Chapter 9: Conclusion

Authors
Evelien Polders, Hasselt University, Belgium
Tom Brijs, Hasselt University, Belgium

The purpose of this handbook is to compile current knowledge on road safety diagnostic techniques into a detailed, practical overview. The described road safety methods include accident data analysis, surrogate safety indicators, self-reported accidents and naturalistic behavioural data and primarily addresses the case of vulnerable road users (VRUs). The handbook is intended to help road safety practitioners, professionals and researchers diagnose road safety problems by gaining more insights into the mistakes by road users that lead to collisions. This handbook assists in linking accident causal factors to accident risk and so contributes to further improving road safety and generating a better, in-depth understanding of the causal factors contributing to unsafety. These enhanced insights allow us to better understand mistakes by road users that are essential to develop and select targeted countermeasures to reduce deaths and serious injuries. The handbook thus also indirectly contributes to the European Commission's (2018) road safety objective to further reduce the number of fatalities and serious injuries by 2030.

In general, road safety in Europe has greatly improved in recent decades. Despite this positive development, VRUs still experience elevated accident and injury risk. The InDeV research project, therefore, specifically focused on improving the road safety of VRUs. Consequently, this handbook mainly addresses how different road safety techniques can be used to identify the accident causal factors for VRUs. Nevertheless, these techniques can also be applied to assess the safety of other road users.

Moreover, depending on the study objectives, various techniques can be used to gain insights into the accident causal factors for VRUs. Overall, six different techniques can be used to collect such data: accident data analysis, self-reported data, behavioural observation studies, traffic conflict observation studies, naturalistic cycling and walking studies and RSA and RSI. The previous chapters provide a detailed, practical-oriented overview of the application areas, characteristics and considerations that should be kept in mind when deciding which particular technique to use. In this chapter, the most important aspects of these six road safety diagnostic techniques are summarised in Table 1. This easily accessible summary table helps practitioners to find the appropriate technique to gain insights into a specific road safety problem for all groups of road users and, in particular, VRUs. Table 1 provides a quick, detailed overview of the different techniques by discussing their main characteristics:

- Context: scope of a technique
- Variables: type of data that can be collected with a technique
- Data collection techniques: possible methods that can be used to collect data
- Study area: geography within a road traffic system for which a technique can be used to collect data
- Data processing efforts: estimated time needed to analyse collected data
- Costs: estimated monetary resources to apply a technique

- External validity: extent to which the results collected through a technique can be generalised to other situations or the whole population of road users
- Experimental control: extent to which a researcher can influence situations and behaviours occurring in the road environment during the data collection phase
- Time: estimated average time needed to apply a technique in a study
- Advantages: descriptions of the desirable features of a technique
- Challenges: specific challenges related to the adoption of a technique

Throughout this handbook, the road safety techniques discussed are unquestionably proven to have added value for performing evidence-based road safety research aimed at identifying accident causal factors for VRUs. This is also illustrated in Table 1. For instance, accident data analyses are very useful to assess and monitor road safety situations in areas of interest, identify the time trends of accident occurrence and resulting injury severity and compare the safety situation among countries, regions and cities. Furthermore, the following three techniques can be used to directly collect information from road users. First, self-reporting is especially useful for gaining knowledge of near-accidents, which are usually not registered, and less severe accidents (e.g. resulting in slight injuries or only property damage), which are largely under-reported in official statistics. Second, on-site behavioural observation studies are used to study the frequency of and to identify particular characteristics of road user behaviour in normal traffic events and near-accidents. On-site traffic conflict observation studies only focus on identifying relevant road user behaviour in near-accidents. It, therefore, is possible to gain knowledge about the behavioural and situational aspects that play a role in encounters with low safety risk, as well as the aspects that precede serious traffic events. These studies thus provide the opportunity to better understand the various contributing factors that influence accident occurrence. Consequently, these studies' results can be used as a basis to identify which target groups and risk-increasing behaviours require attention to reduce road fatalities and serious injuries. Third, naturalistic cycling and walking studies allow unobtrusively and continuously observing road user behaviour in the real world before and during near-accidents and in some cases even accidents to gain in-depth knowledge of the factors contributing to these incidents. Finally, RSA audits and RSI are road infrastructure assessment techniques specifically used to assess which infrastructural elements of new and existing roads influence accident risk.

