The InDeV project in a nutshell

Understanding the causes of accidents is an important prerequisite for developing effective counter-measures and improving safety in general.

The knowledge about such factors is not always as profound as it should be, especially when it comes to non-motorised traffic and vulnerable road users (VRUs).

At this point, the In-depth Understanding of Accident Causation for Vulnerable Road Users (InDeV) project comes into play.

The main objective of the project is to develop an integrated methodology to study causes of accidents with vulnerable road users (such as pedestrians, cyclists and moped riders).

In this project, we spent much effort revising the current study methods of diagnosing safety and attempted to integrate them into a common toolbox for practitioners. The methods covered include analysis of accident data, naturalistic studies, conflict and behaviour observations and safety inspections. Each method has its strengths and weaknesses, and by using them together we hope to improve the general understanding of the safety challenges for vulnerable road users.

A significant part of the project was devoted to the development of technical tools for data collection and analysis, such as software for video analysis and mobile apps for the detection of cyclists’ falls and self-reporting of incidents in traffic. We also suggested a framework for a comprehensive assessment of socio-economic costs related to road-accidents involving VRUs.

About this booklet

Road safety practitioners and analysts often lack comprehensive tools and guidelines to collect and integrate different types of data, making their diagnosis of VRU safety issues incomplete and prone to bias. To combat this issue, InDeV has developed a handbook entitled: ‘How to analyse accident causation? A handbook with focus on vulnerable road users’. This handbook is designed to offer road safety professionals easy access to information regarding road safety diagnostic methods as well as how they can be applied in order to identify a certain road safety problem and gain insights in the causation factors of VRU accidents. The focus within the handbook lies on applying the techniques to assess VRU safety; however, the discussed techniques can also be applied to diagnose the safety of all road users.

The booklet you are holding in your hand shall serve as an introduction to the handbook. It shall give you a quick and condensed overview of the methods analysed and the recommendations for use for practitioners. It shall give you guidance and inform you about what to expect in the handbook. We hope you enjoy reading this booklet and find the information inside valuable.

Sincerest best wishes,
Since the ambition of the handbook is to become the main reference document for VRU safety diagnosis by practitioners, usability by a large group of end users is a key aspect. The handbook therefore focuses on applying state-of-the-art but accessible techniques that make optimal use of existing data and/or data that is relatively easy and cheap to collect. Each chapter describes a different road safety technique that can be applied for in-depth analysis of the causes of accidents involving VRUs (and other road users), such as accident data analysis, surrogate safety indicators, self-reported accidents, road user behavioural data, naturalistic cycling and walking studies and road safety audits and inspections.

The handbook also focuses on delivering better calculations of the socio-economic costs of VRU accidents. For each diagnostic technique, the book provides guidelines on how to choose the right method to study a particular problem, alongside step-by-step instructions on how to design and perform the study and present and interpret the results. For each technique, additional information is included in text boxes, such as best practices, use cases or practical examples. It also clearly indicates the strengths and limitations of the different techniques. Each chapter also contains an extended list of recommended literature that can be used to deepen the reader’s knowledge in the subject and in this way, it can be a useful starting point even for researchers new to the field.

Furthermore, the novel contribution of this handbook lies in the development of an integrated approach to investigate accident causation based on a combination of several data sources and research methods. This allows researchers to overcome the limitations of each individual technique.

This is especially important for VRU accidents as it is widely acknowledged that they suffer from severe under-reporting issues. By combining accident data with self-reported or naturalistic data, the application of this integrated approach provides road safety practitioners and decision makers with enhanced insights in the causational factors that play a role in VRU accidents. Therefore, this integrated approach will allow a wide target group of road safety practitioners and analysts to fill their own ‘micro-level’ knowledge gaps (for example, detecting problematic locations for VRUs in their municipality, gathering insight into the causes of accidents at the level of a specific intersection or road segment, and more) and support them with better methods to identify and analyse VRU safety issues.

Applying the principles described in this book will contribute to the further improvement of road safety and a better, in-depth understanding of the causal factors contributing to unsafe conditions for VRUs, which is crucial to select targeted countermeasures to reduce the number of deaths and serious injuries. Therefore, this handbook also contributes to the ambition of the European Commission to half the number of serious injuries and fatalities by 2030 and achieving the long-term goal of Vision Zero to get to zero fatalities by 2050.
Road accident statistics and available analysis techniques

The book’s chapter on analysing road accident statistics demonstrates how traffic accident data can be used to assess and monitor the road safety situation in an area of interest.

