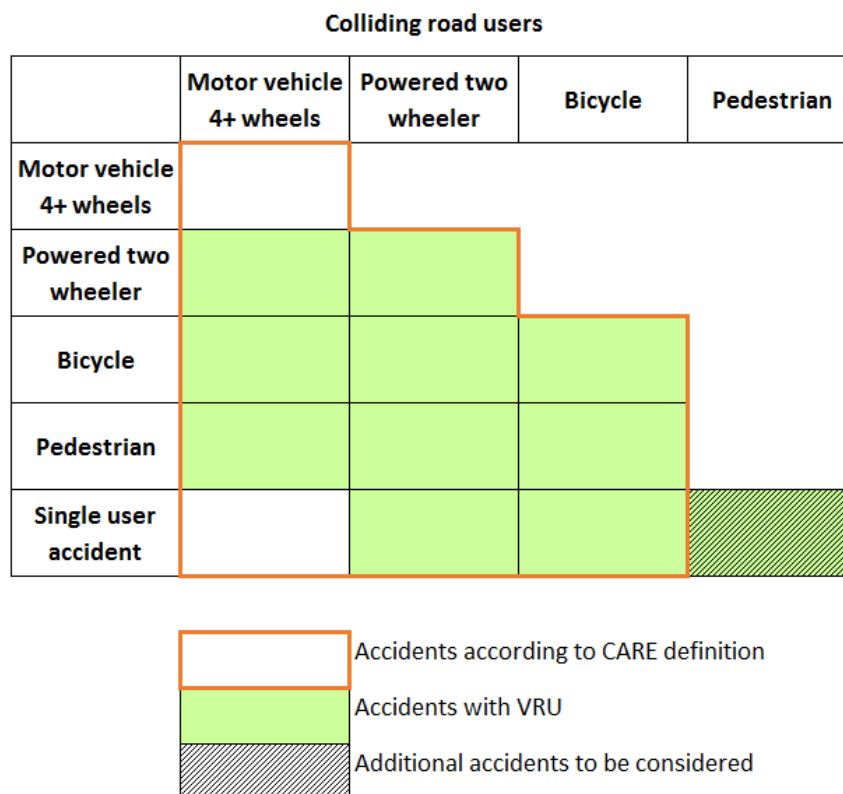
### 4.1.3. Underreporting

All three problems listed in section 4.1.1 contribute to the underreporting of accidents by the police. Misreporting and underreporting are largely due to the fact that in most EU countries, the national road traffic injury databases are only based on police reports (EC, 2013). However, the police are not called to every traffic accident and cannot be expected to perform a medical assessment; their diagnosis is only a rough on-the-spot estimate. This initial assessment by the police is not always checked against subsequent medical reports about injury severity. The serious problem of underreporting, especially among cyclists has been mentioned in many studies, e.g. Langley (2003), Loo and Tsui (2010).

Alsop and Langley (2001) examined police reporting rates of motor vehicle accident victims in New Zealand. They concluded that less than two-thirds of hospitalised accident victims were recorded by the police and that the reporting rate was higher for car occupants than for motorcyclists. The authors also found that the reporting rate was positively correlated with injury severity as measured by the AIS score. In a similar study in France (Amoros et al., 2006) which was based on a large sample of almost 60 thousand road accident casualties, the average reporting rate was only 38%. The study confirmed that underreporting varied with injury severity and road user type. Cyclist victims have the lowest probability of being police-reported (especially when involved in single-user accidents), followed by pedestrians and motorcyclists. Thus, it can be concluded that police records are generally biased against VRU victims.

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<sup>3</sup> A road fatality is any person killed immediately or dying within 30 days as a result of a road traffic accident.



**Figure 4.1: Road user collision matrix**

Because of the incompleteness of police databases, the records collected by the police are being combined with hospital records in some countries, e.g. in Sweden (the STRADA system). The results of a German study on bicycle accidents (Juhra et al., 2012) confirmed the need for this approach. The number of bicycle accidents in Münster, where bicycles are the main transport mode, was nearly two times higher after the police accident database was combined with hospital data.

An international study (Schepers et al., 2014a) looked at the frequency of single-bicycle accidents in different countries. It was found that an average of 17% (between 5% and 30%) of cyclist fatalities are caused by single-user accidents. Moreover, most of the bicycle accident victims admitted to hospitals or treated in emergency departments (between 60% and 95%) are the result of single-bicycle crashes.

#### 4.1.4. Incomplete and inaccurate data

Several epidemiological studies associated with VRU safety, e.g. Twisk and Reurings (2013), Chung and Chang (2015), Muller and Haustein (2016), Dubos et al. (2016) pointed to the limitations of large accident databases maintained by the police, which usually do not contain important information, such as the speeds of the colliding vehicles and the exact location of the accident.

Another problem indicated by Chung and Chang (2015) is the possibility of human error when police officers complete accident reports at the site of the accident and transfer the data to the electronic database. Several studies have been conducted in relation to this problem (Austin, 1995; Chung and Chang, 2015; Conche and Tight, 2006; Loo, 2006). Most errors in police reports occur when filling in information about accident location (Loo, 2006). According to Chung and Chang (2015), the use of vehicle black boxes (VBB) in

accident data collection has great potential to enrich police records and provide information such as time, the GIS-based location of the accident and vehicle speed.

Tsui et al. (2009) as cited in Loo and Tsui (2010) examined the issue of classification of injury severity in traffic accidents in Hong Kong. The study concluded that only 5.15% (36 out of 699 cases) of serious accidents among cyclists are properly classified by the police. Some injuries are reported as serious although they are really not and vice versa. Studies have indicated that only around 70% of all serious injuries are actually reported (Elvik and Mysen, 1999).

## **4.2. International accident data sources**

### **4.2.1. Community database on Accidents on the Roads in Europe CARE**

All EU countries are obligated to provide information about road accidents to the European centralised database, CARE (Community database on Accidents on the Roads in Europe) hosted by the European Commission.

CARE is a disaggregate database which contains information on individual accidents. The following classes of information are collected (IDABC, 2004):

- Person class (road user type: pedestrian, driver, passenger);
- Gender;
- Age group;
- Vehicle group;
- Area type;
- Motorways;
- Junctions;
- Accident type;
- Lighting conditions;
- Weather conditions;
- Time of accident.

Not all of the data categories are provided by all countries. In most EU countries there is a lack of detailed information about the collision type (manoeuvres), there are also different subcategories of junction type.

CARE was created with the goal of harmonising accident information across Europe to make international comparisons more meaningful and to enable accurate benchmarking. Because of the disparate definitions in the CARE database and in national databases, EU countries apply transformation rules to harmonise the data. In spite of that, differences remain regarding data quality, resulting in the incomparability of national datasets. For example, the definition criteria used to classify injury severity vary from country to country and only fatalities can be included in safety analyses.

The CARE definitions of injury severity are presented below (Directorate-General for Mobility and Transport, 2013):

- Injury Road Accident – incident on a public road involving at least one moving vehicle and at least one casualty (person injured or killed)
- Fatally injured – death within 30 days of the road accident, confirmed suicide and natural death are not included

- Injured –road user seriously or slightly injured (but not killed within 30 days) in the road accident
- Seriously injured – injured (although not killed) in the road accident and hospitalized at least 24 hours
- Slightly injured – injured (although not killed) in the road accident and hospitalized less than 24 hours or not hospitalized
- Not injured – person participating in the accident although not injured

The Common Accident Dataset (CADaS) was developed to provide a common framework for road crash data collection in Europe. The minimum data elements selected for CADaS were based on extensive research on data sources and systems available in 25 European countries, and stakeholders’ needs and priorities for crash data analysis at the national level (Yannis et al., 2008). The data elements of CADaS were finalized after more than four years of consultation with road safety data experts and are currently being applied in the European CARE database. The resulting common dataset was reviewed by experts and practitioners in several countries, and revised for relevance and feasibility. The implementation of this common dataset will help countries to improve and standardise their own road accident data bases.

In order to support road safety research in Europe, the web-based Road Safety Knowledge System has been developed within the DaCoTA research project (Yannis et al., 2014). The system contains not only accident data but also exposure, safety performance and socioeconomic indicators as well as information on road user attitudes and traffic laws and regulations. This data is used in road safety analysis to produce Basic Fact Sheets and annual statistical reports.

The scope of the CARE database (variables and values) should enable detailed road accident analysis at the EU level. However, national accident data collection systems use the CADaS format on a voluntary basis. There are a lot of differences between the national databases and some values and variables may not be compatible with the CADaS format. Data transformations are very often difficult, which explains why many entries in the CARE database are currently classified as “not available” or “other”. The level of detail of the variables and values in CARE corresponds to all data that is useful for macroscopic data analysis and not for the detailed reconstruction of the scene of the accident, which is of local interest.

#### **4.2.2. International Road Traffic and Accident Database IRTAD**

The International Road Traffic and Accident Database IRTAD collects and aggregates international data on road crashes from 32 OECD countries. It thereby provides an empirical basis for international comparisons and more effective road safety policies. The IRTAD includes safety and traffic data, aggregated by country and year from 1970 to present. All data is collected directly from the relevant national data providers in IRTAD countries. It is provided in a common format, based on the definitions developed and agreed by the IRTAD Group. Most of IRTAD data can be found in IRTAD's Road Safety Annual Reports. Online access to the full IRTAD database is available for subscribers via the OECD statistics portal.

The IRTAD database contains validated, up-to-date crash and exposure data from the 32 countries in the following categories:

Crash data: fatalities, injury crashes, hospitalised victims, injuries by:

- road type (motorways, urban roads, rural roads)
- road user (pedestrians, cyclists, car occupants, PTWs, other)
- age
- gender
- seat position in the car.

Exposure data:

- vehicle-kilometres
- modal split
- vehicle fleet, by type of vehicles
- population
- driving licence.

Other safety data:

- seatbelt wearing rates
- helmet wearing rates.

The IRTAD database is aggregated and enables the analysis of trends in VRU accidents by type of road user, gender and age. However, it is impossible to perform accident causation analyses.

### **4.2.3. World Health Organisation**

The WHO Global status report on road safety 2013 (WHO, 2013) presents information on road safety from 182 countries. The methodology used to generate the data and information presented in that report involved the collection of data from each country, which was coordinated by a National Data Coordinator. Data collection was driven by a number of individual respondents from different sectors within a country, each of whom completed a self-administered questionnaire providing information on key variables. This group was then required to come to a consensus on the data that best represented their country. The WHO (2013) report highlights road safety data from 182 countries, covering 6.8 billion people (98.6% of the world’s population). Data collection was carried out in 2011 and therefore fatality data referred to 2010, the most recent year for which data were available. The report presents only an overall view of road accident fatalities and the collected data are not sufficient for VRU safety analysis.

### **4.3. InDeV questionnaire survey on data quality**

One of the aims of Task 2.1 is to assess the quality and availability of accident and injury data with relevance to VRU safety problems. The questionnaire survey on accident data quality was designed to examine accident data collection procedures and database creation in each partner country as well as to identify the gaps in the currently used methodology and data.

Task 2.1 should provide a base for Task 2.2 which aims to identify the typical locations and situations where most VRU accidents occur using statistical analysis. The main challenges associated with dataset analysis and with the identification of the most dangerous locations for VRU safety in the EU are the differences in data quality between countries and the lack of detailed information about accidents involving VRU.

To achieve the objectives of Task 2.1, a questionnaire on road accident data quality was sent to all InDeV partners in Europe. The key issues taken into account in the questionnaire-based survey included data comparability among the countries involved in the project and data accuracy and credibility. The complete questionnaire on accident data quality is provided in Appendix 2. Outline of the 9 questions asked is given below.

Q1: Definitions related to road accidents used in respondent’s country (is it consistent with CARE database definitions or not) in the following cases:

- Road accident/injury accident
- Killed/fatally injured
- Injured
- Seriously injured
- Slightly injured
- Not injured

Q2: Details of accident data collection procedure

- Transfer from paper form to computer database
- Source of gathering information about victim's injuries
- Verification of information about victim’s injuries
- Waiting time to verify the information about victim’s injuries

Q3: Classification of victim’s injury severity by the police or other party

Q4: Details of when and how accident data quality control is carried out

Q5: Methods of police accident database quality control

- cross-checking for consistency of information
- comparing with other data sources

Q6: Studies on underreporting of accidents and their availability

Q7: Use of other databases to compare with the police accident database

Q8: Hospital injury database definitions

Q9: Accident location - use of geographic coordinates to define location of accidents

## **4.4. Survey results**

### **4.4.1. Summary tables**

Table 4.1 and Table 4.2 present and summarise the results of the survey. In addition to information that could be tabulated each partner provided detailed comments and explanations related to individual questions. These comments are presented in the following section, country by country.

Table 4.1: Accident data definitions and collection procedures

ROAD ACCIDENT DATA COLLECTION	Belgium	Denmark	Germany	Netherlands	Poland	Spain	Sweden
<b>Q1: Is CARE definition applicable?</b>							
Road accident/injury accident	Yes	Yes	Yes	No	Yes	Yes	No
Killed/fatally injured	Yes	Yes	Yes	Yes	Yes	Yes	No
Injured	Yes	No	Yes	No	No	Yes	No
Seriously injured	Yes	No	Yes	No	No	Yes	No
Slightly injured	Yes	No	Yes	No	No	Yes	No
Not injured	Yes	Yes	Yes	Yes	Yes	No	Yes
<b>Q2(a-b): Data collection procedure</b>							
From paper form to computer database	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Source of gathering information about victim's injuries							
• ambulance	X	X	X			X	
• emergency room/admissions		X	X		X		X
• other hospital departments			X				X
• road users involved in accidents/victims			X	X		X	
• other sources	X	X					
<b>Q2(c-d): Verification of information on injuries</b>							
Verification of information about victim's injuries	Yes	Yes	Yes	Yes	Yes	No	Yes
Waiting time to verify the information about victim's injuries							
• 1-3 days							
• 4-14 days							
• 14-30 days					X		
• other	X	X	X	X	X		X
<b>Q3: Classification of injury severity</b>							
Classification of injury severity by the police	Yes	Yes	Yes	Yes	Yes	Yes	No
• based on doctor's opinion		X			X	X	
• using ICD-10/9 classification							
• using MAIS3+ classification							
• using AIS 2005 classification				X			
• other	X	X	X		X		



Table 4.2: Quality of road accident data

QUALITY OF ROAD ACCIDENT DATA	Belgium	Denmark	Germany	Netherlands	Poland	Spain	Sweden
<b>Q4: Data quality control</b>							
Carrying out of data quality control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• while filling out the paper form	Not known		No	No	Not known	Yes	Not known
• while transferring to the computer	Yes		Yes	No	Yes		Not known
• after transferring to the computer database	Yes	Yes	Yes	Yes	Yes		Yes
<b>Q5: Methods of police accident database quality control</b>							
• cross-checking for consistency of information	No	Yes	Yes	No	Yes	Yes	No
• comparing with other data	No	No	No	Yes	No	No	No
• other	Yes	No	Yes	Yes	No	No	Yes
<b>Q6: Availability of underreporting studies</b>							
Availability of the studies/reports/analyses about underreporting of accidents/victims	Yes	Yes	Yes	Yes	Yes	No	Yes
• including those relating to VRU accidents	No	Yes	Yes	Yes	No	No	Yes
<b>Q7: Comparison of data</b>							
Use of other databases to compare with the police accident database	Yes	Yes	No	Yes	No	Yes	Yes
<b>Q8: Hospital injury database definitions</b>							
Road accident/injury accident		X			Not known		
Killed/fatally injured		X			Not known		
Injured		X			ICD-10		
Seriously injured		No			Not known		
Slightly injured		No			Not known		
<b>Q9: Identifying accident location</b>							
Use of geographic coordinates to determine location of accidents	Yes	Yes	Yes	No	Yes	Yes	No
• GPS	X				X		
• DMS							
• WGS84			X		X	X	
• other		X					

Q10: Suitability of country database to conduct analyses of VRU safety							
• Scope of data	Yes	Yes	Yes		Yes	Yes	Yes
• Data reliability	Yes	Yes	Yes	Yes/No	Yes	Yes	Yes
• Completeness of data	Yes	No	Yes		No	Yes	Yes

#### 4.4.2. Country notes and specific national conditions

##### **BELGIUM**

In Belgium, the police arrive at the scene to gather accident data. Data is collected on a paper form and later transferred to a computer database. The police gather information about victims' injuries from other hospital departments and other sources – if an injured person dies within 30 days of the accident, the judicial services inform the police department. The police verify the information about the victim's injuries when there is feedback from the hospital. Certain police departments have agreements with the hospital administration to provide feedback in case of accidents. The waiting time to have the information about victims' injuries verified by the police is not specified by Belgian law. Police officers assess the severity of injuries based on the length of hospital stay. If the injured person stays longer than 24h in hospital they are treated as heavily injured.

Quality control of accident data collection is carried out during data transfer to the computer and after the transfer to a computer database. During the control of accident data quality, other governmental departments clean the data from inconsistencies and check for correctness (e.g. the location of accidents).

A report is available on the underreporting of accidents/victims. This report is in Dutch with an English summary and covers all road users (including, but not focusing on, VRUs): <http://www.steunpuntverkeersveiligheid.be/sites/default/files/RA-2006-83.pdf>

There are independent research bureaus that compare police data with hospital data in order to assess the MAIS3+ injury level for victims.

In Belgium, some police zones use geographic coordinates in GPS format to determine the location of accidents; however, this is not standard practice. In built-up areas, the name of the street and house number are used to determine accident location. If the accident occurs in a non-built-up area, the name of the street + the hectometre/kilometre pole alongside the road are used. Sometimes reference points in the surroundings are also used.

##### **DENMARK**

In Denmark, the definition of an injury accident is the same as in CARE, but a road accident does not necessarily involve an injured person. The definition of an injured person is different than in CARE and describes a person with injuries for which medical treatment or hospitalization (even if only for observation) is normally required. Persons with lesser wounds, minor cuts and bruises are not recorded as injured.

The definition of seriously injured is also different than in CARE. The distinction between those seriously and slightly injured is based on the type of injury. The following types of injury result in the classification as seriously injured:

1. Skull fracture, concussion, injury to face or eyes

2. Injury of trunk (chest and/or abdomen)
3. Injury of spine/neck and/or pelvis
4. Fracture/dislocation or severe sprain of shoulder, arm or hand
5. Fracture/dislocation or severe sprain of hip/leg/foot
6. Serious injuries in more than one main region
7. Burn

The following types of injury result in the classification as slightly injured: slight injury, observation for concussion.

In Denmark, the police gather information about victims' injuries based on the information from the ambulance (rescue team) or the emergency room/admissions in hospital, or police officers assess the type of injury at the scene. In the case of emergency room treatment and/or admission, the police verify the information about the victim's injuries. The registry of injured road users is compared with the registry of deceased persons in Denmark once a year to control for any fatalities within 30 days of the traffic accident.

As part of the quality control of the computer database, information is cross-checked for consistency. There are a number of (about 50) logical controls in the database. For example, if an accident is registered as an injury accident, there has to be at least 1 injured person registered in the accident record as well. Quarterly controls are performed concerning the likelihood of different values, such as the number of injured persons, number of accidents, etc. All of these controls are performed by the National Road Directorate. The Directorate is responsible for the national accident database. Police registers provide input to this database.

Studies and reports about the underreporting of accidents/victims are available, including those relating to VRU accidents:

- Accident risk and factors associated with non-motorised road users – a central road safety challenge with deficient data:  
<http://www.inderscience.com/offer.php?id=71985>
- A case study on the concordance between self-reported accidents and records kept by hospital and police:  
[http://www.trafikdage.dk/td/papers/papers15/324\\_KatrineMelftofte.pdf](http://www.trafikdage.dk/td/papers/papers15/324_KatrineMelftofte.pdf)

The abovementioned data refer specifically to VRUs. There are also other studies in Denmark that deal with underreporting for all road users in general. In some cases, VRUs are also specified.

The police accident database is compared with the following data:

- The National Hospital Discharge Registry,
- accident data from the University Hospital in Odense (data have been registered since the 1980s and cover the island of Funen),
- data from various hospitals/emergency rooms (typically from a temporary register of 1-3 years).

The comparison is not performed for the purpose of the official traffic accident database but in connection with various research projects. This means that no specific variables and information are being compared: these are one-time comparisons that depend on the specific projects.

The hospital injury database uses the following definitions (based on the National Hospital Discharge Registry as the only nationwide hospital registry):

- road accident/injury accident – an accident involving a vehicle that is used to transport the user from one place to the other,
- killed/fatally injured – the same definition as in CARE,
- injured – all patients registered in LPR are considered injured since they have been in contact with a hospital and/or emergency room,
- seriously injured – not specified,
- slightly injured – not specified.

In Denmark, geographic coordinates in the 2000 EUREF89 system, UTM zone, 32 and 33 format are used to determine accident location.

The Danish national database is not suitable for the analysis of VRU safety in terms of data completeness due to significant underreporting. The extent of underreporting varies depending on the type of road user. For example, the level of underreporting for bicyclists is much higher than for pedestrians.

### **GERMANY**

In Germany, the police gather information about victims' injuries based on the information from the ambulance (rescue team), emergency room/admissions in hospital or other hospital departments or from the road users involved in the accidents. The police verify the information about victims' injuries only when it is necessary for their investigation procedures. Waiting time to have the information about victims' injuries verified depends on the necessity for police investigation procedures.

In Germany, the police do not assess injuries but use the information from the medical services or the road users involved in accidents. Injury severity is assessed based on the CARE definition.