Table 1: Overview of road safety diagnostic techniques.

Road safety diagnostic technique	***Accident data analysis***	***Self-reported data***	***Behavioural observation study***	***Traffic conflict observation study***	***Naturalistic cycling and walking study***	***Road safety audit/inspection***
Context	Accidents (ranging from only material damage to fatal injuries)	Accidents and near-accidents	Road user behaviour in undisturbed passages and near-accidents	Traffic conflicts (i.e. near-accidents)	Road user behaviour in accidents, near-accidents and undisturbed passages	Road infrastructure assessment of new and existing roads
Variables	Accidents and their related characteristics, exposure data, infrastructure data and collision diagram information	Accidents, near-accidents and their descriptions (e.g. location, incident, involved parties and circumstances)	Variables related to road user behaviour (e.g. looking behaviour, priority behaviour and communication), road user characteristics (e.g. gender and age) and more detailed indicators when video cameras are used	Measurable (continuous in the case of video-based observation) parameters of road user behaviour in traffic conflict situations	Detailed and continuously logged data (e.g. speed, acceleration and position), road user behaviour data and characteristics of traffic situations in normal and safety-critical events	Elements of road infrastructure that could influence accident risk
Data collection techniques	Desk research in national accident databases and police-reported accident data (especially for only material damage), possibly enriched with hospital data	Interviews and questionnaires	Human observers and video-based behavioural data	Human observers and video-based trajectory data	Instrumented vehicles (e.g. bicycles, mopeds and motorcycles) and portable equipment (e.g. smartphones and activity bands)	Trained road safety auditors and inspectors

Table 1: Overview of road safety diagnostic techniques (continued).

Road safety diagnostic technique	*Accident data analysis*	*Self-reported data*	*Behavioural observation study*	*Traffic conflict observation study*	*Naturalistic cycling and walking study*	*Road safety audit/inspection*
Study area	Dependent on the study objectives, ranging from country based to network and site based	Dependent on the study objectives, ranging from country to region based	On site	On site	Real-world traffic environment ranging from country based to network based and site based	On site
Data processing efforts	Low (general traffic safety reports and collision diagram analysis) to moderate (black spot analysis, network safety analysis and accident prediction modelling)	Low to moderate depending on the number of respondents and data collection technique (online or not)	Moderate to high depending on the number of registered events and use of (semi-)automated video analysis techniques	Moderate to high depending on the number of registered events and use of (semi-)automated video analysis techniques	High	Low
Costs	Low	Medium	Low to medium	Low to medium	Medium to High	Low (mostly labour costs)
External validity	Low-moderate depending on the number of analysed accidents and the typical characteristics of accident locations	Low-moderate depending on the number of respondents	Low-moderate: natural setting, unobtrusive data collection and actual safety-critical situations and behaviours, but valid study results only for the location studied, difficult to establish link with accidents	Low-moderate: natural setting, unobtrusive data collection and actual safety-critical situations and behaviours, but valid study results only for the location studied	Very high: natural setting, unobtrusive data collection and actual safety-critical situations and behaviour	Low: valid results only for the location studied

Table 1: Overview of road safety diagnostic techniques (continued).