Road accident statistics provide essential information for traffic safety specialists to assess the safety situation in a country, region or city. Reports are prepared to identify the time trends of accident and injury occurrence, and to help assess the relative importance of problems. Benchmarking between countries can help to compare the safety situation among different areas and to monitor progress towards the set targets for traffic safety improvement. Accidents are rare and random events, so any estimates based on accident counts are subject to statistical error. Therefore, basics of statistical theory used in analysing accidents are first introduced.

The chapter introduces accident data sources, such as national and international accident databases, for example, the European CARE database. In using and interpreting these data, one should be aware of the different definitions of injury severity and accident attributes used in different countries.

The chapter shows how to correctly identify dangerous locations using black spot analysis and network safety analysis. In both cases, it is recommended to use the Empirical Bayes method as the proper statistical approach. This method makes use of both accident counts observed at a site and results from an accident prediction model for similar sites. Although the techniques presented concern all road users, the focus is on vulnerable road users, especially pedestrians and cyclists.

**The self-reporting of accidents and near accidents**

Due to a typically low reporting rate of slightly injured road users – and sometimes no reporting at all – supplemental data is needed alongside traditional accident reporting. Self-reporting can help with this and can increase knowledge about traffic safety and contribute to developing a more coherent view on the actual traffic safety challenge in the area in question.

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**Fig. 1** The distribution of road fatalities in the EU according to road user type shows that VRUs comprise almost half of all victims (based on CARE database, years 2009–2013)

**Fig. 2** Similar to accident data from official records, data should be interpreted with caution. Because the road users register the information themselves, one should have in mind that some responses may not be correct, either due to ignorance or on purpose. Most people want to “fit in”, and any socially unacceptable behaviour might be under-reported. However, if the respondent feels sure about anonymity, the reluctance usually decreases and the reliability from self-reporting increases.

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Eu28
- Goods vehicles 3%
- Pedestrians 21%
- Pedal cycles 7%
- Motorcycles 15%
- Cars + taxi 47%
- Goods vehicles 25%
- Other 2%
- Mopeds 3%
- Other 2%
- Motorcycles 15%
- Cars + taxi 47%

SafeVRU

Have you or your bicycle/moped been in physical contact with another road user or vehicle?

- Yes
- No

www.indev-project.eu

4 In-depth Understanding of Accident Causation for Vulnerable Road Users
Surrogate safety measures and traffic conflict observations

Traffic conflicts are breakdowns in normal traffic functioning in which safety margins are compromised. Fortunately, in traffic conflicts the actual collision is often avoided, but the mechanisms and contributing factors are very similar to accidents. While accidents are relatively rare, traffic conflicts are much more frequent. So frequent, in fact, that it is actually possible to observe them, and thus learn a lot about how and why breakdowns (and thus accidents) in traffic take place.

Traditionally, traffic conflict studies relied on using human observers who had to detect and judge conflicts in real time while being present in the traffic environment at the studied site. To avoid subjectivity, it is however preferable to use standardised objective indicators that describe the severity of a traffic conflict. Such indicators can be extracted, for example, from a video camera that has to be properly calibrated and allow measuring speeds and distances between road users.

A great variety of conflict indicators and definitions have been suggested, but only a few of them have actually been validated and tested on large datasets. In the InDeV project, we contributed to the fundamental knowledge regarding the relation between conflicts and accidents and performed a large-scale validation study. We focused on conflicts and accidents involving cyclists and pedestrians, whose vulnerability should be taken into account when judging the conflict severity. We also developed software tools that help to identify and analyse traffic conflicts in recorded video.

Self-reporting of accidents and traffic conflicts is particularly useful for gaining knowledge of traffic conflicts, which are usually not registered, and for getting information on less severe accidents – such as those which result in slight injuries or property damage only – because of a large degree of underreporting in most official accident statistics. With self-reporting, one can collect detailed first-hand information of accidents and traffic conflicts from the road users involved.

The idea of self-reporting is to let road users report accidents or near-accidents themselves, potentially focusing on specific road users groups (such as cyclists or the elderly), a specific topic or a specific geographical area. Such data can be used as a supplement to the official accident statistics. Self-reported accidents, conflicts and incidents can be collected using various methods depending on the study objectives. Overall, there are four data collection approaches: paper questionnaires, online questionnaires, telephone interviews and face-to-face interviews. The most commonly used method is questionnaires – both paper-based and online.

