Road Infrastructure Safety Management Evaluation Tools (RISMET)

Data systems and requirements

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SWOV – Institute for Road Safety Research

Project Partner 2:
TUD - Technische Universität Dresden

Project Partner 3:
LNEC - National Laboratory for Civil Engineering

Project Partner 4:
TØI - Transportøkonomisk institutt Stiftelsen Norsk senter for samterdselsforskning

Project Partner 5:
TRL - Transport Research Laboratory

Project Partner 6:
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Author(s) this deliverable:
Christian Stefan, KfV, Austria
Matthias Dietze, TUD, Germany
Paula Marchesini, SWOV, Netherlands
Walter Louise, TRL, United Kingdom
Nimmi L. Candappa, SWOV, Netherlands

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1 Introduction

"ERA-NET ROAD – Coordination and Implementation of Road Research in Europe" was a Coordination Action funded by the 6th Framework Programme of the EC. The partners in ERA-NET ROAD (ENR) were United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.road-era.net). Within the framework of ENR this joint research project was initiated.

The project aims at developing suitable road safety engineering evaluation tools as anticipated by the ERANET Programme "Safety at the Heart of Road Design" (2009) and furthermore those of the Directive for Road Infrastructure Safety Management (2008). These evaluation tools allow the easy identification of both unsafe (from accidents or related indicators) and potentially unsafe (from design and other criteria) locations in a road network. With such evaluation tools estimates of potential benefits at the local and the network level can be calculated and potential effects on aspects such as driver behaviour can be estimated. Such tools empower road authorities to improve their decision making and to implement (ameliorative) measures to improve the road safety situation on the roads.

RISMET culminates in a set of easy to use guidelines and codes of practice for the development and use of comprehensive road safety engineering evaluation tools, with a specific focus on APMs. These systems based tools will consider the relationship between road design, road user behaviour, traffic and road safety. A guideline and data specification providing the minimum requirements for data collecting and recording will be included.

The first part of this report (Chapter 4) is a literature review on the relationships between accident data, roadway data and traffic data. Chapter 5 of this report provides a detailed description of state-of-the-art databases and information systems; chapter 6 gives an overview of road and traffic data in the EU based on a survey among ten countries.

2 Problem

Data requirements and variables

Road accidents are rare events with extreme outcomes that statistically represent a small proportion of real-life interactions between drivers and the road environment or between drivers themselves. Even though accidents are scarce, the outcomes are life threatening and so all information that can be derived from such events is of great value to road safety engineers when tracing the possible causes on an accident in an attempt to identify solutions. Accident data thus are a crucial element of a safety diagnosis. In addition to accident data, there are other pieces of information such as roadway data, traffic data that help road engineers reveal the hidden relationships between contributing factors. Those relationships and the need to establish links between different data sources are described in the chapter 4.

Databases and information systems

Traditionally, the basic and most reliable source of information concerning road safety statistics consists of accident reports and standard forms filled out by the police at the accident site. However, in the past 5-10 years, a gradual change in the perspective concerning traffic safety was observed. Nowadays, the objectives of the road safety work in most (European) countries are stated in terms of a specific reduction of killed and injured people, not just in terms of accident reduction. Hence, road safety statistics becomes more and more orientated towards injuries with the medical diagnosis as one of the central points of considerations. As a consequence, police reports gradually lose their dominance for road safety statistics in the sense that other sources of information are also being used.

In road safety, data is usually collected to improve one's understanding of specific problems. Why is it the case that injury figures have not declined substantially over the past decade while fatalities were reduced by 30-40% in the European countries? What measures can be undertaken to improve the situation of vulnerable road users? Are there specific (traffic) user groups that are more likely to be involved in an injury accident and therefore need special education and training? With the upcoming of better computers and new statistical procedures (e.g. time series analyses, multivariate modelling), the need for more and better quality data becomes more and more pressing. Hardware (PC, laptop etc.) and software (statistical programmes and methods) are useless to a large extent if the basic data does not improve as well.

Nowadays, the collection of accident and injury information should be based on two basic principles. First: Use available information from various existing sources as much as possible, i.e. information collected for other purposes should be employed for analysis as well. Most road authorities collect traffic data on a regular basis - they gather exposure data in order to calculate the capacity of lanes and traffic lights, use traffic cameras for continuous surveillance in order to report incidents as soon as possible and collect data on skid performance for road maintenance.

Second: If specific collection of information is still needed, the burden of the persons involved in the process should be reduced as far as possible. The police investigate road accidents with the purpose to detect possible violations of the traffic law. For statistical reasons, the police also fill out standardized report forms which are being sent to a statistics department (e.g. the Statistics Austria).Yet, it is not the task of the police to gather all the road and accident information needed by traffic engineers to conduct state-of-the-art analysis and calculate black spots and dangerous road sections e.g. by using Accident Prediction Models. For this task, special investigation teams are needed to reduce the extra workload upon the police.