The following methods are used as part of the quality control of the computer database: cross-checking of information consistency and completeness and plausibility checks.

Studies and reports about the underreporting of accidents and victims are available, including those relating to VRU accidents (*Dunkelziffer bei Unfällen mit Personenschaden Berichte der BAST/Reports of BAST M13 Bergisch Gladbach, 1993*).

In Germany, geographic coordinates in WGS84 format are used to determine accident location. Because geographic coordinates are not available nationwide, the location of accidents that occur in built-up areas is determined via another localisation system: road name(s) and number. In the case of accidents that occur in non-built-up areas, other localisation systems are used depending on the Bundesland: from netnode/to netnode/station; section No; road-km.

### **THE NETHERLANDS**

In the Netherlands, the following definitions are used:

- Road accident/injury accident – an incident on a public road that is traffic-related, inflicts damage to objects or injury to persons and involves at least one moving vehicle;
- Injured – a person that was physically harmed in a traffic accident;

- Seriously injured – the road user was hospitalized and treated in a Dutch hospital and has an AIS (Abbreviated Injury Scale) score of 2 or higher. Maximum AIS (MAIS) represents the road user’s most serious injury;
- Slightly injured – Not entirely sure, but we think that it is a road user who has been physically harmed, although with an AIS < 2.

Police registers are collected in a database created by the Ministry of Infrastructure and the Environment. The database is complete for about 90% of accidents with fatally injured persons. In the case of lighter injuries, the database is less complete. The actual number of victims is estimated by way of combining different databases (for example the police database and the national medical database). Another reason for this procedure is that the police is not always able to assess the seriousness of the injury.

The Dutch police do not register all traffic accidents and victims. The alternative registries are not complete either. The actual rates are estimated by combining resources. Registration by the police further deteriorated after the introduction of some new systems in 2009. Registration has been improving again since 2014.

The police register the accident in a special registration system (BVH). This information is subsequently transferred to the ministry. The ministry then registers the accidents (the vehicles, road users, injuries involved) in the national database (BRON). When the information is not sufficient or not clear, NO extra action is executed unless it was a serious accident with fatal or serious injuries. In which case the ministry contacts the police to:

- complement the missing information or correct false information
- determine the location if this is not possible based on the NWB (National Road Database)
- prevent double registration of an accident.

The ministry verifies the information about victims’ injuries. No information is available on the waiting time for this verification.

Comparison of police data with other data: information is not so much compared but rather combined from different databases since police registries of accidents are far from complete, especially in the case of accidents with light injuries.

Studies and reports about underreporting of accidents and victims are available at: [http://www.swov.nl/NL/Research/cijfers/Cijfers\\_Ongevallen.htm](http://www.swov.nl/NL/Research/cijfers/Cijfers_Ongevallen.htm). This website provides estimates of the actual accident numbers (fatal and severely injured). The national database is mostly complemented with the National Medical Registration database (information from hospitals). This ensures better information on the actual injuries in traffic accidents.

During police registration, the location is determined automatically from the national road database based on the street name and number. The accident is automatically located in the middle of a road section, so the exact location may differ from the registered location.

## **POLAND**

The definitions of road accident/injury accident and killed/fatally injured are the same as in CARE. The definition of seriously injured is different than in CARE. In Poland, a seriously injured person is one who suffered a severe disability, a serious incurable disease or a long-term life-threatening illness, a permanent mental disease, complete/significant permanent incapacity for work or substantial permanent body disfigurement or deformation. This definition also includes persons who suffered other

injuries that caused impaired organ function or derangement of health for a period of more than 7 days. A slightly injured person is one who suffered a health impairment, other than in the case of serious injury, that caused impaired organ function or derangement of health for a period of no more than 7 days, as diagnosed by the physician.

The police verify the injury in the case of suspected serious or fatal injury. The first verification is carried out on the day of the accident, and the second, 30 days after the accident. Police officers assess the severity of injuries based on the doctor’s opinion, their own opinion/experience and/or judicial documentation.

The quality control of the computer database is carried out continuously; when an error is detected in the process of data analysis, feedback is given to the police squad that is responsible for data collection/input for verification.

A report is available about the underreporting of accidents and victims: *Analiza możliwości wykorzystania informacji gromadzonych przez policję i w służbie zdrowia do oceny stanu bezpieczeństwa ruchu drogowego w Polsce*. This report does not focus on VRUs and is not available online but provides additional information which could be used to evaluate Poland’s road safety.

The definitions of: road accident/injury accident, fatally injured, injured, seriously injured and slightly injured applied in hospital injury databases in Poland are unknown. Physicians assess the severity of injuries using the ICD-10 classification.

Analyses can be performed based on the Polish national database but the database is not suitable for analysing VRU safety in the following aspects:

- scope of data – lack of information about the manoeuvres of the vehicles involved in an accident,
- reliability of data – lack of information about data verification procedures,
- completeness of data – lack of data concerning accidents that are unreported to the police, e.g. involving a cyclist and a pedestrian.

Some local authorities/territorial units have their own databases that allow more accurate analyses, including those associated with VRU accidents.

## **SPAIN**

In Spain, all of the definitions applied in the police road accident database are the same as in CARE, except for the “not injured” category which doesn’t exist.

To gather accident data, the police arrive at the scene, the data is collected on a paper form and later transferred to a computer database. However, some municipalities use their own database (different from the official one).

The police gather information about victims’ injuries based on the information from the ambulance (rescue team) or from the road users involved in the accidents but the police never verify this information. The severity of injuries is assessed by the police based on the doctor’s opinion.

As part of the quality control of the computer database, information is cross-checked for consistency. Several processes are carried out to verify and control the quality of the database.

Some municipalities use their own database to compare data with the police accident database. However, the public administration is working with the municipalities to change this situation. When the official and local databases are available, data concerning all of

the accidents registered in both databases are compared in terms of the location, victims, vehicles involved, type of accident, etc.

### **SWEDEN**

In Sweden, both police and hospital records end up in the STRADA database. Since the police is not good at judging injury severity, injury severity is defined based on the hospital register.

The killed/fatally injured is a person who died within 30 days of the accident. The injured is a road user who was seriously or slightly injured (but not killed within 30 days) in the road accident. The seriously injured is a person with an ISS score greater than 9, but there is also a “moderately injured” group with an ISS score of 4-8. Slightly injured are those with an ISS score of 1-3.

The police make a rough classification of the injury, but the final injury classification is made by the hospital personnel. Both the police and the hospital forms are entered into the STRADA database separately. Follow-ups are made and the STRADA database is updated up to 1 year after the accident date.

Police officers don't verify the information about victims' injuries – the hospital does. The police also don't assess the severity of injuries – the hospital does using AIS classification.

As part of the quality control of the computer database, police and hospital records are cross-checked. A study that compared injury accidents registered by the police and traffic injuries registered at the regional hospital in Lund, Sweden, showed that while the police register contained over 85% of injured car occupants, it only contained around 55% of injured bicyclists and only around 22% of injured pedestrians (Berntman et al., 1995). The conclusion from this was that police registers should be combined with hospital registers on traffic injuries. This is the case today in Sweden, where the STRADA database on traffic injuries combines the injury accident data from these two registers. Still, the coverage of the combined database is far from satisfactory; Berntman & Modén (2008) mapped the police records, hospital records and the Hospital Discharge Register in the region of Scania (southern Sweden) in 2004 and found that the police records and hospital records combined contained only 70% of the severely injured.

The Swedish STRADA database that contains accidents recorded by both the police and hospitals is used for comparison with the police accident database. The piece of information that allows to compare these data is the personal number of the accident victim.

Geographic coordinates are not used to determine the location of accidents in Sweden. In built-up areas, the street name and address are used to determine accident location and subsequently entered in the GIS map. If the accident occurs in a non-built-up area, the road number and road section are subsequently entered in the GIS map.

## **4.5. Summary and conclusions**

The information obtained through the InDeV questionnaire survey can be summarised as follows:

- Even in the case of the fundamental definition of “road accident/injury accident”, the definitions used by some countries (the Netherlands and Sweden) differ slightly from the standard used in the CARE database.
- Data on fatalities are quite comparable between the InDeV partner countries. According to the CARE glossary, a fatally injured person is one who dies on the spot or within 30 days of the accident. The CARE definitions of injury severity are applied only in Belgium, Germany and Spain.
- In all of the InDeV partner countries, accident data are collected on a paper form and transferred to a computer database. The information on crash severity is gathered from the ambulance (Belgium, Denmark, Germany, Spain), emergency room (Denmark, Germany, Poland, Sweden), other hospital departments (Germany and Sweden) and the road users involved in the accidents (Germany, the Netherlands, Spain). In the case of fatalities, the information about the accident is provided to the police by the judicial services in Belgium.
- Apart from Spain, the information about victims’ injuries is verified based on the information from hospital departments. The waiting time for the police check of the information on crash severity is not specified in Belgium. In Denmark, the verification is performed once a year by way of comparing the registry of injured road users with the registry of deceased persons in the case of road fatalities. In Germany, it depends on the necessity for police investigation procedures. In Poland, the information about victims is verified twice: on the day of the accident and 30 days after the accident. The verification of data in Sweden is performed automatically via the STRADA database, which links the police database with hospital registries.
- It is acknowledged that there is a large data gap in the Netherlands because the police do not register all traffic accidents, especially injuries. The actual number of victims is estimated by combining different databases.
- Most countries have various classification criteria of injury severity such as the doctor’s opinion (Denmark, Poland, Spain) and the length of hospital stay (Belgium). In Germany, the classification is based on CARE definitions. The AIS classification is used in the Netherlands and Sweden.
- In almost all InDeV partner countries, data quality control is carried out after data is transferred to a computer database; in Spain it is performed while filling out the paper form. Cross-checking for consistency of information is used in Denmark, Germany (also completeness and plausibility checks), Spain and Sweden (between police records and hospital records).
- Studies on the underreporting of road accidents have been performed and are available in most InDeV partner countries (except Spain); those associated with VRU accidents: in Denmark, Germany, the Netherlands and Sweden.
- The police accident databases are compared with hospital databases in Belgium (by research bureaus), Denmark (as part of research projects), the Netherlands and Sweden (the STRADA system) and with the databases maintained by municipalities in Spain.
- To define the location of an accident, two popular positioning systems are used: GPS (Belgium, Poland) and WGS84 (Germany, Poland, Spain). In Denmark, geographic coordinates in the 2000 EUREF89 system are used (UTM zone, 32 and 33 format). In the Netherlands and Sweden, the location of the accident is defined based on the street name and/or road number.



- In all countries except for the Netherlands, national databases are suitable for VRU safety analyses. The reliability of data was confirmed by almost all countries. The data on VRU victims is not complete in Belgium and Poland. In the Netherlands, there is a large gap in accident data (i.e. a serious underreporting problem since the Dutch police changed their system of gathering accident data in 2010: the number of seriously injured has dropped dramatically).

The literature review presented in this chapter and the responses to the InDeV survey allow us to formulate the following general conclusions:

- Despite efforts to harmonise the definitions of injury accidents and their severity at the European and global levels, differences exist both in the definitions and their interpretation.
- There are also considerable differences between countries in terms of accident data collection and data verification procedures resulting in varying levels of underreporting of the various accident categories. A new initiative is required to harmonise the data collection systems and procedures.
- The European CARE database was developed with a comprehensive structure and scope of information as defined in the CADaS glossary. The great advantage of using CARE for safety research is that it is a disaggregate database. However, the guidelines for the scope of data that is to be provided are not followed by all countries. For example, information on the accident type and traffic unit manoeuvres are not provided by most countries. The potential for safety analysis would be greatly improved if the guidelines were followed by all countries.

## 5. In-depth accident investigations

### 5.1. Description of in-depth accident investigation

Accident investigations can be ranked according to different levels, primarily according to the degree of detail in the investigation and the area or situations that they refer to (cf. also Table 5.1).

**Statistical accident investigations** are carried out at the national level in order to monitor the existing problems and trends in accident constellations. At the EU level, the national statistics are comprised in the CARE database as these are regarded the most representative for a specific country. At the global level, the International Traffic Safety Data and Analysis Group (IRTAD) provides a database and has recently published data about 32 countries (IRTAD, 2015).

At the **intermediate level**, special locations are investigated in more detail than in the national statistics, e.g. due to the increased frequency of accident occurrence (e.g. black spots).

**In-depth** accident investigations are the next, higher level of detail. In general, in-depth investigations differ intrinsically from accident analyses based on data obtained by the police at the national level due to the fact that the scientific aim is to understand accident causation and the way people are injured rather than to determine legal responsibility.

The large number of variables, typically a few hundred or more, makes it possible to investigate the mechanisms behind the occurrence of injuries sustained in an accident as well as their link to the design of the infrastructure or the vehicle. This approach aims to identify the factors that contribute to collisions and the sustained injuries with respect to a variety of parameters such as vehicle design, the design of the road environment, traffic management or human factors. Through statistical analysis, in-depth accident data represent current accident characteristics, while the investigation of the development of such characteristics over a longer period may provide evidence of the effectiveness of previously implemented safety measures.

However, one has to keep in mind that the definition of variables is naturally developed with respect to the purpose of investigation. Moreover, the scope of investigation varies greatly and is often more focussed on the vehicle involved. One has to distinguish between the more or less independent approaches (e.g. GIDAS) and non-independent investigations, for example the in-depth investigations of the Audi Accident Research Unit (AARU) from Audi AG where data are collected only if a new Audi vehicle (<2 years) is involved, cf. (Otte, 2015).

**Table 5.1: Categories/levels of road traffic accident investigations**

Level	Definition	Examples
<b>Statistical data collection</b>	Collection of anonymous accident data used mainly for monitoring trends, priority identification	<ul style="list-style-type: none"> <li>National statistics</li> <li>CARE database at EU level</li> <li>IRTAD</li> </ul>
<b>Intermediate level</b>	Medium-level investigations between the statistical and the in-depth, suitable for black spot management. Usually, a subsequent report is drawn up.	<ul style="list-style-type: none"> <li>Qualified police reports</li> <li>Insurance reports</li> </ul>
<b>In-depth investigations</b> (independent / non-independent)	Detailed multidisciplinary investigations, high number of variables (a few hundred to more than a thousand) aimed at developing safety measures through the discovery of structural failures, preferably representative for the country of investigation.	<ul style="list-style-type: none"> <li>GIDAS (Germany)</li> <li>see Table 5.2</li> </ul>
<b>Special accident investigations</b>	Serious or high social impact, normally carried out by government accident agencies. Multidisciplinary investigations with case-tailored methodologies aimed at preventing similar specific serious accidents.	<ul style="list-style-type: none"> <li>Investigations conducted after the Montblanc fire in 1999</li> </ul>

Source: (Moncleus, J., Löwenadler, L.-G., Maier, R., & Repussard, 2007)

Besides directly evaluating the effectiveness of (vehicle) safety systems, another approach is to use current accident information to gain information about the effectiveness of future systems through the reconstruction and simulation of accidents back in the pre-crash phase (see Pre-Crash Matrix, PCM), cf. (Helmer, 2015). The simulation of PCM accidents with generic vehicle safety systems makes it possible to assess the effectiveness of a system in specific situations or scenarios.

### Ingredients of in-depth investigations

One of the most important topics associated with in-depth investigations is the provision of a procedure for the **protection of personal data** once informed consent is obtained.

Data are obtained on-site and/or retrospectively through written observations, measurements and photographs. Thus, a defined **procedure for data collection** e.g. the technique of taking pictures or making alignments is needed.

**Medical data** are collected by interviewing accident participants and witnesses (defined interviewing procedure) and discussions with medical staff, if applicable, including special medical documents.

A variety **of technical data** are documented with respect to vehicle damage, infrastructural influences and other crash-related parameters.

There are several in-depth databases worldwide. The following information is extracted from the 2015 IRTAD report (IRTAD, 2015) or information is provided through IGLAD and further references (Björkman et al., 2008). The listing in Table 5.2 does not claim completeness.

**Table 5.2: Overview of in-depth databases worldwide**

Country	Description	Further information
<b>Australia</b>	<ul style="list-style-type: none"> <li>Research is carried out by the Centre of Automotive Research (CASR).</li> <li>The Australian National Crash In-depth Study (ANCIS) contains over 1000 fully investigated, serious injury crashes (retrospective).</li> <li>The Enhanced Crash Investigation Study (ECIS) is currently examining about 400 serious injury crashes.</li> </ul>	<p>(CASR, 2015)</p> <p>(“In-Depth Crash Investigations and Transport Regulation,” 2016)</p>
<b>Austria</b>	Central database of fatalities in Austria (Zentrale Datenbank zur Tiefenanalyse von Verkehrsunfällen – ZEDATU)	<p>(ZEDATU, 2016)</p> <p>(Tomasch and Steffan, 2007)</p>
<b>Belgium</b>	Fatalities on highways. In-depth analysis of fatal road traffic accidents on Belgian motorways between 2009 and 2013.	(Slootmans and De Schrijver, 2016)
<b>China</b>	Chinese In-Depth Accident Study (CIDAS) carried out by the China Automotive Technology and Research Center (CATARC)	(CATARC, 2016)
<b>Czech Republic</b>	Czech In-Depth Accident Study (CzIDAS) carried out by Idiada Czech and Centrum Dopravního Výzkumu (CDV)	(CzIDAS, 2016)
<b>Denmark</b>	Fatal accident statistics	(Vejdirektoratet, 2016) see 5.4
<b>France</b>	<ul style="list-style-type: none"> <li>In-depth investigations of crashes involving light goods vehicles (Etude Détaillée d’Accidents impliquant des Véhicules Utilitaires Légers – EDAVUL) at the IFSTTAR Laboratory of Accident Mechanism Analysis</li> <li>DIANA, an in-depth database and system for the analysis of real accidents is run and owned by the CIDAUT Foundation.</li> <li>The Rhône Register</li> </ul>	<p>(IFSTTAR, 2016)</p> <p>(Serre et al., 2015)</p> <p>(DIANA, 2016)</p> <p>(Rhône Register, 2016)</p>
<b>Germany</b>	<ul style="list-style-type: none"> <li>The ADAC Accident Investigation Study is carried out by the General German Automobile Club (ADAC) in cooperation with the helicopter rescue team of the ADAC.</li> <li>The German In-Depth Accident Study (GIDAS) is a joint venture of BAST and the Automotive Research Association (FAT) carried out by the accident research units of the Hannover Medical School (MHH) and TU Dresden (VUFO GmbH).</li> </ul>	<p>(ADAC, 2016)</p> <p>(GIDAS, 2016)</p> <p>(Traumaregister, 2016)</p>

	<ul style="list-style-type: none"> <li>The German TraumaRegister DGU® of the German Association of accident surgery (Deutsche Gesellschaft für Unfallchirurgie-DGU)</li> </ul>	
<b>Iceland</b>	An in-depth study is undertaken for each fatal crash and is recorded in a database. Data are studied by the Icelandic Transport Safety Board but since the number of fatalities in Iceland is low, fatality data is comprised in series of five consecutive years.	(IRTAD, 2015)
<b>India</b>	The Road Accident Sampling System in India (RASSI) carried out by JP Research India PVT LTD	(RASSI, 2016)
<b>Italy</b>	An in-depth accident database called LASIS is carried out by the Laboratorio per la Sicurezza e l'Infortunistica Stradale (LASIS) at the University of Firenze.	(LASIS, 2016)
<b>Malaysia</b>	In-depth crash investigation data collected by the Malaysian Institute of Road Safety Research (MIROS)	(MIROS, 2016)
<b>Spain</b>	Short-term investigations and the countrywide METRAS approach	see 5.4
<b>Sweden</b>	Fatal accident in-depth data collection is carried out by the Swedish Transport Administration (Trafikverket).	(Trafikverket, 2016)
<b>The Netherlands</b>	In-depth data regarding elderly cyclists	see 5.4
<b>UK</b>	Road Accident In-Depth Studies (RAIDS) carried out by the Department for Transport	(RAIDS, 2016)
<b>USA</b>	National Automotive Sampling System (NASS) run by the National Highway Traffic Safety Administration (NHTSA)	(NASS, 2016)

## 5.2. Overview of the method’s applications

Due to the large number of variables (a few hundred to a few thousand depending on the particular study) that are collected from the environment and infrastructure as well as the technical data of the accident and medical information on the participants, in-depth studies can be used to investigate a broad field of road traffic accident research.

The use of a statistical approach to data collection makes it possible to relate in-depth data to nationwide accident occurrence and allows extrapolations. This procedure is performed e.g. to estimate the number of MAIS3+ injured road casualties in Germany (Niesen et al., 2016).

The virtual reconstruction of the technical aspects of an accident allows to investigate measures such as vehicle speeds and collision velocities. Apart from technical issues, accident causation can also be investigated using information about human factors (interviews with participants) as well as the medical outcome (medical data from hospitals) and the causation of injuries (e.g. the responsible vehicle parts).

### 5.3. Studies related to VRU safety performed in InDeV partner countries

The questionnaire (Form B) that was sent to InDeV partners formed part of the project that aimed to assess the type of intermediate, in-depth and special investigation studies carried out in partner countries: overall and with respect to VRU safety in particular. To evaluate the in-depth investigations, information about the area, time period and scope of study was requested. The request also included the criteria for data collection, the extent of variables and the number of cases as well as the possibility of data access and the obtained results/publications within the project.

All of the partners responded to the questionnaire with respect to their countries. The very general results of the survey are summarized in Table 5.3.