![Fig. 3 Camera calibration is an important step for taking measurements from video](image1)

![Fig. 4 Abnormal nearness in space and time indicates traffic conflicts of high severity](image2)
Pros and Cons of naturalistic studies

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<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
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<tr>
<td>Collects data continuously and virtually automatically</td>
<td>Data volume is big</td>
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<tr>
<td>Reflects actual behaviour</td>
<td>Time consuming data analysis</td>
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<tr>
<td>Contains information about the time before and during near-accidents and accidents</td>
<td>Special equipment needed</td>
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<td>Compensates for under-reporting of accidents in official statistics</td>
<td>Privacy issues</td>
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<td>Can be used in combination with other data collection methods</td>
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**Behavioural observation studies**

Behavioural observation studies have a long history in the examination of road user behaviour and road safety, and are still in common use today. These studies are particularly useful when seeking to diagnose road safety problems at specific locations or for specific target groups, in order to identify which target groups and risk-increasing behaviours require attention.

Typical behaviours in a behavioural observation study include informal communication, yielding behaviours, crossing behaviours, looking behaviours, red-light running, speeding and seatbelt use. In the context of road safety evaluation and diagnosis, behavioural observation studies are used mainly to monitor the frequency of road user behaviours, to support findings from accident and traffic conflict studies regarding possible accident factors and to evaluate the effects of road safety countermeasures and strategies. Observing road user behaviours in their natural settings is a valuable method because it yields critical knowledge about actual road user behaviour and provides a means to identify and describe the determining features of such behaviour.

Behavioural observation studies are designed according to the specific behaviour and/or situation of interest, and as such require a well-prepared study design, established protocols, extensive observer training and adequate resources to yield valid results. The two most common methods to collect behavioural observation data are on-site trained human observers and video cameras (or a combination).

The main remaining issue with these studies is the generalisability (or lack thereof) of results. Because road user behaviour is observed at a specific location, conclusions that the behaviour will also occur at locations not under study are difficult to secure. To combat this limitation, behavioural observation studies are often supported by other road safety data collection methods (such as accident data, traffic conflict observation studies, driving simulator research, speed and exposure measurements) to compile a comprehensive picture of the road safety situation at a certain location.

**Naturalistic cycling and walking studies**

Naturalistic studies can be used for continuous studies of road users. Naturalistic studies can cover all types of traffic events, from undisturbed passages with no other road users in sight to traffic conflicts or even accidents. Even information about rare events, such as accidents, can be collected from naturalistic studies if there is a large number of participants and a long data collection period.

Naturalistic studies are particularly useful for studying the behaviour of road users when the topic under investigation is location-independent. For instance, this method can be used to identify any combination of activities, other road users, and surroundings and their effect on driving behaviour. Naturalistic studies also allow researchers to collect a large range of information to describe various aspects of road users’ behaviour in their interactions with other road users, the roads, and the roadside environment.

Data in a naturalistic study can be collected in various ways depending on the type of road user, the selected sensors, and the scope of the study. Overall, there are three types of equipment: factory-installed, fixed and portable equipment. The data types collected are most frequently video recordings, while GPS data and acceleration data are also relevant data types. Based on the data collected from the selected equipment, a significant volume of information can be extracted from the data sets and used for assessment of behavioural and safety-related aspects of the road user behaviour.

A number of issues should be considered before deciding upon and conducting a naturalistic study: in general, the data volume grows rapidly, and the analysis of the collected data is often significantly more time consuming than expected or planned for. Also, various aspects of anonymisation and compliance with the general data protection regulation have to be taken into account when collecting data in naturalistic studies.
Site observations of traffic infrastructure

Both road safety inspections (RSI) and road safety audits (RSA) aim to reduce road accidents by analysing road infrastructure elements that could influence accident risk. These techniques allow the mapping of the risk of accidents across the entire European road network, which allows a comparison of the safety levels of roads across Europe. Within these techniques, accident patterns on new and existing roads are studied. Additionally, the self-explaining and forgiving character of the roads are evaluated by assessing the crash-friendliness of the road infrastructure elements. In this respect, both techniques assist in reducing fatal and serious injuries among road users, as it is highly recognised that the self-explaining and forgiving roads concepts assist in reducing injury severity.

The difference between inspection and audit is related to the phase in which the infrastructure is found. RSI are performed if the road is already built and has been opened to traffic for a time period sufficient for accidents to have been registered. On the contrary, RSA are performed for roads in the preliminary stages, before opening to traffic. This includes the phases from planning to construction (and also the first months with traffic). Therefore, one determinant that must be taken into account is that for RSI we have accidents to analyse, and for RSA we analyse only the infrastructure without accidents.