Serious traffic accidents usually require substantial time and manpower for on-scene investigation and, as a result, often cause serious inconveniences and traffic delays. Due to time pressure and work load inflicted on the police officers at crash sites, most accident data fulfil only minimum statistical requirements and do not suffice detailed in-depth investigations needs, as required e.g. for court trials. A recent study published by the Austrian Federal Ministry for Transport, Innovation and Technology [BMVIT, 2007] drew the conclusion that more than 38% of the fatal accidents, i.e. accidents with the most severe consequences for human life, were in fact poorly documented. About 9% of the accident reports did not include pictures, especially photos of vehicles from all directions or of the interior were missing. More than 40% of the accidents investigated also did not have photogrammetry of the accident site. Yet, a photogrammetric examination of the accident scene and documentation of the involved vehicles and roadside infrastructure are absolute conditions for a high quality of reconstruction. Without this information, satisfactory answers concerning accident and collision details cannot be obtained.

3 Objectives

Data requirements and variables

At present it is believed that there is a lack of suitable evaluation tools for effective road safety management (Objective A, Eranet Joint call for Proposals, March 2009). However, the development of such tools depends upon the availability of good quality data, something which is often missing when applying these tools at the road authority level for which the tools are primarily developed.

Task 2.1 of the Detailed Work Plan aims to identify the type of data that are necessary to develop and/or use state-of-the-art evaluation tools for safe infrastructure management. Since the emphasis is on infrastructure this task will predominantly concentrate on scientific studies of the relationship between road design elements and road traffic accidents. The survey will concentrate on higher order rural roads as indicated in the RISMET study proposal and subsequent Detailed Work Plan. In most cases these are 2-lane rural roads although in some cases roads with dual carriageways are also included. Task 2.1 of the detailed Work Plan indicates that it will describe the kind of information that is necessary to answer traffic safety related questions and will include the following categories of data:

- Accident data
- Traffic (Congestion) data
- Hospital data
- In-depth data
- Road (Design) parameters
- Road behaviour
- Weather data

Since road design impacts (directly and indirectly) on behaviour and consequently can affect road safety, it is this relationship that is often described in the literature. The road infrastructure itself is a mechanism that can be altered, bringing about changes in traffic performance (described by traffic flow, behaviour and congestion data) and in safety levels (described by accident, hospital and in-depth data). Therefore, it is primarily the relationship between accidents and road design that is described in the literature review in chapter 4, the other categories are only implicitly dealt with in there and also in chapter 5 (databases and information systems). In chapter 6 (Current road and traffic data in Europe) the availability of data on the categories listed above is summarized for selected EU countries based on a questionnaire survey.

It may seem preferable to develop models that are driven by available data rather than developing models with the hope that these data will be collected and made available. However, it is more likely that a compromise between these approaches will provide a realistic solution. Either way, a review of currently available data and data systems is essential to assess the feasibility and ultimately the potential for the envisaged evaluation tools. However, not all these data have a direct relationship with traffic accidents and more often than not it is a combination of factors that determines the outcome.

To properly diagnose safety problems, an analyst must first have a good understanding of the accidents mechanisms. Typically, some crash types are more prominent, comprising a larger proportion of the total accident numbers. Literature indicates (OECD, 1999) that 80% of all accidents on rural roads fall into the categories single vehicle accidents (including run off the road), head on accidents and accidents at intersections (rear end and lateral crashes). These crash types are explored in more detail in the following section to better understand factors involved in these accidents.

The severity of injury depends on several factors as well, some of which are directly related to road and accident characteristics: such as, impact speed, roadside conditions, collision type. Due to the severe crash angles involved, lateral collisions can be the most severe in outcome, single vehicle and head on crashes also likely to produce high severity crashes due to either the point load intrusions involved in single vehicle crashes, or the higher speeds involved in rural crashes, where head on crashes are likely. Injury severity is on average much less in rear-end collisions (Campbell and Knapp, 2005; Mackenzie, 2008), mainly due to these occurring during congestion and at intersections with merging and diverging traffic when speeds and speeds differences are lower.

Databases and information systems

A number of countries have (started to) set up databases containing information regarding road accidents, traffic volume, road geometry etc. The objective of Task 2.2 of the project work plan is to explore the added value of integrated object-oriented road databases for safety work. Such databases consist of data on various road elements and specific information on road and site characteristics. The new SafetyAnalyst software package, the research database of SWOV, Molasses (UK), the American Highway Safety Information System (HSIS), the German GIDAS Database, the Road Database of the TU Dresden and the German Road Information Bank (ASB) are being considered in this report. This task will entail primarily a literature survey supplemented by interviews with selected specialists in this field. The primary output is a documented description of state-of-the-art database structures.