**Table 5.3: Results of the InDeV questionnaire concerning in-depth investigations in partner countries**

Country	Kind of study/Specifications	Access by InDeV partners
Belgium	Study for legal purposes (public attorney)	No
Denmark	Fatal accident statistics	Yes
	Study according to specific questions	No
Germany	Study recording all road accidents with personal injuries in determined area of investigation and 12 hours per day	Yes
The Netherlands	Studies about crashes involving 50+ cyclists	Yes
	Study on the factors that influence road crashes. Two types of crashes were studied: run-off-road crashes and crashes involving delivery vehicles (Davidse, 2012)	Yes
Poland	Study about crashes including motorcyclists	Yes
Spain	METRAS	
	Study about crashes involving pedestrians	Report only
	Fatal accident statistics	No
Sweden	Fatal accident studies	Yes

#### 5.3.1. Fatal accident statistics

In **Denmark**, fatal accident statistics have been collected since 2010 (Elvebakk et al., 2014; Vejdirektoratet Denmark, 2014). The studies are conducted by the Danish Road Directory (Vejdirektorat) with a 24-7 approach and contain information about all fatalities from all modes of traffic (except train/tram) with about 200 cases per year; however, the number of variables is comparatively low (51). Besides the reports cited above, the data are accessible via Aalborg University for further analysis.

In **Sweden**, studies of all fatal accidents have been conducted by the Swedish Transport Administration (Trafikverket) since 1976. The 24-7 approach covers all fatalities countrywide irrespective of the traffic participation mode. Trafikverket’s investigations into fatal accidents are compiled in a database called the “In-depth Client”. The data are not

easily accessible due to restrictions concerning their use but access for further analysis within the InDeV project could be achieved through Trafikverket (Lars Ekman).

The report entitled “Fatalities at Roadworks” is based on Trafikverket’s in-depth studies of fatal accidents. The aim of this report is to study traffic accidents in connection with roadworks between 2003 and 2013 where the accidents resulted in fatal injuries. Each year, at least 300 traffic accidents resulting in personal injuries occur in connection with roadworks. Between 2003 and 2013, 51 fatal accidents occurred in connection with roadworks with a total of 56 people killed. **Six of the deceased were road workers** and the others were road users. Five of the six road workers that were killed had been involved in mobile or intermittent type of work. Based on the material in the Client, it is sometimes difficult to provide an overall picture of why the accidents occurred and what role the roadworks played in the accidents.

#### *Recommendations*

- warning signs or other warning devices should be positioned well before queues are estimated to begin
- mobile roadworks: motorists need to effectively be made aware of the utility vehicle and its considerably lower speed

In **Spain**, a report is carried out on fatal accidents in the state road network. For the fatal accidents in the state road network, a more detailed data collection form (17 variables) is filled in by an expert in the field at the site of the accident. On average, about 200 cases are recorded per year. This data is not public.

### **5.3.2. Limited time studies addressing specific questions**

Since 2010, the City of Antwerp in Belgium has been conducting a study that aims to include all fatal accidents (50-250 per year) and focuses on legal purposes. The data are not systematically stored in a database and not easily accessible. There are no publications available and the benefit of these data for the InDeV project is assumed low.

In **Denmark**, an in-depth investigation is carried out by the Accident Investigation Board, AIB (Havarkommissionen for vejtrafikulykker). In a defined area of interest, accidents concerning fatally and seriously injured pedestrians are investigated in a period of months up to a year. The nearly 300 cases are available (2010-2013) although not accessible at the moment, but an application for access is possible via Aalborg University for further data analysis. The following conclusions concerning VRU safety may be drawn from publications based on these data:

- **Motorcyclists** (AIB, 2009)

The report contains an investigation of 41 motorcycle accidents, 30 of which involved another party, typically a passenger car. The remaining 11 were single-vehicle accidents. 14 of the motorcyclists were killed, 9 were seriously injured and 18 were moderately or slightly injured. There were pillion passengers in 6 of the accidents. All 6 were injured; 3 seriously. All of the accidents could have been avoided with more careful traffic behaviour. In 1/3 of the accidents involving another party, the accident factor belonged to the motorcyclist; in 1/3, it was the second party and in 1/3, both the motorcyclist and second party were responsible.

- *Motorcyclists themselves can contribute to traffic safety*  
Excessive speed, wrong interpretation of the situation, wrong manoeuvre or reaction, bad braking technique
- *The second party can contribute to motorcyclists' safety*  
Insufficient awareness, rear awareness (motorcyclist overtaking a left-turning car)
- *Increased policing will ensure that more motorcyclists observe traffic laws*  
speeding, drunk driving, inspection of driving licence
- *Safer roads can prevent accidents and result in less serious accidents*  
Lack of maintenance, inconsiderate design of roads  
Many of the accidents occurred when the second party turned left
- *New technical requirements must be introduced for motorcycles*  
Only 2 of the motorcycles in the 41 accidents had ABS brakes

- **Accidents with pedestrians and cars/vans** (Vejdirektoratet Denmark, 2013)

The detailed study of 27 road accidents involving pedestrians in cities is limited to accidents involving pedestrians and cars or vans where serious injury or death occurred. 2/3 of the pedestrians (19 out of 27) in the study were particularly vulnerable for one reason or another (children, elderly, alcoholised, invisible handicaps). None of them possessed either optimal mental or physical capacity to manage themselves effectively in the traffic environment. In 20 out of 27 accidents, the pedestrian was shown to have contributed to its cause. 27 pedestrians were injured, 4 pedestrians were killed.

The accidents were classified into various subgroups, typical scenarios or types of accident according to their common features. Several accidents fit into more than one of these subgroups.

- *Accidents while reversing (5 accidents)*  
Drivers did not take sufficient care  
Restricted view through the rear window  
The vehicle was not equipped with an alarm sensor in any of the cases
- *Accidents on the sidewalk (6 accidents)*  
The driver had lost control  
Excessive speed and risky behaviour of the driver
- *Accidents taking place in the dark (10 accidents)*  
Mostly younger drivers and pedestrians  
Speeding as the main cause
- *Accidents involving children (9 accidents)*  
Insufficient perception of the surroundings, misinterpretation of pedestrian behaviour, or driving through red/yellow traffic lights  
Close to the child's home or in familiar surroundings
- *Accidents related to crossing the road (16 accidents)*



Both drivers and pedestrians had a share in the cause.

Misinterpretation of the other party's actions

Pedestrians: pre-occupied/busy, alcoholised

The pedestrian actually crossed the road only 30-100 meters from a pedestrian crossing.

Motorists: mainly lack of attention, poor orientation

- **Right-turning lorries and cyclist** (Vejdirektoratet Denmark, 2006)

Traffic accidents involving lorries turning right and cyclists travelling straight on are often fatal or lead to serious injuries in the cyclists involved, i.e. about a quarter of all cyclists are killed or injured in these types of accidents. New rules were introduced in 2004 to improve lorry drivers' view by mounting additional or new side mirrors: the so called blind-spot mirror, new mirrors with a greater curvature, mirrors with a larger mirror area, or mounting a camera. However, these new requirements did not lead to a decrease in the number of cyclists killed and injured in these types of accidents.

25 accidents were investigated in an eight-month period in 2005. 9 cyclists were killed, 1 cyclist was seriously injured, and 14 cyclists suffered minor or moderate injuries. 16 cyclists were run over by one or more of the lorry wheels, while the remaining cyclists were injured due to collision with the vehicle body. None of the lorry drivers suffered physical injuries.

*Results and recommendations*

- Unsuccessful lookout for cyclists was an accident factor in all 25 accidents.
- The lack of awareness of the hazards involved in making a right turn is an issue. The driver looked out for cyclists but did not use the correct mirrors or did so at the wrong time, or checked the mirrors but typically not the close-proximity or blind-spot mirrors.

*Campaigns aimed at lorry drivers should focus on responsibility and attention.*

- Inattentiveness or the lack of attention was a contributory accident factor in 9 of the 25 drivers. Inattentiveness was also a contributing factor in 3 of the cyclists.

*Campaigns aimed at cyclists should make them aware of their own vulnerability, focus on due care and attention.*

- Lorry drivers have limited low-level visibility and a reduced field of view through windscreen and side windows.

*Lorries should have a low-level window on the right and a low-level windscreen.*

*Adjusting the mirror should be an easy task.*

*Mirror adjustment and the driver's field of view should be inspected.*

*Lorry driver learning courses and driving tests should include the correct adjustment and use of mirrors.*

*Police control.*

*Requirements of mirror or camera coverage of the front zone for all lorry vehicles.*

*Lorry mirrors should comprise a single mirror unit that can be viewed in one glance.*

- Right-of-way regulations should be amended to force right-turning vehicles to stop before crossing the cycle lane. Better road designs can help prevent right-turn accidents.

*New rules should require lorries to stop and check traffic prior to and during the turning manoeuvre.*

*All signalled junctions should be redesigned to improve the safety of cyclists.*

- **Accidents between cyclists and motor vehicles at road junctions** (Vejdirektoratet Denmark, 2008)

The investigation (30 cases, in 2005) was limited to junctions with dedicated right-of-way as opposed to signal-controlled junctions. These accidents comprise 35-40% of all accidents involving cyclists, as registered by the police. All accidents occurred in daylight hours and in dry weather conditions.

- 24 accidents occurred in urban areas, the remaining six in rural locations.
- In terms of vehicle distribution, the accidents involved 18 cars, 7 lorry vehicles, 3 vans and 2 busses.
- 13 cyclists were killed, 9 of which were over 65 years of age.
- 10 cyclists were seriously injured, 2 were moderately injured and 5, slightly injured. 13 of these were 65+.

12 of the 13 elderly cyclists contributed to the cause of the accident, basically displaying a lack of diligence with respect to other road users. In the cases where cyclists were under the age of 65, only 9 out of the 17 cyclists contributed to the cause of the accident in which they were involved.

- Bad habits in traffic are more than likely to have led to the accidents.

Recommendations concerning elderly:

- Campaigns that target the promotion of safer behaviour in elderly cyclists when turning left at road junctions.
- The implementation of special equipment for elderly cyclists, e.g. tricycles.

In **the Netherlands**, a special in-depth investigation concerning cyclists (50+) was conducted for 4 months in 2012 by SWOV in the provinces of Zuid-Holland and Zeeland (41 cases). However, the study did not consider accidents between cyclists and motorized traffic. Data are available for further analysis. The existing publications yielded the following results:

- **Injury accidents with 50+ cyclists in Zeeland** (Davidse and SWOV, 2014)

In the province of Zeeland in the Netherlands, the SWOV performed an in-depth analysis into accidents in which 50+ cyclists had fallen off the bike, had been riding against an obstacle or had collided with another cyclist or a powered two-wheeler. The SWOV team studied 35 accidents. This resulted in 8 accident scenarios. These scenarios show how these accidents evolve as well as the relevant aspects of the road, the cycle lane, human behaviour and the vehicle.

- **Injury accidents with 50+ cyclists** (Davidse and SWOV, 2014)

The SWOV performed an in-depth analysis into accidents in which 50+ cyclists had fallen off the bike, had been riding against an obstacle or had collided with another cyclists or powered two-wheeler. The SWOV team studied 41 accidents. This resulted in 8 accident scenarios. These scenarios show how these accidents evolve and the relevant aspects of the road, the cycle lane, human behaviour and the vehicle.

3 patterns may be identified in the different scenarios:

- many collisions and one-sided accidents are preceded by an interaction with another road user not involved in the actual collision or accident,
- particular subtypes of accidents are related to gender, age and/or bike type,
- the common feature of accidents with severe injuries (MAIS2 and above) is the involvement of a racing cyclist. This suggests that the high speed of these cyclists played a role.

- **Study on the influence factors of road crashes** (Davidse, 2012)

This is a summary and evaluation of the results of a pilot study about in-depth research carried out by SWOV during the period of 2008-2011. The evaluation focuses on specific types of road crashes: run-off-road crashes and crashes involving delivery vehicles. The general benefit of the study is evaluated and the main findings are as follows:

- many of the crash locations did not comply with the guidelines for safe roadsides, such as prescribed marking and signposting of tight bends and the use of crash-friendly lighting poles (run-off crashes)
- a reversing driver of a delivery vehicle crashes into a pedestrian walking behind the vehicle, leading to the pedestrian falling and ending up under the delivery vehicle; this results in serious injury (MAIS4) or death – so far not reported in regular Dutch crash studies.
- in-depth research is suitable for identifying the causes of crashes for which little information is available thus far (such as single vehicle crashes) and is particularly suitable for answering research questions that require insight into the crash process and into the detailed circumstances at the time of the crash.

In **Poland**, the Motor Transport Institute conducted an in-depth study on motorcycle accident causation in the Warsaw area in 2010 (173 cases, 50 variables). The data was collected directly at the site of the accident or from the police officers who were present at the site. The data are accessible for further analysis through the Motor Transport Institute (Anna Zielińska).

Furthermore, statistical data concerning accidents involving motorcyclists obtained from the police database called SEWiK, the collected data concerning accidents and the results of international research were analysed. Moreover, regulations concerning motorcyclists were compared. (Zielińska et al., 2011). In motorcyclists, the number of fatalities increased by 63% and those injured, by 41% between the years 2001-2010. In-depth analyses of accidents and collisions involving motorcyclists were carried out to determine the main sources of danger for this group of traffic participants.

In **Spain**, research on pedestrian protection was conducted based on data from in-depth studies of traffic accidents in 3 cities (139 cases) and aimed to:

- Create a protocol for data collection on accidents with pedestrians involved to prevent these.
- Create a database of traffic accidents with pedestrians involved.
- Analyse the representativeness of the current experimental methods to determine the level of protection that a vehicle really provides to pedestrians.
- Evaluate, prospectively, the expected effectiveness of different pedestrian protection systems designed to be incorporated in the next generation of vehicles.

The methodology was established in two phases (Olona, 2008). First, the main parameters of this type of accident were set by establishing the criteria for case selection. Accidents were analysed where the pedestrian was run over by the front of a car/minivan/SUV. The analysis was possible due to cooperation agreements with police and city councils. This permitted the creation of multidisciplinary working teams that analysed the accidents on site. Second, for all cases the real situation was compared to what would have happened if the vehicle had been equipped with ABS + BAS (Break Assistance System) and a pedestrian detection system with an automatic brake. The considered variations included speed and injury severity. In this project, a database for research on pedestrian protection containing the 139 accidents compiles extensive information on the vehicle, pedestrian (anthropometric, injuries) and scenario. Some basic results are presented below:

- 59% of pedestrians were men and 41%, women.
- 34% of pedestrians were over 60 and 21%, under 20.
- In 71% of the cases, the speed was below 41 km/h. Additionally, there was some evidence that in all 71% of the cases the driver had made some braking manoeuvre before the crash.
- In 49% of the cases, the vehicle was equipped with ABS, and with BAS in just 8%.
- In 48% of cases, the crash would have been avoided if the vehicle was equipped with an automatic pedestrian detection system.
- In 11% of the cases, the crash would have been avoided if the vehicle was equipped with ABS + BAS.
- 44% of accidents would not have been avoided with any of the analysed systems.
- In 21% of cases, BAS would have reduced the vehicle speed to less than half of its velocity at the time of collision.
- In 74% of cases, a pedestrian detection + automatic braking system would have reduced the vehicle speed to less than half of its initial velocity at the time of collision.
- In 18% of cases, the ratio of severe head injury would have been reduced by 80% if the vehicle had been equipped with ABS + BAS.
- In 66% of cases, the ratio of severe head injury would have been reduced by 80% if the vehicle had been equipped with a pedestrian detection and automatic braking system.

Short-term (1 year) in-depth accident investigations on pedestrian accidents were carried out by Centro Zaragoza and IDIADA Spain (IDIADA, 2011). The aim of these studies was to review and summarize the principal existing methodologies for the in-depth research

of accidents in Europe. However, the usefulness of these data is assumed to be low for the InDeV project because there is no public access to the data except for the results shown.

The accidents on the Spanish territory were examined to identify those not sufficiently or adequately covered by the existing information systems. The sample was determined by the geographical distribution and included more frequent cases because no classification methodology has been established for accident types in Spain. The second part of the project reviewed all investigation activities running in Europe in order to determine the best practices and specify the main requirements of accident investigation protocols. The project analysed different methodologies around the world: in the United Kingdom, Germany, Finland, France, Sweden, the Netherlands and Spain (Basque Country and Catalonia). In accordance with the findings of the second part of the project, accident investigations can be classified as described above (cf. Table 5.1).

### **5.3.3. Permanent studies**

In **Germany**, the permanent German In-Depth Accident Study (GIDAS) has been conducted by the Federal Highway Research Institute (BAST) and the Research Association of Automotive Technology (FAT) since 1999. The project has a 24-7 approach and is carried out in the regions of Hanover and Dresden. The research teams, consisting of two technical and one medical investigators, are informed by the police about an accident. The inclusion criterion is an accident with at least one person injured (without single pedestrian accidents). Thus, the project collects about 2 000 cases per year with up to 3 000 variables concerning environmental, technical and medical data, includes all modes of traffic and is considered to be statistically representative for all of Germany (Otte, 2015; Otte et al., 2013). Publications on VRU safety based on that data are available. Full access to the data within the InDeV project for specific analysis is provided by BAST.

In terms of methodology, the so-called METRAS method was developed in **Spain**. METRAS (Measuring and Recording Traffic Accident Sequence) is a method of accident data collection that improves the limitations of traditional accident type classification methods by collecting and coding the sequence of events that happened during the course of a traffic accident in an ordinate and detailed way. The method was developed by IRTAD and describes each event with its corresponding traffic unit according to its order of appearance, and in a relatively simple, practical and accessible way in the context of the police statistical accident form.

This method allows to collect each event and assign it to the traffic units involved, as well as to determine its relationship with the elements that were present before the accident in an effort to help explore both the possible preventive measures and those directed at appropriate intervention on the road, in the vehicle and in the person. The objective is to achieve a greater level of accuracy in the collected information and to reflect the development of the dynamic process of the accident by defining the key aspects of its progress (Tormo et al., 2009).

## **5.4. Best practice examples of in-depth studies**

At the international level, it is always hard to compare the results of different databases due to the different definitions of variables, different foci of investigation and different ranges of data representativeness. The international approach of the IGLAD project

which aims to homogenize in-depth data at the global level to provide comparability seems to be the best practice approach for the international level.

At the national level, a database that provides statistical representativeness for an area or the entire country, e.g. GIDAS, is the best solution when multiple questions are to be answered. However, this might be the most expensive solution and one that is useful only if the study is conducted over a longer period of time.

For specific research questions, short-term studies that are restricted to specific accident constellations (such as the pedestrian/cyclist-related studies presented above) may be conducted relatively easily but still come along with a high amount of manpower and time.

## 5.5. Summary

In-depth investigations are a good tool to investigate crash scenarios and configurations both at the single-case level and at a level where a statistical approach is used to find crash/injury contributing factors.

This method allows to derive general safety measures; however, the conclusions of single studies should be discussed in the context of their limitations and the possible biases in the investigation method. Statistical analyses are possible but if the number of cases, the period of time, and variables are limited, a limited knowledge and validity can be expected. The comparison of different in-depth databases is difficult due to the different investigation criteria used. For a national comparison, the IGLAD project (IGLAD, n.d.) seems to be appropriate to provide comparable in-depth data in the near future.

In-depth investigations are time- and cost-consuming, but highly effective in terms of the investigation of individual crashes as well as the investigation of a large number of accidents with the aim of answering specific questions and gaining insight. Large datasets allow to investigate a wide range of questions that may potentially be raised.

Even on-site investigations have their drawbacks, such as the retrospective view (compared to video-documented crashes) and the introduction of uncertainties in the process of data collection and encoding e.g. due to interpretation.

All of the reported studies are useful for analyses regarding VRUs. The following studies appear to be the most useful for analyses regarding VRU safety:

- National fatal accident statistics
- Specific studies on crashes involving pedestrians and/or motorcycles
- GIDAS – the permanent German In-Depth Accident Study.

## **6. Naturalistic driving studies**

### **6.1. Description of the naturalistic driving study method**

Knowledge about the process leading up to the occurrence of an accident is important in road safety evaluations. In particular, the behaviour of road users and the situational aspects in the seconds preceding the accident can provide useful information about the chain of events whose end result was the accident. However, this information is not available from official accident records kept by the police and/or hospital, which consist primarily of information that is gathered after the accident had occurred, based on observations and interviews at the accident site, e.g. the location, the time and date, who was involved, the weather conditions, road surface conditions, the manoeuvres of the road users, etc.

Naturalistic studies can be used to collect information about road user behaviour. In a naturalistic study, data is collected continuously and unobtrusively from road users while they travel in their own vehicle during their daily trips, as they normally do.

Special equipment is installed in the vehicle to collect data concerning the road user, the vehicle and the surrounding environment. For instance, information about the speed, acceleration, deceleration, location, position on the road, turning movements, pedal use, weather, road and traffic conditions is collected via sensors. Usually, multiple video cameras are installed to supplement travel information with video recordings of the surroundings as well as the road user. This makes it possible to see what the road users saw, e.g. with the use of eye tracking, and to observe their reactions during the trip and the in-vehicle activities that they performed while travelling. For vulnerable road users, however, the weight and size of the equipment is a crucial issue during naturalistic data collection. Nevertheless, since many road users carry a smartphone while travelling and most new smartphones have built-in sensors such as accelerometers, gyroscopes, magnetometers and GPS receivers, there is a large potential for the use of smartphones instead of special equipment in naturalistic studies.