Road safety diagnostic technique	***Accident data analysis***	***Self-reported data***	***Behavioural observation study***	***Traffic conflict observation study***	***Naturalistic cycling and walking study***	***Road safety audit/inspection***
Experimental control	No control over road users' interactions or the traffic environment	No control over road users' interactions or the traffic environment	No control over road users' interactions or the traffic environment	No control over road users' interactions or the traffic environment	No control over road users' interactions or the traffic environment	Not applicable
Average study duration	1 to several years	Several weeks to months	Several days to weeks	Several days to weeks	Several months, up to one year or longer	Several days (RSI), months to years (RSA)
Specific advantages	Direct assessment of the outcome indicator of road safety (e.g. number and severity of accidents)	First-hand information, correction for underreporting (data on slight accidents), near-accident information, tailored study design and swift road safety diagnosis and evaluation	Direct observation of road user behaviour, non-intrusive data collection, practice ready, large sample size, swift road safety diagnosis, inexpensive and insights into accident development process	Direct observation of road user behaviour in safety-critical events, non-intrusive data collection, practice ready, large sample size, swift road safety diagnosis and possible supplement or replacement for accident data	In-depth understanding of road users' natural behaviour, possibility to study behaviour over extended time periods, compensation for underreporting of accidents, automatic data collection, reflection of actual behaviour, information on the accident development process and study of normal, conflict and accident situations	Reduced accident risk, safer facilities for vulnerable and other road users and better road safety targets, standards and design guidelines

Table 1: Overview of road safety diagnostic techniques (continued).

Road safety diagnostic technique	*Accident data analysis*	*Self-reported data*	*Behavioural observation study*	*Traffic conflict observation study*	*Naturalistic cycling and walking study*	*Road safety audit/inspection*
Challenges	Underreporting, random variation, ethical concerns, no information on road user behaviour and accident development process and slow road safety diagnosis and evaluation (extensive accident data needed for 3–5 years)	Privacy issues, no expert information, response bias, data from only one of the involved road users and no data on severe and fatal accidents	Generalisability, findings on only road user behaviour, observer bias, labour-intensive data collection (observers) and susceptible to adverse weather conditions and difficult at night	Labour-intensive data collection (observers), generalisability, validity, inter- and intra-observer variability, advanced video analysis techniques still under development and susceptible to adverse weather conditions and difficult at night	High set-up costs, time-consuming data–analysis process, selection bias, data from only one of the involved road users, privacy issues and limited sample size due to high costs	No standardised approach to RSI

Each technique, in its own way, can provide valuable insights into the road safety situation of VRUs. However, based on the information presented in this handbook, it can be concluded that there is no perfect technique to assess road safety but only the most suitable technique given the study's scope, time frame, available human and monetary resources and expected outcomes. However, each technique also suffers from limitations, so it is very difficult to gain a sound picture of the road safety situation based on one technique alone (see Table 1). Consequently, a crucial opportunity lies in complementing the results from different road safety techniques to overcome the limitations of individual techniques. Exploring the different opportunities for such an integrated approach was also the rationale of the InDeV-project (and this handbook).

Based on the information presented in this handbook, the following recommendations for combining different road safety techniques can be suggested.

1. **Accident data and self-reported data**
   Accident data analysis is the most commonly used technique to assess the road safety situation of VRUs and other road users. However, accident data suffer from underreporting and injury misclassification. The degree of underreporting in police accident records is the highest for accidents with VRUs and of a less severe nature, such as accidents with slight injuries or only property damage. Combining police-reported accident data with hospital data can help to overcome some of these problems and is becoming a more widely adopted approach in the road safety field. The use of self-reported accident data in combination with police-reported accident data is a useful approach especially for gaining more knowledge about less severe accidents because it can capture more less-severe accidents, thus overcoming underreporting and the associated potential for biased data.

   Combining self- and police-reported accident data thus can contribute to better, more complete insights into the current state of traffic safety. However, combining police-reported accident data with hospital data remains the recommended approach to address the underreporting of accidents with serious and fatal injuries.

2. **Accident data and behavioural observation and traffic conflict data**
   Accident data analysis directly examines the phenomenon one wants to avoid from a safety perspective—namely, accidents and their related consequences. This direct assessment can be regarded as the main advantage of accident data analysis. However, such data contain information on the outcomes of accidents (the severity of accident-related injuries) but lack information on accident causal factors (situational and behavioural aspects preceding accidents). The accident development process, therefore, remains unclear.

   To overcome this limitation, accident data can be combined with behavioural and traffic conflict observation data. Both techniques are used to study the frequency of and to identify particular characteristics of road user behaviour in normal traffic events and near-accidents. These techniques, therefore, are very useful to gain knowledge on the behavioural and situational aspects that play a role in encounters with low safety risk, as well as the aspects that lead to accident occurrence.