It is generally accepted that RSI are performed on existing roads, and RSA are performed during the design process. However, some countries refer to both analysis for similar processes.

Each road safety check should be considered in every infrastructure project regardless of its nature or scale. This means that even though we deal with a small-scale project it is important to start performing road safety checks from the beginning.

Estimating socio-economic costs of injuries to vulnerable road users

The monetary valuation of accidents and injuries, often referred to as the costs of accidents or injuries, is a key element of cost-benefit analyses of road safety measures. Virtually all European countries have official estimates of road accident costs. In conjunction with the Horizon 2020 project SafetyCube, InDeV has collected data on official road accident costs for 31 European countries.

Cost components included in the calculations and their respective calculation methods vary widely between countries. For fatalities, human costs are the largest item in countries relying on the willingness-to-pay approach for obtaining monetary values. The second largest item is usually lost productive capacity.

Fig. 6 It was found that vulnerable road users are hardly ever considered separately in costs estimates. Official accident costs apply to all road accidents and injuries. The costs are usually specified according to accident or injury severity, but it is not usual to specify costs for different road user groups or different types of accident. To meaningfully estimate the costs of injuries to vulnerable road users, it is important to account for incomplete reporting of injuries in official accident statistics. Moreover, it should be noted that the mean cost of injuries that are not reported in official statistics is likely to be lower than the mean cost of reported injuries, since the unreported injuries tend to be less severe.
The RUBA Watchdog Video Analysis Tool

The increasing use of video footage for traffic analyses means that the tools which can assist in the processing of video data are in ever more demand. In particular, for the behavioural analyses where one seeks to assess specific road user behaviour, it is important that the behaviour can be identified in the video. In some cases, the occurrence of a specific behaviour or specific traffic event is rare, and hence requires large quantities of video data in order to capture a significant number of events for further analysis. For instance, traffic conflicts are rare on a specific site, and it thus requires several weeks or months of traffic video to capture enough traffic conflicts.

To facilitate the data reduction of these large quantities of traffic video, we have developed a watchdog video analysis tool called RUBA (Road User Behaviour Analysis) which can be used for processing traffic video. The purpose of the tool is to remove large parts of the video where no events of interest occur and thereby reduce the volume of video, and highlight the parts of interest for the user.

RUBA allows the user to draw fields (detectors) on the input traffic video image by using a simple, click-based drawing tool. The sensitivity of the detector, regarding movement in the image, can be adjusted by different parameters in the program. Multiple detectors in different areas of the video can be applied with a pre-defined logic to aid the data reduction for a specific type of traffic event, for example right-turning vehicles and cyclists.

RUBA is open-source and freely available for Windows and Mac at: https://bitbucket.org/aauvap/ruba/
Naturalistic VRU Study – A Hands-on Manual

Accident data from official records, such as police reports or emergency room data, are affected by a large degree of under-reporting, particularly for vulnerable road users. Naturalistic data collected automatically from the road users can be a means to overcome this problem.

The large amount of collected data, however, necessitates the use of technology to facilitate data processing and analysis. To aid in this process, we developed smartphone apps with the aim of getting more insight and knowledge of accidents among vulnerable road users based on naturalistic data.

The VRUMonitor app was developed to detect accidents based on an analysis of the motion data of the phone. The underlying idea is that abnormal motion occurs in the event of an accident and that this motion differs from everyday activities. Due to the fact that different smartphones contain different motion sensors, it is a complex task to make a fully functional system across all smartphone brands and models. Therefore, it has not yet been tested on a larger scale.

In addition, the SafeVRU app was developed for self-reporting of accidents and near-accidents and has been used by more than 400 participants.

The apps and source codes are available at: https://bitbucket.org/aauvap/vrumonitorapp/

![Fig. 9a SafeVRU app for self-reporting of accidents and near-accidents. The user can press a button, “register incident”, to report a (near-)incident](image)

![Fig. 9b The user is directed to the questionnaire to provide detailed information, e.g. regarding what happened in the accident](image)

![Fig. 10 Acceleration (magnitude of x, y, z) [m/s²] from sideways cycling fall performed by stuntman with the phone placed in the jacket chest pocket](image)
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The handbook will be useful for traffic safety professionals for their everyday work. We hope that it will work as a toolbox and everyone can find the right method and tool depending on their problem, available data and resources.

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