The intention of a naturalistic study is to observe the road users in a naturalistic setting where they are not influenced by the study, not given instructions and no intervention is made as to how, where and when to travel. Studies have shown that although the presence of the equipment for data collection can influence the behaviour of the road users in the beginning due to their awareness of being observed, the road users will quickly grow accustomed to its presence and forget that it is there (Jørgensen, 2010).

Other methods are also used to collect information about road user behaviour. In controlled experiments, e.g. conducted in a driving simulator, researchers can obtain information about road user behaviour while controlling for factors that may influence behaviour. Furthermore, the experiment can be run multiple times and/or with different road users under the exact same conditions every time. The disadvantage compared to naturalistic studies is, however, that the observed behaviour may be different than actual traffic behaviour. In behavioural observation studies, road users are observed at a specific location without knowing that they are observed. No equipment is installed in the vehicle but it can be present on-site to collect naturalistic data from the road users travelling at a particular location. While this type of observations is useful for assessments of the behaviour at a specific location, no continuous data can be collected to provide an overview of the behaviour over a longer distance or for whole trips.

The collection of continuous data in a naturalistic study is particularly interesting from a traffic safety perspective because it makes it possible to collect data from actual safety-critical situations or actual accidents. Although accidents are rare, and the occurrence of safety-critical events is only a bit more frequent, naturalistic studies often involve large numbers of road users collecting data over a long period of time, e.g. months or years, which increases the probability of observing these events. The data collected before, during and after safety-critical events or accidents contains important information about the interplay between the road user, the vehicle and the environment as well as the interaction between the road users involved in the situation. By observing and analysing these events, it is possible to increase knowledge about the course of an accident or near-accident. This is particularly important for vulnerable road users, since naturalistic riding, cycling or walking studies can potentially be a means to compensate for the large degree of underreporting of accidents, which is higher for vulnerable road users – especially for cyclists – compared to other modes of transport.

## 6.2. Overview of the application of naturalistic studies

The collection of naturalistic data using equipped vehicles originally involved studies of passenger cars in naturalistic driving studies. Examples of such studies include *The 100-Car Naturalistic Driving Study*, *The Strategic Highway Research Program 2 (SHRP2)*, *The Australian Naturalistic Driving Study* and *UDRIVE*. In *The 100-Car Naturalistic Driving Study*, which was one of the first naturalistic studies in the United States, 100 passenger cars were equipped with various sensors such as video cameras, an accelerometer, a radar antenna and a GPS sensor to collect data for about one year (Neale et al., 2005).

In a subsequent study, the SHRP2, 3 147 participants drove for up to 38 months with special equipment installed in their private cars (Blatt et al., 2015).

In Australia, a naturalistic driving study is being conducted with 108 drivers of passenger cars so far who have had their private vehicle equipped with sensors such as video cameras, GPS, accelerometers, gyroscopes, radar, lane trackers, etc. The aim is to have 360 drivers collecting data for four months each (University of South Wales, 2016, n.d.)

Although many naturalistic studies have focused on passenger cars, other types of vehicles can be fitted with special equipment as well. For instance, the first large-scale European naturalistic driving study, UDRIVE, collects data from 120 passenger cars, 40 trucks and 40 powered two-wheelers (Barnard et al., 2016).

Naturalistic travel data has also been collected from vulnerable road users and used for accident detection or accident prevention. For instance, naturalistic riding data from equipped motorcycles was collected with the purpose of detecting accidents and detecting obstacles to prevent crashes (Attal et al., 2014; Boubezoul et al., 2013; Fang et al., 2014; Vlahogianni et al., 2014). For pedestrians, naturalistic walking data was collected to warn the visually impaired that they were approaching stairs (Lin et al., 2014) and to assess their behaviour before crossing the street (Dozza et al., 2014b). Similarly, naturalistic cycling data was collected from equipped bicycles to detect accidents (Dozza and Werneke, 2014).

Naturalistic studies have also been conducted to collect data for travel surveys, e.g. (L. Gustafsson & Archer, 2013), mode classification, e.g. (Nitsche et al., 2014; Shin et al., 2015; Xiao et al., 2015), mileage measurements e.g. (Hamann et al., 2014) and traffic counts (Strauss et al., 2015; Xiao et al., 2015).



### **6.3. Summary of a scoping review of literature on naturalistic driving studies**

A systematic literature review was carried out with the aim of assessing the extent and nature of naturalistic studies for vulnerable road users. A full report on the review can be found in Appendix 4 (part 2 of this report).

The purpose of the review was to identify studies based on naturalistic data from vulnerable road users (pedestrians, cyclists, moped riders and motorcyclists) to provide an overview of how data was collected and used. In the literature review, the use of naturalistic studies as a tool for road safety evaluations was given special attention.

Four databases were used in the search for publications: ScienceDirect, Transport Research International Documentation (TRID), IEEE Xplore and PubMed.

The systematic literature review covered the following types of studies:

- Studies collecting naturalistic data from vulnerable road users (pedestrians, cyclists, moped riders, motorcyclists).
- Studies collecting accidents or safety-critical situations via smartphones from vulnerable road users and motorized vehicles.
- Studies collecting falls that did not occur on roads via smartphones.

To identify the relevant studies, combinations of the search terms “naturalistic”, “smartphone”, “mobile phone”, “fall”, “accident”, “crash” and variations of road user types (e.g. pedestrian, walking, bicycle, cyclist, moped, PTW, motorcycle, etc.) were used.

The search was carried out in February 2016 and resulted in a total of 1 592 hits in the four databases. After the removal of duplicate publications that showed up in multiple databases and the removal of publications that did not meet the inclusion criteria (via screenings of titles and abstracts and screenings of full texts), 80 publications remained. Of these, 42 described naturalistic studies of vulnerable road users and 38 described studies of falls that did not occur on roads, e.g. falls among the elderly in their home. Naturalistic studies of vulnerable road users were carried out primarily by way of data collection from cyclists and pedestrians and to a smaller degree, from motorcyclists. Data was collected in two ways: using specially equipped bicycles/mopeds/motorcycles or using portable equipment, e.g. smartphones, GPS receivers, etc. Most studies used the built-in sensors of smartphones for data collection, although equipped bicycles or motorcycles were used in some studies. Other types of portable equipment were used to a lesser degree, particularly for cycling studies.

The naturalistic studies were carried out for various purposes: mode classification, travel surveys, measuring the distance and number of trips travelled and conducting traffic counts. Naturalistic data was also used for the assessment of safety based on accidents, safety-critical events or other safety-related aspects such as speed behaviour, head turning and obstacle detection.

Few studies that assess safety by identifying accidents or safety-critical events detect incidents automatically based on indicators collected via special equipment such as accelerometers, gyroscopes, GPS receivers, switches, etc. Instead, studies rely on self-reporting or the manual review of video footage.

The results of the review indicate that there is a large potential for detecting accidents via naturalistic data. A large number of studies focused on the detection of falls among elderly people. Participants’ movements were monitored continuously using smartphone sensors. Most studies used acceleration as an indicator of falls. In some cases, measurements of acceleration were supplemented by measurements of rotation to indicate the occurrence of a fall.

Most studies where kinematic triggers were used for the detection of falls, accidents and safety-critical events served primarily to demonstrate the prototypes of detection algorithms. Few studies involved real accidents or falls. Instead, simulated falls were used in both studies of vulnerable road users and studies of falls in elderly people.

## 6.4. Studies related to VRU safety performed in InDeV partner countries

A questionnaire survey was carried out among the project partners. The aim of the questionnaire was to identify naturalistic driving studies of vulnerable road users (cyclists, pedestrians, moped riders and motorcyclists) in each partner country. Only studies in which the data was collected by the vulnerable road user were included. Thus, if data was collected from cars, the study was not included, even when the study focused on vulnerable road users.

In total, 7 studies were reported from the partner countries (see Table 6.1).

**Table 6.1: Naturalistic driving studies of VRUs in partner countries**

Country	Survey responses	Description
<b>Canada (PM)</b>	1	Cyclists, smartphone
<b>Denmark (AAU)</b>	1	Cyclists, smartphone
<b>Germany (BAST)</b>	1	Cyclists, equipped bicycle
<b>The Netherlands (TNO)</b>	1	Cyclists, equipped bicycle
<b>Poland (WUT)</b>	0	-
<b>Spain (INTRA)</b>	1	Cyclists, questionnaire
<b>Sweden (LU)</b>	2	Cyclists, equipped bicycle Cyclists, smartphone

All studies reported by the partner countries dealt with naturalistic studies of cyclists. No studies with pedestrians were found. Out of the seven studies, three collected data from equipped bicycles (Germany, the Netherlands, Sweden), three via smartphones (Canada, Denmark, Sweden) and one via questionnaires only (Spain).

A German study was conducted to compare the safety of electric bicycles compared to regular bikes. Data was collected by a bicycle equipped with two cameras, a GPS sensor, sensors on wheels, pedals and brakes, and an accelerometer. The study showed that the use of electric bicycles did not result in an increased number of critical situations (Schleinitz et al., 2014).

In the Netherlands, naturalistic cycling studies were carried out to study potentially dangerous situations and dangerous behaviours. GPS data, video footage, speed and

lateral position were collected with an equipped bicycle (Westerhuis and de Waard, 2014).

In Denmark and Canada, smartphone apps (Canada: Mon RésoVélo (Ville de Montréal, 2015), Denmark: Herning Cykler (Herning Komune, 2015)) have been developed to collect naturalistic cycling data via the smartphone. The Danish app collects data about the location of the smartphone and thus tracks users' routes. From the smartphone, measurements of GPS position, acceleration and vibration determined if the trip was carried out on a bicycle or in a car. The data was used for road user classification, the identification of popular bike routes and to provide cycling statistics (trip length, speed, etc.). The Canadian data have furthermore been applied for the detection of dangerous situations based on acceleration measurements.

In Sweden, the BikeSAFE project studied how cyclists obey traffic rules by collecting naturalistic cycling data with an equipped bicycle. Intersections, road maintenance and interaction with other road users were identified as the factors contributing to accident causation (Dozza et al., 2013).

Another study in Sweden explored if cyclist data could be collected with the smartphone and used to detect cyclist accidents so that an eCall function for cyclists could be developed (Candefjord et al., 2014). Acceleration, rotation, position and speed were collected from the built-in sensors of the smartphone. Based on acceleration and rotation data, cyclist accidents were detected. However, this was a small feasibility study of only 5.5 hours and accident detection was not tested with real accidents. Nevertheless, the study showed that it does seem possible to create an algorithm for real-time motion analysis and crash detection of cyclists via the built-in sensors of smartphones.

Only one study combined the use of smartphones and accident detection (Candefjord et al., 2014). In the study, 5-6 hours of naturalistic cycling data and six crashes using a crash test dummy were recorded. All crashes were properly detected via the smartphone app. However, the study was small and the ability to detect real accidents was not assessed.

## **6.5. Best practice examples of naturalistic driving studies**

Naturalistic studies of vulnerable road users for safety assessment have mainly been carried out for cyclists and motorcyclists. The safety of cyclists was assessed in several naturalistic studies. In the *German Naturalistic Cycling Study* (Schleinitz et al., 2015), 31 cyclists were monitored via speed sensors, video cameras and switches mounted on the bicycle. 77 safety-critical events were identified from the video footage. In a Swedish naturalistic cycling study (Gustafsson and Archer, 2013), 16 cyclists collected naturalistic data from GPS receivers and video cameras. Safety-critical events were self-reported via trip diaries. During the study, the cyclists registered 220 safety-critical events. An Australian cycling study (Johnson et al., 2015) studied the behaviour of 36 cyclists using almost 9 000 km of naturalistic cycling data. An analysis of the video footage identified 91 safety-critical events. The *BikeSAFE* project (Dozza and Werneke, 2014) collected naturalistic cycling data from 16 cyclists who had their bicycles equipped with special equipment. From 114 hours of data, which covered a travelled distance of more than 1 500 km, 63 safety-critical events were identified partly via kinematic triggers, partly via self-reporting and interviews with the participants. In a similar study of electric bicycles (Dozza et al., 2014a), 12 cyclists rode an equipped electric bicycle. Almost 1 500 km of travel was covered during the study. Via self-reporting, the participants reported 88 safety-critical events. In a large-scale naturalistic cycling study carried out in Oregon, USA

(Figliozzi and Blanc, 2015), 164 cyclists collected GPS data for five months via a smartphone app, *ORcycle*. Accidents and safety-critical events were self-reported via the app during the study. In total, 62 incidents were registered.

In the *2-BE-SAFE* project (Vlahogianni et al., 2014), motorcycles were equipped with sensors to collect naturalistic data. Based on indicators such as speed, acceleration and brake activation, data was analysed to identify safety-critical events. The safety of motorcyclists was also assessed in the *MSF 100 Motorcyclist Naturalistic Study* (Williams et al., 2015) where 100 participants collected naturalistic riding data for up to two years after having their motorcycle equipped with GPS receivers, accelerometers, gyroscopes, switches and video cameras. In total, about 38 600 trips were recorded. 22 accidents occurred during the study.

## 6.6. Summary

The InDeV project aims to create a toolbox for understanding the causation of accidents involving vulnerable road users. Naturalistic studies may provide an important insight into these aspects and can be used for instance to identify dangerous locations where vulnerable road users are involved in accidents or critical situations. So far, naturalistic driving data from vulnerable road users has mostly been collected via equipped motorcycles or bicycles. Accidents and critical situations of vulnerable road users have rarely been detected based on kinematic triggers such as acceleration, rotation, speed, etc. In most cases, incidents have been identified via manual review of video footage or self-reporting of accidents/critical situations.

Although the detection of accidents and critical situations based on kinematic triggers is limited in naturalistic studies, their potential was demonstrated in a wide range of studies of falls among the elderly. These studies showed that particularly acceleration and rotation may be relevant indicators for the detection of accidents and critical situations. However, in order to examine accident causation it is necessary to collect additional information from road users, e.g. via a questionnaire that is sent to road users after an accident is detected. Another limitation of naturalistic studies is that data is typically collected from only one of the road users involved in the conflict or accident. This makes it difficult to gain a complete understanding of the collision processes and causes leading to accidents.

## 7. Behavioural observations

The aim of the project activity described in this chapter is to provide a comprehensive review of road user behavioural observation studies as a tool for road safety evaluation. The main objective is to critically review the usefulness of these studies for accident causation with relevance to vulnerable road users.

A well-known concept in the field of traffic safety is the human-environment-vehicle system that identifies human behaviour, the road environment and the vehicles (with their technology) as the three main contributory factors of accidents, e.g. (Sabey and Taylor, 1980), of which human behaviour is present in almost all accidents. Therefore, it is important to examine human behaviour in order to identify the behavioural processes that lead to accident occurrence.

### 7.1. Description of road user behavioural observation studies

Naturalistic data collection methodologies focus on the observation of behaviour that is shown in the real driving environment. A distinction can be made between studies in which road users are aware of being observed (naturalistic driving studies) and studies in which unobtrusive observations of road user behaviour are made (behavioural observation and traffic conflict studies). Although the concept of unobtrusive is not clearly defined in behavioural observation studies, it is generally regarded as the avoidance of informing road users of their participation in the study. When road users know that they are being observed, they may change the behaviour of interest (Eby, 2011).

Naturalistic driving studies enable the collection of vast amounts of data during individuals' trips, but, as described above, the awareness of the sensors on their vehicle might cause behavioural adaptation effects. Therefore, we regard behavioural observation studies, and, by extension, traffic conflict studies, to most closely represent natural road user behaviour. The main difference between these two methodologies is that traffic conflict studies try to measure traffic safety in terms of the expected number of (injury) accidents, while road user behavioural observation studies focus on observing what is happening, rather than quantifying traffic safety levels. In this research, road user behavioural observation studies are defined as follows:

- Studies observing road user behaviour, in which the road users observed are not informed (beforehand) of their participation in the research. These studies focus on how road users behave when passing the observation site in a real life situation with regard to traffic safety aspects.

Observations of road user behaviour have been reported since as early as the 1930s, but the number of (peer-reviewed) studies and reports has been increasing especially rapidly in recent years. Using a systematic approach, all currently available literature on road user behavioural observation studies was assessed to provide an overview of the different methodologies and indicators used in behavioural observation studies carried out to date. Additionally, a questionnaire was distributed among the partner countries a) to acquire an overview of the research efforts and b) to provide additional literature for the scoping review. The following sections describe the results of the questionnaire briefly, present a best-practice example of a road user behavioural observation study and describe the scoping review. A description of the review process can be found in Appendix 3. The full report, including the list of papers and articles reviewed, is included in Appendix 5 and forms part 3 of this Deliverable.

## 7.2. Summary of a scoping review on the current practices in behavioural observations studies in scientific literature

Observations of road user behaviour have been reported since as early as the 1930s, but the number of (peer-reviewed) studies and reports has been increasing especially rapidly in recent years. Several methodologies have been developed to study road user behaviour; of these, behavioural observation studies aim to collect road user behaviour data in a naturalistic setting.

A scoping review was conducted to provide an overview of the current extent, range and nature of this type of research. A review team made up of two members carefully created and tested a search protocol to systematically retrieve relevant literature from three major databases (ScienceDirect, Web of Science and TRID). The search term “*Traffic Behavio\*r*” AND “*Safety OR Observation*” was used and ultimately yielded 600 peer-reviewed journal articles in English, following the elimination of references that did not meet the inclusion criteria or were irretrievable. The descriptive analyses showed that behavioural observation studies can have four main goals:

- **Monitoring:** One location or multiple locations are observed simply to observe what is happening.
- **Evaluation:** Using a before-after, with-without or cross-sectional research design, the effect of an intervention or safety improvement measure is evaluated.
- **Model development:** Video data is used to develop/calibrate a simulation model.
- **Software development:** Video data of traffic events is used to develop and test automated video analysis tools (e.g. tracking algorithms and road user classification). Because the development of such tools is relatively new, publications of studies with this research goal are limited in number and can only be found from recent years.

The descriptive analyses distinguished two study types: studies that contained at least one type of vulnerable road user (VRU) (37% of all studies) – defined as a road user without a protective shell (e.g. pedestrians, cyclists and motorcyclists) – and studies that contained at least one type of non-vulnerable road user (82% of all studies, labelled as driver studies). Figure 7.1 shows how the different research goals relate to the two study categories; the main observation is that for both categories, the primary goal of most behavioural observation studies is monitoring (more than 50% of cases).

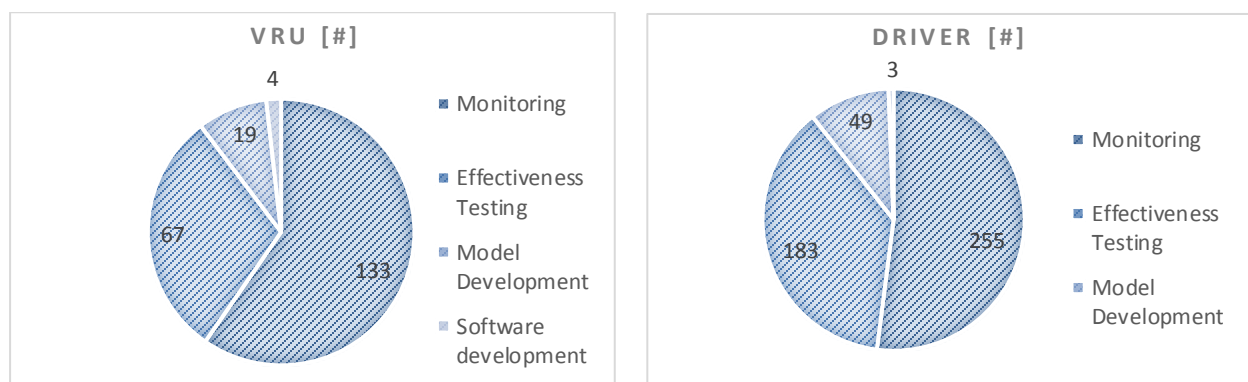


Figure 7.1: The main goals of road user behaviour observation studies

Among VRU studies, pedestrians were included in 65% of these – a much higher proportion than cyclists (around 25%). Among driver studies, car drivers were included in all but one study. Determining the share of heavy goods vehicles proved challenging

since most researchers did not state clearly whether they included these or not. With regard to the focus of research, 26 topics were identified. VRU studies were found to focus mainly on crossing behaviour (40%), yielding behaviour (23%) and red light running (10%), while driver studies focused mainly on speeding (16%).

Due to their research aim, most studies used a basic research design where one location or multiple comparable locations were observed, without any form of comparison between the sites (around 60% for both study types). However, when a safety evaluation was performed, the most frequently used research design was a before-after study in both study types (around 50%). The percentage shares of with-without and cross-sectional research designs are comparable: 25% each. The review also revealed large numbers of behavioural indicators. A total of 47 indicators were defined: behavioural and situational indicators and road user characteristics. The behavioural indicators most commonly used for VRU data collection include red light running (35%) and yielding (32%), whereas in the case of driver studies speed (59%) and headways (18%) are examined most often.

### Strengths, weaknesses, opportunities and threats

In total, 600 behavioural observation studies were analysed. Based on the extracted information and the findings of the analysis, a SWOT analysis was conducted to point out the advantages and disadvantages of using behavioural observation studies (Table 7.1). Below is a brief description of the identified elements.