Road safety evaluation and assessment based on accident data also require extensive accident data (typically 3–5 years) to produce reliable results. Sometimes, there are little accident data available, or the available data are insufficiently detailed to obtain a good evaluation or diagnosis. In such cases, behavioural and traffic conflict observations provide a vital complement to accident analysis as a support for action design and, where appropriate, may even compensate for a shortage of information on accident-generating processes. Furthermore, the behavioural and conflict items observed and the locations of interest for both observations are mostly determined by the findings of accident analysis.

3. **Self-reported data and traffic conflict data**
Similarly to accident data, traffic conflict data on slight conflicts and near-accidents can be combined with self-reported data to gain more knowledge on the occurrence of less severe conflict situations.

4. **Behavioural observation data and traffic conflict data**
Behavioural observation studies are often combined with traffic conflict studies to broaden coverage of different aspects of road safety situations. Insights into the different road user behaviours that occur at studied sites serve as a useful basis for describing what is going on at sites and makes them unsafe. Behavioural observations, therefore, offer added value to traffic conflict studies by providing more insight into the risk-increasing behavioural aspects and elements that play a role in traffic conflicts.

5. **Naturalistic cycling and walking studies and behavioural observation and traffic conflict data**
Naturalistic cycling and walking studies are a useful technique to continuously collect data on road user behaviour. In these studies, data are collected with instrumented vehicles and portable measuring devices. Continuously collecting data, these studies can evaluate not only the last movements and constellations leading to accidents but also the underlying factors that may have led to road users ending up in safety-critical situations. However, this technique only collects data from the viewpoint of one of the involved road users (the road user with a portable measuring device or using an instrumented vehicle). Consequently, the collected information on the other road user is sometimes limited as the measuring devices might not have detected evasive action or behaviour by the other road user. This complicates obtaining a complete understanding of accidents' contributing factors.

However, this issue can be solved by combing naturalistic walking and cycling studies with behavioural and conflict observation studies on designated sites of the road network, such as intersections. These site-based observation studies create the opportunity to collect supplementary information on the position and speed of other road users in the vicinity of participants in naturalistic cycling and walking studies. The added value of combining both techniques lies in the opportunities to obtain a more in-depth understanding of road safety and to relate the behaviour of participants and non-participants in naturalistic walking and cycling studies.

To conclude, these insights make a strong case for an integrated approach to assessing the road safety of VRUs and other road users. The added value of this integrated approach lies in the opportunity to enrich the results from one technique with the complementary results from another and to check whether the techniques' findings align. This approach not only overcomes the limitations of each individual technique but also allows drawing highly detailed, sound road safety inferences, ultimately producing a more comprehensive picture of the road safety situation. Furthermore, higher road safety levels on the road traffic system have gradually evolved over recent decades. If this positive trend continues, accidents will become even rarer and thus less suitable for reliable road safety analyses. An integrated approach based on a combination of the road safety techniques discussed in this handbook, therefore, will perform an important role in future road safety evaluation policies.

Additionally, in light of the Safe System and Vision Zero approach, a strong case has been made in the scientific community for adopting a system approach to conducting road safety research. The new European road safety vision, moreover, recommends the Safe System approach as a common framework to achieve further reductions in road fatalities and serious injuries during 2020–2030 (European Commission, 2018). Throughout this handbook, it has become apparent that the most important merit of combining different techniques to study the road safety of VRUs lies in the possibility to study road safety from a system perspective. It, therefore, is recommended that countries pursuing a system-based road safety vision should adopt an integrated approach based on a combination of techniques observing road user behaviour in interactions, near-accidents and accident data. Doing so can enable investigating road safety from a system perspective, further reducing the number of road fatalities and serious injuries and formulating policy priorities to pursue an inherently safe road traffic system.

References

European Commission. (2018). Europe on the move: sustainable mobility for Europe: safe, connected, and clean, pub. l. no. COM/2018/293 final, communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Retrieved from https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52018DC0293