**Table 7.1: A SWOT analysis on road user behavioural observation studies**

	<b>Positive</b>	<b>Negative</b>
Internal factors	<u>Strength</u> Natural road user behaviour Behavioural and situational processes Data quality	<u>Weakness</u> Control of traffic events Control groups Data processing Bias
External factors	<u>Opportunities</u> Amount of data Control group	<u>Threats</u> Privacy legislation Validity

### Strengths

The main strength of road user behavioural observation studies is that naturalistic data are gathered without road users’ knowledge of being observed for research purposes, thereby limiting the effects of behavioural adaptation. In surveys, for example, respondents try to answer the questions in a way that shows them in a positive light (Paulhus, 1984). Natural settings where road users are unaware of being observed allow to reduce this bias and may expose risky and aggressive behaviour while driving (Shinar, 1998). Note should be made of the recent trend to install permanent traffic cameras for monitoring purposes, but we assume that road users have grown accustomed to them and therefore do not adapt their behaviour anymore. Furthermore, the use of these unobtrusive observations enables researchers to examine the natural behaviour of road users, providing the opportunity to identify behavioural and situational processes that lead to traffic safety issues. This is important since other forms of data collection fail to include such information. Current studies have led to the development of microsimulation models and suggestions as to why road users behave in a certain manner (e.g. informal traffic rules).

Another strength of behavioural observation studies is associated with the quality of the data. Although earlier studies that involved human observers frequently reported inter-observer agreement rates, the application of video cameras enables to watch the traffic

events of interest as many times as needed. This improves data quality since real-world driving behaviour can be examined multiple times from different perspectives (for example to identify looking behaviour or to examine the situational circumstances such as weather and road conditions).

### **Weaknesses**

One of the major drawbacks of behavioural observation studies is that researchers are dependent on what happens on the traffic scene. Unlike for example driving simulator research or microsimulation, traffic events of interest cannot be triggered without the ability to collect data concerning all of the road users involved. Semi-controlled research designs allow to overcome this issue to some extent by using instructed road users with the aim of provoking certain traffic events (e.g. yielding), but are still constrained by the limitation that data can be collected only for the road user that is being “trapped” in the traffic event of interest.

According to the findings of the review, the main aim of behavioural observation studies is to observe what happens rather than to perform specific safety evaluations. However, when the effects of safety treatments were tested (n = 202), only 24 studies (4%) were found that included some sort of control group (e.g. locations with or without the treatment). These studies found that the results needed to be adjusted to control for natural variability. This suggests that, as is the case for many other domains, behavioural studies also need control groups when the effectiveness of a safety treatment is tested. However, the review showed that control groups are rarely applied.

Other weaknesses are associated with the way data is collected. When human observers are used, one should be careful to guarantee the objectivity of data collection and keep track of the inter-observer agreement rates among trained observers. As mentioned before, video data can address this issue to some extent, but one should be aware that technical problems and occlusions by, for example, other road users can limit its quality. Furthermore, video cameras enable the continuous collection of large samples of data, but the labour and costs necessary to analyse the data are quite extensive. Current efforts to develop automated video analysis software tools could provide a valuable asset for data analysis. However, given the current accuracy of these software tools it is not always possible to obtain the quality needed for traffic safety evaluation and observation. Moreover people define the selection variables used to automatically select parts of observations, which means that the selection depends on human criteria.

Finally, sampling bias can influence the results of behavioural observation studies (and other research methodologies). Observed behaviour is only a small sample of the behaviours that may occur and it can never be concluded that people who were not observed would have displayed the same behaviours (Eby, 2011). Although this type of bias can be minimized by an appropriate sampling design, it cannot be eliminated altogether.



## **Opportunities**

The streetscape has been changing in recent years. Cameras are being installed rapidly with the main purpose of monitoring the current state of traffic and the environment. There are opportunities to use the video footage from these cameras to observe road user behaviour. However, issues regarding data storage, privacy legislation and data quality should be taken into account. Combined with the current efforts to develop and improve automated video analysis software tools, these cameras provide huge opportunities to ease safety evaluation practices. Current software applications are already able to classify road users and track them through the video image; once (tracking) accuracy is further improved, this software could be used to observe crossing and yielding behaviour in more detail.

Almost 14% of the studies were found to combine the observation of behaviour with other methodologies. Such combinations offer the opportunity to compare behaviours in the real driving environment with stated or simulated behaviour. What is more, behavioural observation data could be used as a validation tool since it reflects natural road user behaviour.

## **Threats**

The most important threat for road user behavioural observation studies is associated with privacy legislation concerning the use of video cameras for data collection. Personal experience with video observation studies showed that the collection of personal data is regulated by strict rules. Video recordings are only allowed once permits are acquired and license plates and faces cannot be recognizable. This prohibits observations of the inside of drivers' vehicles and consequently excludes certain research topics (e.g. seatbelt use, mobile phone use and looking behaviour). These data can be gathered with human observers but, as explained earlier, there is a greater risk of human subjectivity.

Another important threat is associated with the validity of the behavioural indicators. The review showed that a wide variety of indicators are used to describe behaviour, but the relationship between these behaviours and safety is rarely validated. Literature has shown a correlation between speed and safety (Elvik et al., 2004), but no such link has been proven so far for other indicators. It is generally assumed that the behavioural indicators used are a valid proxy for traffic safety.

## **7.3. Studies related to VRU safety performed in InDeV partner countries**

A questionnaire survey regarding the use of behavioural observation studies was carried out among the project partners. The results are summarized in Table 7.2. A distinction into three categories can be made, namely “single road user – monitoring”, “single road user – measurement testing” and “interaction”. The majority of the reported studies are dedicated to single road user – monitoring topics. The topics of the conducted studies can be found in Table 7.3.

**Table 7.2: Behavioural observation studies reported by partner countries**

Type	Belgium	Denmark	Germany	The Netherlands	Poland	Spain	Sweden
Single road user (measurement testing)	6	2	6		5	2	3
Single road user (intervention)	2						
Interaction	3	1		1		1	8
Total	11	3	6	1	5	3	11

**Table 7.3: The topics of the behavioural observation studies reported by partner countries**

Type	Belgium	Denmark	Germany	The Netherlands	Poland	Spain	Sweden
Speeding							
Seatbelt usage							
Helmet usage							
Following distance							
Mobile phone usage							
Protective clothing PWT							
Child restraint usage							
Distance to stop line							
Red light running							
Yielding							
Street crossing VRUs							

The majority of the “interaction” studies examined vulnerable road users’ safety specifically, focusing on the interactions between motorized and vulnerable road users and are therefore relevant for the project. These studies include yielding behaviour at roundabouts (Sakshaug et al., 2010) and right-hand priority and priority-controlled intersections (De Ceunynck et al., 2013), as well as the design of pedestrian crossings, e.g. (Johansson et al., 2011).

The other studies, however, did not specifically focus on vulnerable road user safety: relevant topics (e.g. speeding and red light running) were examined but not in direct relation to pedestrians or cyclists.

## 7.4. Best practice example of a behavioural observation study

An example of a behavioural observation study can be found in a paper by Diependaele (2015) where the researchers observed road user behaviour at signalized intersections to investigate red light negation by pedestrians.

In total, 80 signalized intersections in the nine most populated areas of Belgium were observed during intervals of 15 minutes. Ten teams of two observers were dispatched 33

times to conduct four observations at the different legs of a selected signalized intersection, resulting in 1 320 observations of 15-minute intervals. One of the two observers counted the number of pedestrians that started crossing during the red or green phase, using two mechanical counters, and the other one counted the number of vehicles that passed during the green phase for motorized traffic. Prior to the start of the observations, the teams were trained with video footage and training sessions in the field. Additionally, they received information on how to measure correctly during strongly fluctuating traffic volumes and how to observe as unobtrusively as possible.

## 7.5. Summary

Road user behavioural observation studies are mainly used to monitor traffic events and to simply observe what is happening (> 50%). A third of all studies includes the evaluation of safety improvement measures, suggesting that behavioural observations can also be used to directly evaluate traffic safety aspects. Out of the 600 studies included in this review, 37% dealt with VRUs. An increase in research efforts concerning VRU safety has been observed, especially during the last fifteen years. Behavioural observations seem to be very useful to examine how road users interact with other road users or navigate through a crossing. Almost all studies involving a VRU were found to take place at some sort of crossing (e.g. intersection, railroad crossing, pedestrian crossing). In the case of studies involving drivers, most currently reported research efforts focus on road stretches where interaction with other road users was not necessary.

It is important to note that incomplete reporting limits the value of articles. For example, the review found that the majority of the included articles did not mention whether heavy goods vehicles were included in the sample size. Furthermore, information about the observation period should be clearly stated for the sake of transparency and replicability and to enable comparisons between studies. 12% of all studies did not provide any information, while information regarding peak or off-peak, daytime or night-time and week or weekend observations was missing in 51%, 44% and 32% of the studies, respectively. Additionally, 18% of all studies failed to specify the sample size.

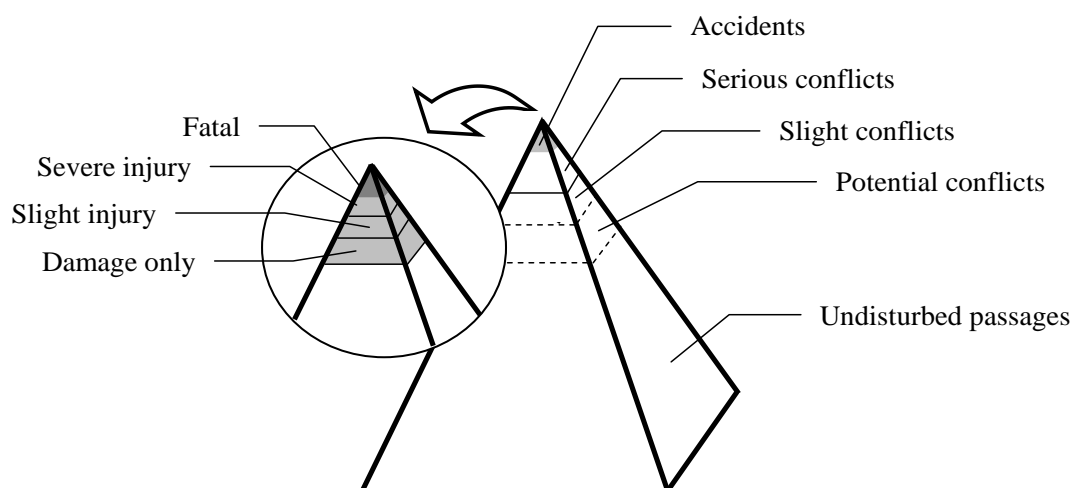
This scoping review was limited to peer-reviewed journal articles published in English. Although this review did not aim to depict the current practice everywhere (one is limited in resources), the results suggest that certain topics have not been the subject of extensive research. For example, railroad crossings are considered to be a major safety hazard across the EU (EC, 2016) and powered two-wheelers are highly represented in crashes (WHO, 2004) but both were only found sporadically in the review. However, the InDeV questionnaire hinted that many relevant studies might be published as research reports only. Therefore, it is advisable to extend the boundaries of this scoping review in future research.

## 8. Traffic conflict studies

### 8.1. Description of traffic conflict studies

The last decade has been characterized by great improvements in sensor techniques, in particular computer vision, that can be used to automate traffic data collection to varying degrees. These technical advances, in combination with the well-known limitations of traditional methods of road safety analysis based on accident data, have led to a strong increase in interest in safety diagnosis methods that do not rely on accident data, i.e. surrogate measures of safety. Such methods rely on the assessment of the “severity” of events in traffic. Severity usually refers to the degree of closeness to a crash that is attained during an interaction between road users, and is usually expressed in terms of closeness in time and/or space through various indicators such as Time-to-Collision, Post-Encroachment Time, etc. However, the potential severity of the consequences in the event that a crash does take place is another dimension of “severity” that also should be taken into account in some way (Laureshyn, 2010).

Traffic conflicts are a common type of surrogate measures of safety. The basic concept at the heart of traffic conflict theory is seeing traffic as a number of elementary events. These events differ in their degree of severity (or degree of closeness to an accident) and there exists some relationship between the degree of severity and the frequency of events of that severity. Hydén (1987) illustrated the concept with a “safety pyramid” (Figure 8.1). The base of the pyramid represents the undistributed passages that are safe and occur most of the time. At the other end, the very top of the pyramid consists of the most severe events such as fatal or injury accidents that are very infrequent compared to the total number of events. If the relationship between the severity and frequency of the events is known, it is theoretically possible to calculate the frequency of the very severe but infrequent events (crashes) based on the known frequency of the less severe but more easily observable events (conflicts).



**Figure 8.1: “Safety pyramid”**

Source: (Hydén, 1987)

There are two main advantages of using conflict studies compared to using only accident records for safety analyses. One is that conflict studies require only one or two weeks of observation in order to estimate the safety situation of a site compared to accident records which require years of data. The second advantage is enabling the direct observation of the course of events and making it easier to explain the safety level of a certain traffic site, while direct observations of accidents are very rare.

Trained observers can observe a traffic situation on-site or from video recordings relatively reliably, or automated tracking systems can be used to generate trajectories which may serve to identify traffic conflicts and obtain conflict indicators (Laureshyn, 2010).

## **8.2. Overview of the method’s applications**

Traditionally, traffic conflict data were collected on site by trained observers. This technique first emerged in the late 1960s (Perkins and Harris, 1967). After the success of the first attempts, traffic conflict techniques rapidly gained popularity, leading to the development of numerous new conflict observation techniques in the 1970s. Countries that developed their own technique(s) include Canada, Finland, France, Germany, the Netherlands, the United Kingdom, the United States and Sweden (Amundson and Hydén, 1977; Grayson, 1984). Since the different techniques used different indicators and/or protocols to identify traffic conflicts, transferability, validity and comparison of study results were identified as significant issues. Therefore, in the 1980s and early 1990s, research efforts in the field of conflict observation emphasized aspects such as validity (Hauer and Garder, 1986; Williams, 1981), comparability (Grayson, 1984) and reliability of observations and assessments (Kruyssen, 1991; Kruyssen and Wijnhuizen, 1992). However, the techniques were applied less frequently after the early 1990s. The most important reasons for this languish were the significant efforts in time and money required to collect such data in field, as well as doubts about the validity of such techniques and the reliability of data collection (Glendon et al., 1977; Williams, 1981). Recent improvements in advanced video analysis techniques and other sensor technologies have led to a renewed interest in the use of traffic conflicts as a surrogate indicator to assess road safety.

The Traffic Conflict Technique is applicable in the following situations (Almqvist and Hyden, 1994):

- As a complement to accident analyses where the factors contributing to dangerous behaviour are investigated,
- Fast traffic safety estimation at sites where accident data do not provide an appropriate basis (the number of accidents is under a statistical criterion, or the data is incomplete),
- Fast evaluation of the effects of road safety measures with before-after investigation.

The TCT is mainly used in urban areas. Most of the studies are performed at urban intersections but the technique has also been used in rural sites (Hydén and Gaarder, 1977).

The TCT works best in combination with other methods, for example: behavioural studies, accident analyses, studies of road user interactions, and interviews with road users (Hydén and Várhelyi, 2000; van der Horst et al., 2016).

### **8.3. Summary of the scoping literature review on surrogate measures of safety in site-based traffic observations**

New data collection methods allow a more automated and objective collection of surrogate measures of safety that can be done by human observers. This shift poses new questions and challenges to the field. Researchers who are new in the field of traffic conflict observation struggle to gain a clear overview of its current state. The relevant literature is vast and diverse, and it is rapidly evolving due to current technical improvements in the field. Even experienced researchers risk losing track of the critical points of attention in this subject area. This seems to lead to “reinventing the wheel” and repeating the errors from the past because researchers do not have a sufficient overview of the relevant literature.

Therefore, this report presents a scoping review of the current state of the field, providing descriptive insight into the available literature and identifying the critical challenges and opportunities that should be central to future research. The focus is on studies that measure (in some way) the severity of individual traffic interactions through site-based observations (i.e. observations at fixed sites). This implies that studies that (only) make use for instance of instrumented vehicles, microsimulation models and observations of non-critical road user behaviour are beyond the scope of this review.

Using a systematic search protocol and a predefined code book, relevant literature in the field is identified and structured as objectively as possible. The final database includes data from 238 unique publications from the years 1957-2016. An analysis of the year of publication shows a recent steep increase in the number of publications on surrogate safety measures that started around 2010. The period from the late 1970s till the late 1980s also shows a peak in traffic conflict publications. This is when many traffic conflict techniques were introduced and tested.

The review shows that various indicators and techniques have been applied. A traffic conflict technique refers to a broader, established framework of practice to assess and classify events in traffic, and to estimate safety (i.e. to convert the number of conflicts to the expected number of crashes). Many traffic conflict techniques depart from the idea that one single indicator is sufficient to classify all events in traffic in a meaningful way. A traffic conflict indicator measures the severity of an event. The classification of events often combines different indicators and/or includes a subjective component.

In terms of the traffic conflict indicators that are used, a number of categories have been defined to present the results in a comprehensible way. The most commonly used indicators belong to the Time-to-Collision (TTC) “family”, followed by indicators from the Post-Encroachment Time (PET) and Deceleration “families”. The minimum TTC ( $TTC_{min}$ ) is by far the most commonly used indicator. Further analysis of the threshold value applied in studies using  $TTC_{min}$  to distinguish between severe and non-severe events shows that there is little agreement on which threshold value should be applied. The most frequently applied threshold values are 1.5s, 2s and 3s. Approximately one-third of all publications that use  $TTC_{min}$  do not use a predefined threshold value, but include all interactions in the analysis irrespective of the TTC values. On the other hand, in studies that apply the PET value, the use of a threshold value is far less common and most frequently all interactions are analysed.

While the vast majority of the included studies that apply traffic conflict indicators is fairly recent (2005-2015), the use of traffic conflict techniques is apparently becoming relatively

less common during the last 10 years. The Swedish Traffic Conflict Technique and the US Traffic Conflict Technique appear to have been most commonly used over the years.

An analysis of the study design shows that a large number of studies (approximately one-third) is carried out at only one observation site. In one-third of the studies, observations were performed at more than five sites. In terms of the duration of observations, relatively short observation periods per site appear to be quite common; in 25% of studies the observations lasted less than 4h per site. Another remarkable finding is that 23% of studies did not include information on the duration of observations. When both elements are combined, it turns out that a relatively high proportion of studies with observations at only one site also use observations with a short duration; 28% of studies with only one observation site use observations with a duration of less than 4h.

Studies where only motor vehicles are observed constitute the largest group of surrogate measure based safety studies the observation of VRUs is less frequent. In studies that include one or more VRU categories, pedestrians are more frequently observed than bicyclists or moped riders. Most studies are carried out at observation sites in urban areas.

On-site manual observations used to be popular but have been rarely performed during the last decade. The use of video analysis tools has become quite popular during the last decade. Manual observations directly from video in office (i.e. without human observers at the observation site) are quite common as well.

Many studies collect other types of data together with traffic conflicts. Exposure data and, to a lesser extent, accident data are the most frequently collected types of additional data. Simple counts or descriptive statistics of traffic conflicts are the most common type of data analysis, and are often the only form of analysis. Statistical models and tests, before-after comparisons and visualisations of the conflict patterns on a map (e.g. heat map, conflict diagram) are less common types of analysis.

A number of recommendations for future development of traffic conflict techniques can be found in literature. More research on the validity of traffic conflicts as a surrogate measure of safety is strongly recommended, but one should keep in mind that high product validity does not seem to be a prerequisite for such measures to serve as a useful and valid tool for road safety studies. Sufficiently high levels of process and/or relative validity allow for a wide range of road safety evaluation and diagnosis activities. Better use of the full continuum of events in traffic coupled with the use of continuous time series (describing the full development of the interaction instead of taking a single point or value of the interaction) for road user interactions should contribute to the enhancement of insights as well as a better understanding of collision factors and processes. Including the severity of the outcome into surrogate safety measures in the event that an accident takes place could further improve usability of the studies and help to identify and investigate the patterns that lead to the most severe accidents in traffic.

#### **8.4. Studies related to VRU safety performed in InDeV partner countries**

A questionnaire survey regarding the use of traffic conflict studies was carried out among the project partners. The results are summarized in Table 8.1.

**Table 8.1: The status of use of traffic conflict studies among safety professionals in InDeV countries**

Partner (country)	Status of use of the Traffic Conflict Technique among safety professionals in InDeV partner countries
<b>Belgium</b>	Not established yet, but there is interest to use it more widely
<b>Canada</b>	Not established yet, but there is interest to use it more widely
<b>Denmark</b>	Not established yet, but there is interest to use it more widely
<b>Germany</b>	One-time attempts that have no follow-ups
<b>The Netherlands</b>	Well-established, frequently and recently used
<b>Poland</b>	Not established yet, but there is interest to use it more widely
<b>Spain</b>	Not established yet, but there is interest to use it more widely
<b>Sweden</b>	Not established yet, but there is interest to use it more widely

Two partners in InDeV (LU in Sweden and TNO in the Netherlands) have well-established, frequent and recent experience with traffic conflict studies. Both of these partners have also developed their own conflict technique: the Swedish technique was developed by LU and the Dutch one - DOCTOR was developed by TNO. Both LU and TNO have conducted studies that focus on motor vehicles as well as on vulnerable road users and both have used manual observation and computer vision techniques.

Some of the other partners (DE, BE and DK) have performed some minor conflict studies but the use of traffic conflicts has not been widely established.

## 8.5. Best practice examples of traffic conflict studies

An experiment with small roundabouts – as speed reducing measures – was carried out in a Swedish city (Hydén and Várhelyi, 2000) using the Swedish conflict technique. The purpose of the study was to test the large-scale and long-term effects of the roundabouts. Traffic conflict observations were carried out at each of the 21 intersections rebuilt into small roundabouts both before and one year after the reconstruction: behavioural observations, speed measurements and interviews with road users were performed as well. The results showed that the roundabouts reduced the speed considerably both at the junctions and on the links between them. A roundabout forces the driver to a lateral displacement which is of great importance for the speed of cars entering the roundabout. The speed-reducing effect is already significant at a 1.5-m deflection. A larger deflection does not result in a larger effect. Conflict studies indicated an overall decrease in accident risk by 44%. Vulnerable road-users’ risk was reduced significantly but no reduction was observed for car occupants. Car drivers were less positive about the roundabouts than bicyclists. In the long term, the unchanged roundabouts worked almost as well as they did shortly after the conversion. The study showed that details in the design are of critical importance for road user safety. The situation of bicyclists requires special attention.

In the Netherlands, single-bicycle accidents, bicycle-bicycle and bicycle-moped accidents constitute a considerable proportion of all cyclist injuries on bicycle paths. Over three-quarters of all hospitalised bicyclist victims cannot be directly related to a crash with motorised traffic. As the usage of bicycle paths steadily increases, safety on bicycle paths is expected to become a major issue. A study was conducted on the behaviour of bicyclists and moped riders to improve traffic safety on bicycle paths (van der Horst et al., 2014). Behavioural observations with video served to record and analyse mutual conflicts



and bicyclist behaviour on bicycle paths using techniques that included the DOCTOR conflict observation method. The explorative phase of the study (phase 1) included two research locations: one in the city of Amsterdam and one in Eindhoven. The results served as guidance for a better understanding of the behaviour between different users of separate two-directional bicycle paths. One example is the relationship between bicyclist-moped rider behaviour and the width of the bicycle path. In the case of busy bicycle traffic in both directions, a bicycle path width of 3.55 m is relatively narrow, whereas a bicycle path width of >4.94 m appears to be sufficient to accommodate large flows of bicyclists. The large flow of crossing pedestrians and the resulting (severe) conflicts with bicyclists in Amsterdam require additional countermeasures to better control these interactions. The DOCTOR conflict observation method from video appears to be applicable to conflicts between intersecting road users and to head-on conflicts on the bicycle path. Conflict situations between bicyclists in the same direction (which constitute an important proportion of injury accidents on bicycle paths) require an additional and more general systematic observation of specific behaviour.

## 8.6. Summary

Traffic conflicts are surrogate measurements of safety that aim to complement accident history analysis or serve as an alternative in cases with no accident history. The observation and analysis of traffic conflicts as a surrogate for accidents offers two main advantages compared to accident data analysis: first, conflicts are more frequent which makes them more time-efficient for safety assessment and second, direct observation of critical events allows better understanding of the processes that result in traffic safety problems.

The basic theory behind the use of traffic conflicts for safety analysis is the assumption of continuity in the severity of all events that take place in a certain traffic environment. On a severity scale, injury accidents are rated high while normal interactions are rated low. There is also a relationship between the severity and frequency of events, i.e. injury accidents are rare, while normal interactions are frequent.

The performed scoping review of literature shows an increase in the use of traffic conflicts and a particular increase in the use of video analysis tools to identify conflicts. The most commonly used surrogate indicators are Time-to-Collision (TTC) and Post-Encroachment Time (PET). The review also shows that there is a considerable number of validation studies that investigate the relationship between conflicts and accidents. However, most of them are quite old and use manual observations of conflicts. Recently, new indicators with high potential have also been suggested and there is a clear need for new validation studies using video analysis tools.

Emerging technologies (e.g. automated video analysis) open up new possibilities for the wider use of site-based traffic conflict studies. Nevertheless, a combination of conflict studies with other types of behavioural observations and accident analysis provides even better insight into road safety problems.

## 9. Self-reported accidents

### 9.1. Description of self-reported accidents

The main idea behind the self-reporting of accidents is to ask people about their traffic accidents and gain knowledge on these accidents without relying on the official records kept by police and/or hospitals. The ways of getting information from people can vary; people may be asked to fill out paper questionnaires, interviews may be performed (either face-to-face or via telephone) and people may be asked to report their accident via an app on their mobile device. The method for gaining self-reported information thus varies greatly – and so does the information that people are asked to give. In most studies, only the number of accidents in which the respondent was involved is relevant for the researcher. In other studies, respondents are asked about possible accident causation factors, and some studies deal with respondents’ recall of the accident details. In other words, self-reporting can have many different aims depending on the research question that is being investigated.

There is also a large variation in the selection process of respondents, also depending on the research question. Some studies only deal with specific groups of drivers (e.g. older drivers (Finestone et al., 2011) or stroke survivors (McGwin et al., 1998)), who voluntarily participate in a scientific research project. Some studies include people who have already registered an accident as their respondent group and the research is aimed at gaining more knowledge on the accidents and their causation factors (Tivesten and Wiberg, 2013; Versteegh, 2013). Some studies are aimed at investigating the level of underreporting, hence the group of respondents is chosen either as a sample of the entire population of a country (such as the sample seen in e.g. (Gustafsson and Thulin, 2000) or (Lahrmann et al., 2016) or all residents of a municipality are simply given access to an app through which their accidents may be reported.

The advantages and disadvantages are closely connected. As self-reporting provides us with information directly from the person involved in the accident, it is an opportunity to gain information on the issues that cannot be measured after an accident: what does the person involved think was the reason for the accident – e.g. was he/she feeling tired or stressed? Yet this is, at the same time, the biggest disadvantage of the method: we only gain knowledge from one of the parties involved – and we only know what they choose to tell. There is no guarantee that the respondent is telling the truth – and even if the respondent is absolutely honest, one cannot guarantee that the experience remembered by the respondent corresponds fully with what happened. These elements play an important role when discussing the disadvantages of self-reports: memory (as researched for instance by Versteegh (2013)) and the willingness to answer truthfully (e.g. the social desirability effects discussed by Wåhlberg et al. (2010)).

When self-reports are used to estimate the level of underreporting of accidents, the advantage is clear as it is quite difficult to estimate the number of accidents that are not reported to the police if no other data source than police records is available. All other official records (insurance, hospital) are by their nature incomplete e.g. (Roberts et al., 2008) and (Elvik and Mysen, 1999) as not all accidents will be reported. Therefore, self-reports should, in theory, allow to gain the most complete idea of the total number of accidents. The disadvantage of self-reporting used for this purpose is also related to memory and truth telling – can we be sure that respondents remember their number of accidents correctly and can we be sure that they have no motive for omitting or making

up accidents? As with self-reporting used for the knowledge of accident causation factors, one cannot guarantee this, but one can try to minimize the uncertainties introduced by these factors – for instance by minimizing the period of recall, hence easing memory load, and by carefully wording the questions so as to minimize the obviousness of the social value within the answers.

The choice of respondents will also influence the answers – a number of different biases may be introduced due to the selection of respondents. The bias associated with the characteristics of the invited respondents who do not respond to a questionnaire or participate in an interview (non-response bias) is one of these, as investigated by Tivesten et al. (2012) in relation to the self-reporting of accidents.

## **9.2. Overview of the method’s applications**

One thing is relatively clear about self-reporting of traffic accidents: most studies use this method as a way of investigating the level of underreporting. This means that self-reports are in some way or another compared with either hospital records or police records, as a way of discussing either the amount of missing data in the official records or the validity of the self-reported information. These studies often only ask the respondents to recall how many accidents they have had in a given period. Quite often no other information regarding the accident is needed. Examples of international studies that fall within this category are (Arthur et al., 2001; Boufous et al., 2010; Finestone et al., 2011; McGwin et al., 1998; Roberts et al., 2008).

Some studies fall into another category where self-reporting is used as a way of gaining detailed accident information that could not have been gathered otherwise – for instance on accident causation factors. There are not many examples of these studies, but the ones worth mentioning are (Hanley and Sikka, 2012; Tivesten et al., 2012; Tivesten and Wiberg, 2013).

Others deal mainly with methodology and how the research design influences the validity of answers. Examples of these include (Maycock et al., 1996; Tivesten et al., 2012; Versteegh, 2013; Wählberg et al., 2010). Moreover, it is worth mentioning that there are other fields of research apart from traffic safety that use self-reports as a way of gaining knowledge. Self-reporting is quite commonly used in criminology, and one might argue that some of the methodological considerations in this field could also apply to traffic research, making it worthwhile to become familiar with the methodological research done in this field, for instance by Junger-Tas and Marshall (1999).

## **9.3. Summary of a scoping review of literature on self-reported accidents**

One hundred and forty four studies described in 136 publications were systematically reviewed in order to map the current practice when collecting self-reported traffic accidents. The purpose of the review was to identify studies where traffic accidents are reported by the involved road users. The full review is presented in Appendix 7.

In summary, the reviewed studies focused mainly on car accidents involving adult road users. The majority of the studies were conducted in Europe, North America and Australia/New Zealand and had a practical and/or applied focus.

The collection of self-reported accidents may involve one or more of three different objectives: 1) To evaluate the safety effect of a specific measure, 2) To estimate the total

number of accidents within a specific group of people, 3) To assess accident causation factors.

More than half of the reviewed studies recruited their respondents from a random sample: either a random sample of the entire population in a country or more often a random sample amongst a specific group of people. The sample size in self-reporting studies varies from 10 to almost 2 million respondents. Likewise, the response rate varies from around 10% to 100%. The sample size was not specified in twenty-five studies, and the response rate was not specified or retrievable in forty-two studies.

In general, information on self-reported traffic accidents is collected either by interview or by questionnaire. Questionnaires, both online and paper, are typically used to collect information. In more than half of the studies, respondents were asked to recall their accidents within the previous 3 months to 1 year. One-fourth of the studies did not specify how far back in time respondents were asked to recall. Almost all studies only asked their respondents to self-report accidents once. A small percentage (15%) of the studies asked their respondents to self-report twice or several times within a period of time.

In 60% of the studies, self-reported accidents were not compared to other sources of accident data. However, 40% of the studies did compare the information with data sources of some sort, such as hospital records, insurance records, police accident records or company records. The full review report and reference list is included in Appendix 7 – Systematic literature review: Self-reported accidents.

## 9.4. Studies related to VRU safety performed in InDeV partner countries

Part F of the distributed questionnaire (see Appendix 1) contained questions (see Appendix 1) regarding InDeV partners’ knowledge on the use of self-reporting of accidents in their countries. The answers are presented in the table below. Some countries reported no use of self-reporting at all in their country, while the method seemed to be used more in other countries. No partner reported more than three studies performed in their country, even though the questionnaire did not ask for studies performed within a specific timeframe or only ones that dealt with VRUs. Thus, the reported number of studies seems quite low and may serve as an indication that the method is not commonly used in any of the countries.

**Table 9.1: The number of self-reported studies in InDeV countries reported by the partners**

Country	Belgium	Denmark	Germany	Netherlands	Poland	Spain	Sweden
<b>Number of self-report studies reported</b>	0	3	1	2	0	2	2

The groups of road users in the studies reported by InDeV partners include:

- 1 study with pedestrians, bicyclists, mopeds and motorcyclists (Sweden)
- 5 studies with bicyclists only (Denmark and Netherlands)
- 1 study with motorcyclists only (Germany)
- 1 study with bus drivers (Sweden)
- 2 studies that seem difficult to classify before a more detailed literature study is carried out (Spain)

Only 6 studies deal with VRUs (pedestrians, bicyclists or mopeds) in InDeV partner countries. The majority of these studies concerns bicyclists only. The reported studies

with VRUs are of varying scientific quality and varying usefulness for the InDeV project. The table below shows the relevant studies as well as the information provided by the InDeV partners on some of the key points of the studies.

**Table 9.2: Studies performed in partner countries concerning VRUs**

Information provided by	Lund	TNO	TNO	AAU	AAU	AAU
Project name	<i>Pedestrians and cyclists – exposure and injury risks in different traffic environments for different age groups</i>	<i>Safe and conscious on your bicycle</i>	<i>Bicycle accidents in the Netherlands</i>	<i>Safety impact of a yellow bicycle jacket</i>	<i>Self-reporting of bicycle accidents</i>	<i>Safety effects of running lights on bicycles</i>
Research scope	Risk estimation based on exposure data	Design of bike for elderly users	To investigate whether electrical bikes lead to more accidents than regular bikes	Estimation of accident reduction when using fluorescent bike wear	Estimation of number of accidents and accident causation	Estimation of the safety effects of permanent running lights (number of accidents)
Number of respondents	23 030	879	5 587	Approx. 6 800	Approx. 7 000	3 845
Sample	Stratified age 1-84	Elderly (age >65)	Victims of electrical bicycle accidents from 13 different hospitals	Volunteers, nationwide	Members of national survey panel	Geographically limited, volunteers
Recall period	1 month	Unknown	2 months	1 month	2 years	2 months
Data collection method	Paper questionnaire	Online, paper and interview	Paper questionnaire	Online questionnaire	Unknown	Online questionnaire
Self-reports compared with other data?	No	No	No	Yes, hospital and police	No	No
References	(Gustafsson and Thulin 2003)	(Engbers et al., 2013)	(Kruijer et al., 2012)	(Lahrman et al., 2016; Meltofte et al., 2015)	(Berg, 2015)	(Madsen, Andersen, and Lahrman, 2013)

## **9.5. Best practice example of self-reported accident**

There is little experience with self-reports for VRUs in partner countries overall. As none of the scopes of research are the same as the scope of InDeV (estimating the level of underreporting and finding situation-specific correction values for socioeconomic costs), it seems clear that one cannot simply state that one of the abovementioned studies could serve as a best practice example for the InDeV project. For instance, the use of paper questionnaires might be considered very good practice in cases where the sample consists of elderly people due to their (often) lesser computer skills and access to computers. Conversely, if the sample consists mainly of younger people, the exact opposite could be true: that online questionnaires are perceived as easier to use than writing on paper and sending by post.

The only study that shared, to some extent, the research scope of estimating the level of underreporting is the study reported by AAU entitled “Self-reporting of bicycle accidents”. However, it must be noted that this study was carried out with very little scientific documentation and cannot contribute with any methodological insights to the development of a best practice guideline unless further information is provided by the foundation that performed the study.

## **9.6. Summary**

The method is highly relevant for InDeV as self-reporting provides the advantage of gaining knowledge on accident causation factors as well as the events that led to the accident. It is also clear that this method can be used to obtain information on accidents that are not reported to either the police or hospital, making it possible to estimate the level of underreporting.

A systematic literature review has shown that the practice for collecting self-reported accidents varies. The various studies focus mainly on car accidents. Self-reported accidents are used to evaluate safety measures, estimate the total number of accidents and to assess accident causation factors. Only one study used self-reported accidents to estimate the cost of traffic accidents. Information on self-reported accidents is typically collected via online or paper questionnaires. Respondents in the different studies are asked to recall accidents from a period ranging from the previous month to more than 5 years.

Most importantly, the use of this method in traffic safety research was found not to be common in InDeV countries; no analysis procedure, questionnaire design or respondent sampling procedure was found to be established as best practice or state of the art when the scope of research was to estimate the level of underreporting or to determine socioeconomic factors. Therefore, the conclusion is that while this method may have relevance and seems to be a promising way of gaining knowledge on accident causation factors, the level of underreporting and socioeconomic factors, it is still quite untested. The careful consideration of the methodological challenges and issues must form part of this project before conclusions on underreporting can be drawn based on self-reports alone.

## 10. Summary and Conclusions

### 10.1. Summary of the review findings

Task 2.1 involved a review of the accident causation study methods used today and aimed to link accident causation factors to VRU accident risk. The review covered the following categories of the current study methods: epidemiological studies based on accident and injury data; in-depth accident investigations; naturalistic driving studies; behavioural observations; traffic conflict studies; and self-reported accident studies. Questionnaires were sent out to all InDeV partner institutions in order to obtain information and a critical appraisal of the currently used study methods related to VRU safety. The main question of the survey was: to what extent can the existing methods help us identify the contributory factors to accidents of VRUs?

The survey results show that epidemiological studies based on accident and injury records form the basis of traffic safety assessment in every partner country. General accident reports help identify the time trends of accident occurrence and to compare the safety situation among countries and cities. This is important especially when exceptions from the generally positive trends occur. Benchmarking between countries can help monitor progress towards the goals set as targets for traffic safety improvement. For example, two worrying trends are currently observed in Europe: while in general the traffic safety situation is improving from year to year, the proportion of accidents with vulnerable road users among all traffic accidents is increasing, which means that VRU safety problems are gaining importance. The second trend is the increasing proportion of the elderly among all VRU victims of road accidents.

Comparing the situation among different countries can also help to assess the relative importance of problems that contribute to poor safety performance. While the exact causes of accidents cannot be determined, the contributing factors can often be deduced. The problem with comparing traffic accident and injury data among countries is the inconsistency of definitions. Although common definitions of what makes up a “traffic accident” and how to count fatalities have been worked out as part of the common CARE database, there is no common definition of severe injury and slight injury. This means that in practice, only the numbers of fatalities and fatality rates are fully comparable.

The identification of dangerous locations has traditionally been performed using black spot analysis and more recently, network safety analysis. Both are important and useful for VRU safety assessment: black spots help identify dangerous intersections and road crossings, and network analysis – dangerous road links. The exposure measures should be appropriate for VRU, i.e. pedestrian and bicycle volumes should be used in addition to motorised traffic volumes.

The literature review and survey on accident data quality conducted among InDeV partners shows that despite efforts to harmonise the definitions of injury road accidents and their severity at the European and global levels, differences exist both in the definitions and their interpretation. Even in the case of the fundamental definition of “road accident/injury accident”, the definitions used in some countries differ slightly from the CARE database standard. The data on fatalities are quite comparable between the InDeV partner countries: the 30-day road accident fatality definition is used. CARE definitions of injury severity are applied in only 3 out of the 7 countries. There are also considerable differences between countries in terms of accident data collection and data verification procedures, resulting in varying levels of underreporting of the various accident

categories. In all InDeV partner countries, accident data are collected on a paper form and transferred to a computer database. The information on crash severity is gathered from the ambulance, emergency room, hospital departments or the road users involved in the accidents. Apart from Spain, the information about victims’ injuries is verified based on hospital information. The waiting time for the information check on crash severity varies from 30 days to one year. In Sweden, data verification is performed automatically via the STRADA database, which links the police database with hospital registries.

It is acknowledged that there is a large data gap in the Netherlands, because the police do not register all traffic accidents, especially injuries. Most countries have various classification criteria of injury severity, such as the doctor’s opinion, the length of hospital stay or the AIS classification. In almost all InDeV partner countries the data quality control is carried out after data is transferred to the computer database. Cross-checking for consistency of information is performed in some countries. Studies on the underreporting of road accidents have been carried out and are available in most InDeV partner countries. In all countries except for the Netherlands, national databases are suitable for analyses of VRU safety. The reliability of data was confirmed by almost all countries.

The European CARE database was developed with a comprehensive structure and scope of information. The great advantage of using CARE for safety research is that it is a disaggregate database, i.e. information is available about every single accident. However, not all countries provide accident data according to the guidelines. For example, information on the accident type is not provided by any country except for Denmark. The possibilities of safety analysis would be greatly improved if the guidelines were followed by all countries. A new European initiative is also required to harmonise the data collection systems and procedures.

The in-depth investigation study is a good tool to investigate accident scenarios and configurations both on a single-case level and when using a statistical approach to find accident/injury contributing factors. Statistical analyses are possible, but if the number of cases, the period of time and the number of variables are limited, limited knowledge and validity can be expected. The comparison of different in-depth databases is difficult due to different investigation criteria. The drawbacks include the study’s retrospective view (compared to video-documented crashes) and the introduction of uncertainties in the process of data collection and encoding, e.g. due to interpretation. In general, in-depth investigations are time- and cost-consuming, but highly effective in terms of the investigation of individual accidents.

A systematic scoping review of the available scientific literature was conducted, covering four types of safety-related studies: naturalistic driving studies, behavioural observations, surrogate measures of safety (traffic conflict studies) and self-reported accidents. The numbers of publications found and finally included in the review are given in Table 10.1. In total, over one thousand publications were included in the scoping reviews. Full reports on the results of the four reviews are extensive and are therefore published as separate parts of this report (Appendices 4-7).



**Table 10.1: Number of publications found and reviewed**

Type of studies	Number of publications		
	Found (duplicates excluded)	Remained after screening	Included in the review
Naturalistic driving studies	1 358	118	80
Behavioural observations	12 121	583	583
Traffic conflict studies	2 726	389	239
Self-reported accidents	1 171	150	136

A review of naturalistic studies shows that this method can provide important insights into understanding the causation of accidents with VRUs. These studies can also be used to identify dangerous locations where vulnerable road users are involved in accidents or critical situations. So far, naturalistic driving data from VRUs have mostly been collected via equipped motorcycles or bicycles. In only a few cases, accidents and critical situations of VRUs were detected based on kinematic triggers such as acceleration, rotation, etc. In most cases, incidents were identified via manual review of video footage or self-reporting of accidents. The potential for detecting critical situations based on kinematic triggers was shown through studies of falls among the elderly. However, in order to examine accident causation it is necessary to collect additional information from road users, e.g. via a questionnaire that is sent to them after an accident. Another limitation of naturalistic studies is that data is typically collected from only one of the road users involved in the accident. This makes it difficult to gain a full understanding of the collision processes and causes that lead to accidents.

Behavioural observation studies are an important tool to understand the contributory factors to accidents that involve vulnerable road users because such studies provide insight into the situational and behavioural processes that lead to accident occurrence. These two important aspects are missing in the safety evaluation based on accident data. The survey conducted among partner countries provides an overview of the behavioural observation studies conducted in the partner countries and identifies several topics that can be addressed by this method, such as speeding, red light running and pedestrian street-crossing behaviour.

A review of about 600 publications on road user behavioural observation studies shows that these are mainly used to monitor traffic events and to evaluate safety improvement measures. Some 37% of the studies included VRUs and a recent increase in such research efforts is observed. Behavioural observations seem very useful for examining how road users interact with each other or navigate through a crossing. While most studies involving VRUs were found to take place at some kind of crossing (e.g. intersection, railroad crossing, pedestrian crossing), studies involving drivers were focused on road stretches. Determining the observation periods and sample sizes used in the studies proved challenging in this review. Twelve percent of all studies did not provide any information, while information regarding peak- or off-peak, daytime or night-time and weekday or weekend observations was missing in 51%, 44% and 32% of the studies reviewed, respectively. Additionally, 18% of all studies failed to specify the sample size. Certain topics were found not to have been the subject of extensive research – for example, railroad crossings and powered two-wheelers are highly represented in crashes but both were only found sporadically in the review. However, the InDeV-questionnaire hinted that many relevant studies were published as research reports only.

Observing and analysing traffic conflicts as surrogates for accidents has two main advantages: (i) conflicts appear more frequently than accidents which makes studying conflicts more time-efficient for safety assessment and (ii) direct observation of critical events allows better understanding of the processes that result in traffic safety problems. The basic theory behind the use of traffic conflicts for safety analysis is the assumption of continuity in the severity of all events that take place in a certain traffic environment. On a severity scale, injury accidents are rated high while normal interactions are rated low. There is also a relationship between the severity and frequency of the events, i.e. injury accidents are rare, while normal interactions are frequent. An understanding of the shape of this relationship makes it possible to estimate the expected number of accidents based on the frequency of events with lower severity. In addition, severe critical events (traffic conflicts) are so close to real accidents that the process of their development is very similar and therefore observations of severe conflicts can be used to understand the mechanism of accident development.

The scoping review of literature shows an increase in the use of traffic conflicts and a particular increase in the use of video analysis tools for their identification. The most commonly used surrogate indicators are Time-to-Collision and Post-Encroachment Time. The review also shows that a considerable number of validation studies investigated the relationship between conflicts and accidents. However, most of these are quite old and use manual observation of conflicts. Recently, new indicators with high potential have also been suggested and there is a clear need for new validation studies that use video analysis tools. Emerging technologies (e.g. automated video analysis) open up new possibilities for the wider use of site-based traffic conflict studies. Nevertheless, the combination of conflict studies with other types of behavioural observations and accident frequency analyses provides even better insight into road safety problems.

The self-reported accident study method is highly relevant for InDeV as it provides the opportunity to gain knowledge on accident causation factors as well as the events that led to the accident. It is also clear that this method can be used to obtain information on accidents that are not reported to either the police or hospital, thus making it possible to estimate the level of underreporting.

The systematic literature review shows that the practice for the collection of self-reported accidents varies and most studies focus on car accidents. Self-reported accidents are used to evaluate safety measures, estimate the total number of accidents and identify accident causation factors. Only one study used self-reported accidents to estimate the costs of traffic accidents. Self-reported accident data are most commonly collected via online and paper questionnaires. Respondents are asked to recall past accidents from a period ranging from one month to 5 years.

The survey among the InDeV partners shows that the use of the self-reporting method is not quite common in InDeV countries. No analysis procedure, questionnaire design or respondent sampling procedure was found to be established as best practice to estimate the level of underreporting or to determine socioeconomic factors. While the method has relevance and seems a promising way of gaining knowledge on accident causation factors, the level of underreporting and socioeconomic factors, it is still quite untested. Careful consideration of the methodological challenges and issues is required before conclusions on underreporting can be drawn based on self-reports alone.

## 10.2. Integrated approach to safety assessment

The study methods discussed in this report serve a common general goal: to collect information in order to assess the level of traffic safety and the risks associated with the movement of people and vehicles on public roads. However, these methods differ in terms of the focus, approach, method of data collection and specific aims. Therefore, the methods often complement each other in terms of the results that may be achieved with a specific objective in mind. For example, when the goal is to determine accident risk factors, a traffic conflict study works best in combination with behavioural studies, in-depth accident analyses and interviews with road users.

Table 10.2 shows this complementarity in the form of a matrix. Seven specific aims are listed against six assessment methods. Each method can serve either as the main source of information, a complementary source or be irrelevant for the achievement of each specific aim.

**Table 10.2: VRU safety assessment method complementarity table**

Aims	Method					
	Epidemiological studies	In-depth investigations	Naturalistic driving	Behavioural studies	Traffic Conflict studies	Self-reported accidents
Assessing and monitoring the safety situation	M			C		M
Determining risk factors	C	M	C	M	C	C
Identifying critical locations (black spots), RNSA	C		M			
Determining accident contributory factors		M		C	M	C
Assessing data quality/underreporting	C	C				M
Estimating accident costs	M	C				C
Before-and-after evaluation	M			C	C	

Source of Information:

M	Main
C	Complementary

Table 10.2 should be helpful in deciding which method (or combination of methods) to use in order to achieve a specific objective. For example, if we want to assess the effectiveness of new traffic calming measures for safety, the standard before-and-after study will be based on the collection of accident statistics (epidemiological study). However, a long period of observations (3 years before and after the intervention) is required. Quicker results may be obtained by observing traffic conflicts (conflict study) and observing the changes in safety relevant road user behaviour. Thus, the use of a mix of different methods can produce more comprehensive assessments.

Thus, InDeV proposes an integrated approach to safety assessment that combines information from various sources of relevance. In this combined study methodology, the traffic conflict study plays an important role.

### **10.3. Recommendations for improving VRU safety assessment**

The review of road safety assessment methods based on scientific literature and surveys conducted in the course of the InDeV project allows to put forward several general recommendations for improving VRU safety assessment. These recommendations also relate to improving data quality as well as comparability and compatibility of the national road accident data.

- The standard definition of injury accidents adopted by the United Nations as well as by the EC (CARE database) covers virtually all traffic accidents involving VRU with one exception: single pedestrian accidents (falls). Other single road user VRU accidents are probably seriously underreported. It is recommendable to include this additional category in VRU safety assessment studies as well as in the economic calculations of total accident costs.
- There is no clear definition of what constitutes an “injury” suffered by the victims of a road accident. Minor scratches and bruises will be called an injury in some countries but not in others. Since the occurrence of an “injury” is one of the preconditions to classify a collision as an accident, there is a grey area between “slight injury” and “property damage only” accidents. For the sake of consistency, minimum health damage which constitutes an “injury” should be defined.
- The determination of injury severity in road accident victims poses considerable challenges. The EC’s current efforts have not yet succeeded in producing a reliable system of reporting accurate numbers of the severely injured in different countries. The proposed criterion of serious injury based on the MAIS3+ level is difficult to implement and has its disadvantages. This definition has not been yet applied in practice in the surveyed countries.
- There is a need to harmonise not just the definitions of injury and its severity levels but also the procedures of accident data collection and verification among different countries as these procedures affect the quality, compatibility and completeness of the national databases. A review of the current procedures should be conducted and common guidelines worked out. However, this type of international study is beyond the scope of the InDeV project and should be undertaken by the EC or global organisations (WHO, OECD).
- One way of improving police accident data quality is to verify these using hospital/medical records. However, when comparing police-reported numbers of traffic accident victims with hospital data, one should bear in mind the differences in definitions and the scope of available information. For example, a serious injury resulting from a cyclist fall will be recorded in medical data without any information on whether it happened on a public road (and thus was a road accident) or in the forest (and thus was not a road accident).
- Lack of appropriate exposure measures to calculate the safety indicators for VRUs is a serious problem. Local population numbers can be used as exposure to calculate and compare fatality rates in cities and regions. Pedestrian and bicycle volumes should be used in addition to motorised traffic volumes to identify black spots at intersections and road crossings.
- An integrated approach to VRU safety assessment is proposed for improved results. This approach comprises a matrix of methods depending on the aim of the assessment: a combination of methods is proposed in order to obtain a more accurate, more comprehensive and faster safety evaluation.

## 10.4. Future research needs

Although most of the safety assessment methods discussed in this report have a long history and have been in use for many years, they need further development and improvement in terms of accuracy, validity, reliability and effectiveness. Several of these methods are planned to be further developed and used in research within the Work Packages of the InDeV project.

- Typical epidemiological road safety studies do not focus on vulnerable road users. Hence, development of proper statistical analysis tools is necessary to allow important conclusions to be drawn from accident databases concerning the accident risks to VRUs and the factors that contribute to accidents. Task 2.2 of InDeV involves such an epidemiological study of accidents with VRUs in the European Union based on the CARE database in which a new approach to analysing accident trends will be applied.
- Traffic conflict studies have been shown to be a useful method to detect and analyse safety critical events involving vehicular traffic. When it comes to analysis of the safety situation of VRUs, there is a need for further development and validation of the method. Today the method uses human observers and therefore is very resource-intensive in terms of time and labour. Research and development is needed on how to achieve reliable automatic video detection and classification of safety-critical traffic events involving pedestrians, cyclists and PTW riders. Within InDeV, WP3 will carry out work on validation of the method and WP4 will develop software tools for automatic detection and analysis of relevant traffic events.
- Naturalistic driving/riding studies have relied on specialized monitoring equipment installed in cars or on motorcycles and bicycles. The challenge is to develop applications that would use smartphones to monitor cycling as well as walking. This task will be undertaken as part of WP4 research.
- Self-reported accidents are a valuable source of information to assess the scale of underreporting in police accident records. This method is especially useful to capture information on VRU accidents that are never reported to the police. A methodology of conducting large-scale Internet-based self-reporting accident surveys has to be developed and tested. This work is part of WP5 of InDeV.

Apart from the issues described above, there are future research needs which go beyond the scope of the InDeV project. These are mostly related to accident data collection and quality control procedures.

- A methodology should be developed for improving police accident data quality with the use of hospital/medical records. Guidelines for the integration of police and medical data based on current best practices (e.g. the STRADA system in Sweden) would be very useful.
- Overall, there is a lack of appropriate exposure measures to calculate the safety indicators for VRUs. This is a serious problem which deserves further research. The question is: what are the most appropriate exposure measures to calculate accident rates involving different categories of vulnerable road users?

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# **Appendix 1**

## **Questionnaire survey 1**

## Project InDeV

### WP2

## Review of the current accident study methods and data

### Questionnaire survey 1

### Version 2.0

Country:	
Partner Institution:	
Person completing the questionnaire:	
E-mail:	

General notes:

**1. The objective of this questionnaire survey is to critically review the usefulness of the currently used methods for accident causation studies with relevance to VRUs.**

2. One set of forms A to F is to be filled for each InDeV partner country. The forms should present the situation in the whole partner country, not just studies carried out by partners.
3. The forms are to be filled by InDeV partners with input by external experts, if necessary. We feel that the Project partners are in the best position to report on the situation in their countries and know best where to seek the necessary information from external sources.
4. If more than one method in a particular category is used in your country, you should describe the most useful one from the point of view of VRU safety. However, you can decide to describe more than one method per category – in such a case please duplicate the tables necessary.
5. If a certain type of study (e.g. self-reported accidents) has never been conducted in your country – please put a comment “not applicable” in the relevant form.
6. At the beginning of each part A to F guidelines are provided. Please read the guidelines carefully as there may be differences between parts concerning how many studies/methods should be reported, from what time period, etc.
7. Comments are to be provided in the last row of each table. These comments should be numbered and the numbers inserted in relevant boxes. Comments can be written directly in the relevant boxes.
8. Please return the completed questionnaire forms to WUT ([p.olszewski@il.pw.edu.pl](mailto:p.olszewski@il.pw.edu.pl); [b.osinska@il.pw.edu.pl](mailto:b.osinska@il.pw.edu.pl)) by 12 September 2015.

**PART A - EPIDEMIOLOGICAL STUDIES BASED ON ACCIDENT DATA**

Partner responsible: WUT

Guidelines for filling FORMS A.1, A.2 and A.3:

1. This part of the questionnaire is concerned with reports on road safety situation in an area, based on police records of traffic accidents and injury. Three forms are provided according to the type of report:
  - a. General road safety report (Form A.1) is defined as a result of any accident frequency analysis in an area (country, region, city), presenting average accident statistics, charts, distributions, trends and traffic safety indicators without identification of high risk locations. An example of such report is:  
[http://ec.europa.eu/transport/road\\_safety/pdf/vademecum\\_2015.pdf](http://ec.europa.eu/transport/road_safety/pdf/vademecum_2015.pdf)
  - b. Black spot analysis (Form A.2) is defined as a study to identify high risk accident locations (intersections or short road sections – less than 0.5 km long), that is locations with high concentration of accidents. Black spot analysis is part of Black Spot Management Programme.
  - c. Road network safety analysis (Form A.3) is defined as a study aimed at ‘ranking of high accident concentration sections’. It means a method to identify, analyse and rank sections of the road network where a large number of accidents have occurred in proportion to the traffic flow or road length. Road network safety analysis is part of Road Network Safety Management process. An example of Road network safety analysis is the Eurorap Project: <http://www.eurorap.org/>
2. Three levels of geographical coverage (scale) are suggested for each form: “national, regional and city” – for Form A.1 and “region, city and road” for Forms A.2 and A.3. For each form and each level please describe only one report/study. Choose as an example the report which would be most useful from the VRU accident causation point of view.
3. Please report only on the most recent (last 3 years) or the most comprehensive (from the VRU safety point of view) studies in your country.
4. If another type of report/method is used in your country (i.e. not complying with any of the above definitions), please create a new Form A.4 to describe and assess it.
5. Definitions of terms used in Forms A.1-A.3 follow CADaS Glossary of the CARE DATABASE.

<b>Form A.1 Epidemiological studies based on accident data - method assessment</b>			
Method: <b>GENERAL TRAFFIC SAFETY REPORT</b>	<b>Geographical coverage/scale</b>		
	<b>National</b>	<b>Regional</b>	<b>Local/city</b>
• Applications so far for:			
• Name of report:			
• Institution publishing report:			
• Frequency of report:			
<b>Content with respect to VRU victims:</b>			
• Pedestrians	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Cyclists	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Motorcyclists	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Moped riders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Is there tabulation of accidents by VRU category for*:</b>			
• Urban area (inside/outside urban boundary signs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Junction (not at junction, crossroad, roundabout, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Junction control (give way or stop sign, traffic signal, uncontrolled, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Carriageway type (single carriageway: one way, two way, dual carriageway)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Pedestrian crossing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Timing (distribution by month, day of the week, hour)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Weather conditions (dry, rain, snow...)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Light conditions (daylight, darkness...)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Injury severity of VRU (killed, serious, slight injury)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• VRU victim's age (distribution)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Other (please describe):			
Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:			
• contributing factors?	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO
• risk level?	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO
Exposure level used (veh-km, population, road length):			
Usefulness of the method for project InDeV:	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW
Comments (i.e. problems/gaps in the current method):			

\* according to CADaS Glossary (CARE DATABASE).

<b>Form A.2 Epidemiological studies based on accident data - method assessment</b>			
Method: <b>BLACK SPOT ANALYSIS</b>	<b>Geographical coverage/scale</b>		
	<b>Region</b>	<b>City</b>	<b>Road/District</b>
• Applications so far for:			
• Name of analysis/report:			
• Institution publishing report:			
• Frequency of report:			
• What is the definition of black spot?			
<b>Content with respect to VRU victims:</b>			
• Pedestrians	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Cyclists	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Motorcyclists	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Moped riders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• VRU injury severity (killed, serious, slight)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Road users involved	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Manoeuvres of vehicles/traffic units			
• Other (please describe):			
Detailed collision diagrams	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:			
• contributing factors?	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO
• risk level?	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO
Usefulness of the method for project InDeV:	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW
Comments:			

<b>Form A.3 Epidemiological studies based on accident data - method assessment</b>			
Method: <b>ROAD NETWORK SAFETY ANALYSIS</b>	<b>Geographical coverage/scale</b>		
	<b>Region</b>	<b>City</b>	<b>Road/District</b>
• Applications so far for:			
• Name of analysis/report:			
• Institution publishing report:			
• Frequency of report:			
<b>Content with respect to VRU victims:</b>			
• Pedestrians	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Cyclists	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Motorcyclists	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Moped riders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Exposure level used (veh-km, population, road length):			
Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:			
• contributing factors?	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO
• risk level?	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO	<input type="checkbox"/> YES <input type="checkbox"/> NO
Usefulness of the method for project InDeV:	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW
Comments:			

**PART B: IN-DEPTH ACCIDENT INVESTIGATIONS**

(Partner responsible: BAST)

Guidelines for the In-Depth accident investigation studies form B.1:

- This questionnaire aims to identify different In-depth projects concerning traffic accident investigation. Since every project uses a different methodology, the data may differ in their applicability to the VRU aspect in the InDeV project.
- Please use one form for each project (= data base).
- In the following the different sections of the form shall be explained:
  1. Names the project, e.g. GIDAS
  2. **Country and area** of data collection
  3. Gives a short **introduction** of the project.
  4. Asks for the criteria of the data collection. What are the **key criteria** to include an accident in the investigation? Which kind of traffic modes are considered?
  5. What is the **methodology** behind? Is there a statistical approach in the data collection? At What times are data collected, e.g. every day, only on weekdays,...? Are the data collected on-site or in retrospective? Are the data representative for the country considering national accident data? Please leave a comment about restrictions.
  6. Which **type of data** is available- a data base, pictures, technical reconstruction?
  7. How are **injury severities** encoded? Is the information available also for VRUs?
  8. Please give the **number of cases** per year and the total number of cases available in the data base.
  9. Based on this data, is an investigation of VRU accidents with respect to contributing factors and risk levels possible?
  10. Please characterize method's requirements in terms of skilled personnel, time effort, costs, etc. Does the InDeV project have **access** to the data, if yes through which partner? How **useful** is the data base for the InDeV Project?
  11. Please provide references to publications, papers, web pages, etc.
  12. Please leave a comment.



<b>Form B.1 In-depth accident investigations - method assessment</b>	
1. project name	
2. 2.1 Country 2.2 Area of investigation	
3. Institution conducting the study	
4. Criteria of data collection	
4.1 Which kind of accident?	
4.2 Participation mode	<input type="checkbox"/> car <input type="checkbox"/> truck <input type="checkbox"/> bus <input type="checkbox"/> train/tram <input type="checkbox"/> cyclist <input type="checkbox"/> pedestrian <input type="checkbox"/> moped rider <input type="checkbox"/> motorcyclist <input type="checkbox"/> other, e.g. _____
5. Methodology	<input type="checkbox"/> observation <input type="checkbox"/> police data <input type="checkbox"/> interview of participants <input type="checkbox"/> hospital data
5.1 statistical method	
5.2 time of data collection	
5.3 data quality, number of variables	
5.4 data collection procedure	<input type="checkbox"/> on-site <input type="checkbox"/> retrospective <input type="checkbox"/> both <input type="checkbox"/> other, e.g.: _____
5.5 representativeness? Any restrictions?	<input type="checkbox"/> yes <input type="checkbox"/> no
6. Type of data available	<input type="checkbox"/> data base <input type="checkbox"/> pictures <input type="checkbox"/> technical reconstruction <input type="checkbox"/> others e.g. _____
7. injury severity encoding	<input type="checkbox"/> slight <input type="checkbox"/> serious <input type="checkbox"/> killed <input type="checkbox"/> other, e.g. <input type="checkbox"/> AIS <input type="checkbox"/> MAIS <input type="checkbox"/> ISS <input type="checkbox"/> available for VRU
8. Number of cases	_____ per year    _____ in total
9. Data analysis process to define VRU accident causation –Is it possible to analyze and identify	
• contributing factors?	<input type="checkbox"/> no <input type="checkbox"/> yes
• risk level?	<input type="checkbox"/> no <input type="checkbox"/> yes
10. Method characteristics	
10.1 Conditions for using the method – equipment, trained personnel, etc	
10.2 Cost (per accident), labour and time requirements, difficulties	
10.3 Access for InDeV project?	<input type="checkbox"/> no <input type="checkbox"/> yes, through: _____
10.4 Usefulness for the Project	<input type="checkbox"/> high <input type="checkbox"/> low
11. References to papers/web pages/...	
12. Comments	

**PART C.: NATURALISTIC DRIVING STUDIES**

(Partner responsible: AAU)

Guidelines for the naturalistic “driving” studies form C.1:

- This questionnaire aims to identify naturalistic “driving/cycling” studies of vulnerable road users (cyclists, pedestrians, moped riders, motorcyclists) in your country.
- Please only include studies that collect naturalistic data from VRUs. Data collected from vehicles should be excluded.
- Please use one form for each study. When there are **multiple publications about a single study** (e.g. report and paper about the same study), consider it as one study and **merge them into one form**.
- Site-based data collection should not be described.

<b>Form C.1 Naturalistic driving studies - method assessment</b>	
Method/ project name:	
Brief description of the method/project:	
Institution conducting the study:	
VRU type:	<input type="checkbox"/> cyclist <input type="checkbox"/> pedestrian <input type="checkbox"/> moped rider <input type="checkbox"/> motorcyclist
Data collection method:	<input type="checkbox"/> smartphone <input type="checkbox"/> other portable equipment <input type="checkbox"/> equipped bicycle/moped/motorcycle
Data collected (video, GPS coordinates, speed, acceleration, etc.):	
Number of participants:	
Duration of data collection:	
Applications of data (counts, accident risk, accident cause, road user classification, exposure/distance measurements, etc.):	
Results:	
Access to data:	
Usefulness of the method for project InDeV:	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW
Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:	
• contributing factors?	<input type="checkbox"/> YES <input type="checkbox"/> NO
• risk level?	<input type="checkbox"/> YES <input type="checkbox"/> NO
Conditions for using the method – equipment, trained personnel, permissions, etc.:	
Cost, labour and time requirements, difficulties:	
References to papers/web pages/...:	
Comments:	

## PART D: BEHAVIOURAL OBSERVATIONS

(Partner responsible: HU)

Guidelines for behavioral observation studies form D.1:

- This questionnaire aims to aid in the process of identifying relevant studies for the literature review regarding behavioral observations. Please identify each topic that has been addressed in your country and has been officially published in some form. **The topics should not necessarily focus on vulnerable road users only.**
- Please try to be as complete as possible.
- Please use **one form for each topic** (if a certain study is repeated (e.g. yearly monitoring of seatbelt usage), please indicate how often).
- The main goal of the studies should be to observe safety-relevant behavior of road users, either in the form of interaction with other road users (e.g. yielding behavior), the use of safety equipment or systems (e.g. seat belts, helmets), adherence to traffic rules (e.g. speeding, red light violations), etc.
- Studies that also involved law enforcement (e.g. fining drivers that broke the rules) should not be included.
- The behavioral observation studies should meet the following criteria:
  - Observations took place on-site
  - Road users being observed were not aware of this
  - The study has been carried out after 2004. In the case of repeated observations, also include studies that started earlier, but have at least one iteration after 2004.
- Since the focus lies on behavioral observations, exposure data measurements should not be included.
- When there are **multiple publications about a single study** (e.g. report and paper about the same study), consider it as one study and **merge them into one form.**
- **Multiple responses can be indicated if necessary.**
- Naturalistic driving studies and traffic conflict studies should be excluded.



**PART E: STUDIES BASED ON SURROGATE SAFETY MEASURES** (Partner responsible: LU)

Guidelines for FORME.1 and FORME.2:

- This questionnaire aims to identify every surrogate safety method/technique that has ever been practically applied and documented in your country.
- By surrogate safety measures here we mean indicators, other than accidents, that are believed to reflect the safety at a certain traffic site. We aim only at indicators that try to **measure severity of observable situations in some way**. This can either be in form of identifying discrete events (“traffic conflicts”) or using more continuous or integrated indicators. Observational studies that observe traffic behaviour without assessing the severity of situations (e.g. normal yielding behaviour) are not included!
- “In your country” is defined as: the data have been collected at locations in your country AND/OR analyses have been (partly) performed by researchers from an institute in your country.
- This overview addresses only **site-based studies**. Studies that collect data in other ways, such as naturalistic driving/cycling studies and microsimulation studies, should be excluded.
- Even the methods/studies that address VRU issues only indirectly (e.g. using an indicator that could be applied for VRU conflicts), or that only partly focus on VRUs (e.g. all conflicts at a specific intersection are analysed) should be included.
- Since much research on surrogate safety measures was done in 1970-1980s, we don’t have any limit on how recent the study must be, even “old” studies should be included if possible.
- Use a separate FORME.1 for each technique/method that you can identify.
- Use the FORME.2 to list the publications that describe the methods/their application mentioned in FORME.1. The secondary goal is to assist in the literature search and review that will be done at a later stage. Include publications that you consider of great importance (that should not be missed) and those that might be difficult to find (in local language, old and existing only on paper, high quality consultancy reports, etc.)
- The focus of the publication is considered “methodological” when the study aims to contribute to the theory of surrogate safety measures (examples are development of new indicators, validation, etc.). The focus is “applied/practical” when the study is used to gain knowledge on specific aspects of traffic safety, or for answering policy related questions (e.g. comparing safety of different types of infrastructure, before-and-after studies, analysing the cause of particular types of conflicts...)
- **Multiple responses (checkboxes) can be indicated** in both forms.

<b>Form E.1 Studies based on surrogate safety measures - method assessment</b>	
Method name:	
Institution using/ experts in the method:	
Method based on:	<input type="checkbox"/> counts of critical events (traffic conflicts) <input type="checkbox"/> calculation of an integrated safety index <input type="checkbox"/> other, namely: _____
Types of indicators used to estimate severity:	<input type="checkbox"/> Time-to-Collision <input type="checkbox"/> Post-Encroachment Time <input type="checkbox"/> speed-based <input type="checkbox"/> deceleration-based <input type="checkbox"/> subjective or descriptive <input type="checkbox"/> other, namely _____
Has the method been validated against accidents?	<input type="checkbox"/> no, not at all <input type="checkbox"/> yes, but only very limited <input type="checkbox"/> yes, to a reasonable extent <input type="checkbox"/> yes, very thoroughly <input type="checkbox"/> don't know
Applications so far for:	
• number of studies:	
• number of publications:	
How would you judge the status of the methods among safety professionals in your country	<input type="checkbox"/> well-established, frequently and recently used <input type="checkbox"/> well-established, but is not used any more <input type="checkbox"/> not established yet, but there is interest to use it wider <input type="checkbox"/> one-time attempt that had no follow-ups <input type="checkbox"/> don't know
Usefulness of the method for project InDeV:	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW
Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:	
• contributing factors?	<input type="checkbox"/> YES <input type="checkbox"/> NO
• risk level?	<input type="checkbox"/> YES <input type="checkbox"/> NO
Conditions for using the method – equipment, trained personnel, permissions, etc.:	
Cost, labour and time requirements, difficulties:	
Comments:	

<b>Form E.2 Studies based on surrogate safety measures - publications</b>	
<b>GENERAL INFORMATION</b>	
Title of study:	
Author(s):	
Institution(s) conducting the study:	
Year:	
Brief description of the study:	
<b>PUBLICATION</b>	
Type(s) of publication(s):	<input type="checkbox"/> Research report <input type="checkbox"/> Conference paper <input type="checkbox"/> Journal paper <input type="checkbox"/> Dissertation <input type="checkbox"/> other, namely: _____
Language	<input type="checkbox"/> English <input type="checkbox"/> Other (with English summary), namely: _____ <input type="checkbox"/> Other (no English summary), namely: _____
Accessibility	<input type="checkbox"/> Online accessible <input type="checkbox"/> Not online, but my institution has a copy <input type="checkbox"/> Not online, but my institution can obtain a copy if necessary <input type="checkbox"/> Not accessible
Bibliographic details (e.g. report number, proceedings name, journal name etc.).	
<b>CONTENT</b>	
Focus	<input type="checkbox"/> Methodological <input type="checkbox"/> Applied/Practical
Applied surrogate safety technique, method, indicators	
Does the study involve VRUs?	<input type="checkbox"/> yes, main focus <input type="checkbox"/> yes, but not the main focus <input type="checkbox"/> no, VRUs are excluded
<b>OTHER</b>	
Comments:	



**PART F: SELF-REPORTED ACCIDENTS**

(Partner responsible: AAU)

Guidelines for form F.1:

- This questionnaire aims to identify studies where self-reporting of accidents have been used. Self-reporting is when people are asked (for example via telephone, mail, email or interviews) if they have experienced a traffic accident in the last XX months or years.
- You may include studies with all groups of road users, not just VRU's (as we expect that there are very, very few studies only with VRU's).
- Please use one form for each study. When there are **multiple publications about a single study** (e.g. report and paper about the same study), consider it as one study and **merge them into one form**.

<b>Form F.1 Self-reported accidents - method assessment</b>	
Method/ project name:	
Brief description of the method/project:	
Institution conducting the study:	
Number of respondents:	
Sample quality (representative/geographical limited/age/volunteers...):	
VRU type:	<input type="checkbox"/> cyclist <input type="checkbox"/> pedestrian <input type="checkbox"/> moped rider <input type="checkbox"/> motorcyclist
Period of recall – was the respondent asked to recall accidents in the last year/5 years/10 years etc.:	
Method of data collection (online, paper, telephone, interview...):	
Was self-reported data compared with other data (insurance/police/hospital/...):	
Self-reports used for (estimate of number of accidents/accident causation/accident costs/...):	
Access to data:	
Usefulness of the method for project InDeV:	<input type="checkbox"/> HIGH <input type="checkbox"/> LOW
Data analysis process to define VRU accident causation – is there a well-defined analysis procedure for identifying:	
• contributing factors?	<input type="checkbox"/> YES <input type="checkbox"/> NO
• risk level?	<input type="checkbox"/> YES <input type="checkbox"/> NO
Conditions for using the method – equipment, trained personnel, permissions, etc.:	
Cost, labour and time requirements, difficulties:	
References to papers/web pages/...:	
Comments:	

## **Appendix 2**

### **Questionnaire survey 2**

## Project InDeV

### WP2

## Quality of road accident data

### Questionnaire survey 2

### Version 1.3

Country:	
Partner Institution:	
Person completing the questionnaire:	
E-mail:	

#### General notes:

- InDeV analyses of accident data conducted so far indicate that the quality and reliability of traffic accident data varies across countries. Differences between countries in fatality and injury rates are very difficult to explain and the proportions of victims killed, severely injured and slightly injured vary widely for no apparent reason. This makes accident data of limited use for assessing the safety of vulnerable road users.**
- The objective of this questionnaire survey is to critically review the scope and methods of collecting road accidents data and methods of their verification. We hope that this will help to explain some of the differences and inconsistencies in VRU fatality and injury rates in different countries.**
- One questionnaire, consisting of ten questions, is to be filled by the InDeV partner in each country. The answers should present the situation in the whole partner country.
- The questions are to be answered by InDeV partners with input by external experts, if necessary. We feel that the Project partners are in the best position to report on the situation in their countries and should know best where to seek the necessary information from external sources.
- Comments can be provided after each question, if necessary.
- Please return the completed questionnaire forms to WUT ([p.olszewski@il.pw.edu.pl](mailto:p.olszewski@il.pw.edu.pl); [b.osinska@il.pw.edu.pl](mailto:b.osinska@il.pw.edu.pl)) by 24 June 2016.

**CARE database definitions** are given as a reference for questions 1 and 8:

**Injury Road Accident:** incident on a public road involving at least one moving vehicle and at least one casualty (person injured or killed)

**Fatally injured**

Death within 30 days of the road accident, confirmed suicide and natural death are not included.

**Injured**

The road user was seriously or slightly injured (but not killed within 30 days) in the road accident.

**Seriously injured**

Injured (although not killed) in the road accident and hospitalized at least 24 hours.

**Slightly injured**

Injured (although not killed) in the road accident and hospitalized less than 24 hours or not hospitalized.

**Not injured**

Person participating in the accident although not injured.

1. Please specify the definitions which apply in your country in the Police road accident database:

a. Road accident/injury accident

Same as CARE definition above

Other (please give the definition below)

.....

b. Killed/fatally injured

Same as CARE definition above

Other (please give the definition below)

.....

c. Injured

Same as CARE definition above

Other (please give the definition below)

.....

d. Seriously injured (as reported)

Same as CARE definition above

Other (please give the definition below)

.....

e. Slightly injured (as reported)

Same as CARE definition above

Other (please give the definition below)

.....

f. Not injured

Same as CARE definition above

Other (please give the definition below)

.....



7. Do you use other databases to compare with the Police accident database?  
 Yes  No

If Yes, which database do you use?

.....

If Yes, please describe how you compare these data (which information/variables do you use?)

.....  
.....

8. If hospital injury database is used, what definitions are used in that database?  
a. Road accident/injury accident

.....  
.....

- b. Killed/fatally injured

.....  
.....

- c. Injured

.....  
.....

- d. Seriously injured

.....  
.....

- e. Slightly injured

.....  
.....

9. Do you use geographic coordinates to define localization of accidents?  
 Yes  No

If Yes, which format do you use:

GPS

DMS

WGS84

If No how do you define location of the accident?

- a. in built-up areas

.....

- b. non built up areas

.....

10. Please comment on whether your country data base is suitable for conducting analyses of VRU safety in following aspects:

- a. Scope of data  Yes  No (please describe below)

.....  
.....

- b. Data reliability  Yes  No (please describe below)

.....  
.....

- c. Completeness of data  Yes  No (please describe below)

.....  
.....

## Appendix 3

### Scoping literature review method

This section presents the methodology used to conduct the scoping literature review that was performed in four areas: behavioural observations, traffic conflict studies, naturalistic driving studies and self-reported accidents. The results of these reviews are presented in Appendices 4 to 7 to this report. A common method was applied which is presented here using the “behavioural observation studies” review as an example.

Because the number of published studies concerning behavioural observation studies has been increasing rapidly in recent years, it is important to synthesize the available evidence. Literature reviews help summarise the findings and identify relevant research opportunities. Most studies use narrative reviews with implicit processes to provide evidence (Garg et al., 2008). However, the reader cannot determine if this evidence is based on the author’s experience, how much literature was researched and whether or not certain studies were ignored due to contradicting findings. Studies described in a narrative review are mostly those that reinforce the ideas and research objectives of the conducted study. In order to avoid subjectivity in the process of summarizing the available literature on a certain topic, other reviewing techniques have been developed. Scoping reviews, for example, use a systematic approach to retrieve relevant articles. Such reviews aim to “map rapidly the key concepts underpinning a research area and the main sources and types of evidence available. They can be undertaken as stand-alone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before” (Mays, Roberts & Popay, 2001; Wilson, Lavis & Guta, 2012). Guiding future research and reducing duplicate efforts are important objectives (Armstrong et al., 2011; Wee & Banister, 2016). An additional advantage is that such reviews can be used for many applications, even outside the authors’ intended purposes (Armstrong et al., 2011). The quality of a scoping review is determined by its clear definition of terms, the systematic retrieval of relevant literature, the transparency and replicability of the data extraction process and the acknowledgement of posed limitations. The following sections describe the important elements of the review process.

#### A3.1 Review team

Although it was originally planned for members of all partner countries to be included in the review team, it was decided, based on the high amount of references, that the review team should be as small as possible. Subjectivity issues are inevitable when the review team is large as each member of the review team may interpret the defined criteria differently (Mallet et al., 2012). Therefore, the review team was limited to two members who created and tested the search protocol and designed the first version of the codebook. Regular discussions and multiple consistency checks were part of the entire review process.

#### A3.2 Search Protocol

The search protocol describes the databases and search terms that are used to collect data. Three major online databases were systematically searched for possible relevant journal articles: Web of Science, Science Direct and TRID. The authors believed that these three electronic databases were comprehensive enough to yield most relevant references regarding observation studies of road user behaviour. After testing several combinations of terms in the Web of Science and Science Direct databases, a search



term was formulated and used in all three databases: Traffic AND (Behavior OR Safety). Several additional filters that were set for the databases can be found in Annex 1. References were retrieved in the late afternoon on December 2<sup>nd</sup> 2015. Thirteen papers accepted for publication in 2016 were found but were recoded in our review as papers published in 2015. The three databases yielded 21,169 papers which were all imported to the Endnote referencing software. After the automatic and manual removal of duplicate entries, 12,121 references remained for screening.

### **A3.3 Screening**

One of the most important stages of a scoping review is the screening of references found by the search strategy. During this stage, the identified references are assessed for relevance. It is important for the exclusion criteria to be defined as clearly and unambiguously as possible in order to limit the influence of selection bias (the extent to which different individuals include or exclude references) and to guarantee the replicability of the review process for other researchers. In our review, three rounds of screening were used to identify the relevant references:

- Selection screening: The first screening round was used to remove all references that were not peer-reviewed journal articles published in English. Examples include conference proceedings, non-peer-reviewed journal articles, book sections and research reports. After this screening round, 7,007 references remained. Unlike the other steps of the screening process, selection screening was performed by only one member of the review team.
- Relevance screening: The second round of screening evaluated the relevance of the identified references. Both members of the research team checked the titles and abstracts to determine if the articles dealt with unobtrusive observations of road user behaviour. Three exclusion criteria were formulated: not relating to (road) traffic, no collection of uninformed observed behaviour (e.g. driving simulator, questionnaires, crash data analyses) and being a traffic conflict study only. During this stage, the differences in in- or exclusion among the research members were discussed. In case of doubt, references were kept for eligibility screening.
- Eligibility screening: Almost 700 full papers were examined for data extraction. At the start of this screening round, papers were coded into the codebook by both review members until a satisfactory level of consistency was reached (after about 75 references). The papers were then divided based on the year of publication (even vs odd years). Additionally, a subsample of papers was coded by both review members in another effort to check for consistency. Whenever a reviewer was not sure about certain aspects of the extracted information or if an article did not seem to be eligible for information extraction, a notation was made and the reference was checked by the other review member as well. Some papers were found that used the same data (the NGSIM data-set) but remained included nonetheless because the application and use of the data was different.

### **A3.4 Paper retrieval**

The automatic text retrieval function in Endnote was used to access full text articles. Papers that could not be found were searched for manually through google scholar and Research Gate. A list of missing articles was then formulated and sent to the partners involved in the project. Finally, the library of Hasselt University was consulted in an

attempt to acquire the missing articles. Out of the 600 references, 24 publications could not be located.

### A3.5 Codebook

A codebook was created to structure the information of interest. A subsample of references was used to compose and test both the completeness of the codebook and the consistency of coding between the members of the review team. Around 55 papers were used before the final working version of the codebook was created. After the information extraction process, the codebook was revised again to include elements that were difficult to categorize based on the definitions used in the working version. Aspects such as general information (full reference, research goal and research focus), topic (infrastructural element and subject of the study), methodological information and indicators were coded.

20150205 Codebook
Behavioral Observation Studies

ID: 
Coder: 
Research Goal: 
 Traffic Safety  Mobility
Year: 
Frequency:

REFERENCE

Comments (if any):   Exclude

#### Topic

<p style="text-align: center; margin: 0;">Infrastructure</p> <input type="checkbox"/> Signalized Intersection <input type="checkbox"/> Pedestrian Crossing <input type="checkbox"/> Cyclist Crossing <input type="checkbox"/> Roundabout <input type="checkbox"/> Channelized Right-Turn <input type="checkbox"/> Priority Controlled <input type="checkbox"/> Priority from the right <input type="checkbox"/> Stop controlled <input type="checkbox"/> Railroad crossing <input type="checkbox"/> Highway <input type="checkbox"/> Work zone <input type="checkbox"/> <input type="text"/>	<input type="checkbox"/> Yielding <input type="checkbox"/> Crossing Behavior <input type="checkbox"/> Red-Light Running <input type="checkbox"/> Merging <input type="checkbox"/> Lane change <input type="checkbox"/> Dilemma Zone	<input type="checkbox"/> Gap acceptance <input type="checkbox"/> Turn indicator use <input type="checkbox"/> Countdown Timers <input type="checkbox"/> Driver distractions <input type="checkbox"/> Speeding: <input type="text"/>	<input type="checkbox"/> Mobile phone use <input type="checkbox"/> Seatbelt usage <input type="checkbox"/> Child restraint use <input type="checkbox"/> Driving Under Influence <input type="checkbox"/> Protective clothing
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Other topic, namely:

#### General Information

<p><b>Road Users Involved</b></p> <input type="checkbox"/> Pedestrians <input type="checkbox"/> Cyclists <input type="checkbox"/> Powered-Two-Wheelers <input type="checkbox"/> Car Drivers <input type="checkbox"/> Heavy vehicle drivers (specifically) <input type="checkbox"/> Trains <input type="checkbox"/> <input type="text"/>	<p><b>Combined with (if applicable):</b></p> <input type="checkbox"/> Driving Simulator <input type="checkbox"/> Naturalistic Driving <input type="checkbox"/> Questionnaires <input type="checkbox"/> Traffic Conflict Technique <input type="checkbox"/> Microsimulation <input type="checkbox"/> Crash data analysis <input type="checkbox"/> <input type="text"/>	<p><b>Characteristics</b></p> <p>Type: <input type="text"/></p> <p>Number of sites: <input type="text"/></p> <p>Number of records: <input type="text"/></p> <p>Observation period, please specify:</p> <input type="checkbox"/> Weekdays <input type="checkbox"/> Weekend <input type="checkbox"/> Peak <input type="checkbox"/> Off peak <input type="checkbox"/> Daytime <input type="checkbox"/> Nighttime
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Focus:

Location:

Comments (if any):

#### Data Collection

<p><b>Source</b></p> <input type="checkbox"/> Human observer <input type="checkbox"/> Video cameras <input type="checkbox"/> ANPR cameras <input type="checkbox"/> Loop Detectors <input type="checkbox"/> Speedguns <input type="checkbox"/> Sensors <input type="checkbox"/> Traffic Fines <input type="checkbox"/> <input type="text"/>	<p><b>Parameters</b></p> <input type="checkbox"/> Yielding behavior <input type="checkbox"/> Looking behavior <input type="checkbox"/> Gap Acceptance <input type="checkbox"/> Waiting position <input type="checkbox"/> Waiting time <input type="checkbox"/> Lane change <input type="checkbox"/> Crossing path <input type="checkbox"/> Distraction <input type="checkbox"/> Turn indicator <input type="checkbox"/> Seatbelt usage <input type="checkbox"/> Mobile phone <input type="checkbox"/> Smoking <input type="checkbox"/> Helmet wearing <input type="checkbox"/> Headlight use <input type="checkbox"/> Age <input type="checkbox"/> Gender	<input type="checkbox"/> Speed <input type="checkbox"/> Merging <input type="checkbox"/> Following distance (space/time headway) <input type="checkbox"/> Lateral position <input type="checkbox"/> Red light running <input type="checkbox"/> TTC (or other conflict indicator) <input type="checkbox"/> Traffic counts <input type="checkbox"/> <input type="text"/>
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Comments (if any):

Comments (if any):