4 A literature review of relevant and prominent accident factors

This chapter describes accident factors and their assumed relationships for head-on and single vehicle accidents (including run-off road, overturning and collisions with fixed objects), lateral collisions and rear-end collisions. These primarily describe the relationship between accidents and road design and related factors and are based on a review of literature in which these relationships have been studied and analysed.

In the detailed work plan (Eranet, 2010) a meta-analysis forms part of the literature review. A meta-analysis statistically combines the results of a number of different studies that have a common research question of hypothesis. It follows a systematic process of review and statistical methods to combine the results of different studies. The objective of this part of the study is to describe the relationship between accidents and (design) factors influencing the occurrence and/or the outcome. It must supplement the primary output which is a description of data systems and data requirements for safety evaluations of road infrastructure. Its main purpose is to provide evidence of known relationships in order to motivate or justify the need to collect certain data required in such evaluations. Consequently it was decided to rely on previously conducted meta-analyses conducted by Elvik and Vaa (2004) as a primary literature source and to supplement these findings with the results of more general studies.

4.1 Head-on and single vehicle collisions

A US study indicates that two-lane rural roads are involved with higher accident rates, higher percentage of head-on and single vehicle collisions (Brinkman and Smith, 1984; cited in Lam m et al., 1999). The European Community database on Accidents on the Roads in Europe (CARE) keeps records on reported and recorded accidents in member countries. Due to a lack of uniformity in the definitions and in the collected accident parameters it has as yet not been possible to compare head-on collisions and single vehicle accidents across countries (Matena et al., 2008). However, fatalities on rural single carriageway roads in most European countries represent between 30% and 65% of all fatalities. In countries such as the Netherlands where head-on collisions and single vehicle accidents are separately recorded along with speed limits and road type, these accidents constitute in excess of 50% of all fatal accidents on rural 80 and 100km/h rural roads. In Norway, head on accidents represent 15% of all police reported accidents whereas they make up more than 30% of the fatalities and serious injuries. Single vehicle accidents (run off the road) make up nearly 30% of all injury accidents.

An OECD report (OECD, 1999) revealed that this situation is common in most developed and motorised countries with head on and run off the road accidents contributing to as much as 67% (Switzerland) of all fatalities. Factors contributing to these accidents were found to include inappropriate speeds (in curves); design discontinuities, dangerous and illegal overtaking, soft or poorly maintained shoulders, obstacles next to the road and temporary risks such as snow and ice (Matena et al., 2008).

This section explores a number of related studies into the relationship between these accidents and specific elements of geometric design. Where relevant, relationships with other contributing factors are also described. The accident factors that are described in this section are:

- Curves;
- Vertical alignment;
- Sight distance;
- Design consistency;
- Traffic control devices;
- Cross sectional elements;
- Services and equipment; and
- Road surface

Detailed description of accident factors

Curves

Accident risk is not uniform along a road. With all other (environmental) characteristics being equal, the risk of injury accidents is greater on horizontal curves than on adjoining tangents. About one-third of all injury accidents in Norway, and more than half of all head-on collisions and road departure accidents occur in curves on rural roads (Elvik and Muskaug, 1994). According to Milton and Mannering (1996), accident rates in curves are between 1.5 and 4 times as high as on straight sections. Lamm et al. (2007) found that tangents had roughly a 50 percent lower accident rate than adjoining curves with designs adjudged to be good (1.17 accidents/million veh-km on tangents versus 2.29 on well designed curves) whereas the accident rate was about 90% lower when compared to poorly designed curves. Geometric properties of curves such as curve radius, deflection angle, distance to other curves (tangent length) and curve density affect accident rates.

<u>Accident factors and assumed relationship</u>

- Curve density

The general curvature of a road has a direct effect on the drivers' level of attention and expectations with respect to the forthcoming road alignment. The expectations of the driver with regards to the road design are of key importance to traffic safety; so a road with an isolated curve can be seen as problematic with regard to driver expectations. In this case a road section with a series of curves can be seen as safer than a straight stretch of road with one isolated curve that is likely to take the driver by surprise – that is, the road alignment would not conform to driver expectation. However, on the whole, road sections with curves are regarded as more dangerous, (between 1.5 and 4 times) than road sections with a straight alignment (Lamm et al., 1999). Although such findings may be construed to suggest that all roads should be as straight as possible, curves remain an essential and dominant design element. Long straight roads have other potential risks including higher speeds, fatigue, lack of visual and other stimuli, glare etc.. Since curves are an essential element the aim is to achieve consistency in the overall design whereby curves are an integral part of the design and there are no irregular and unexpected curvature changes (i.e. more curves with harmonized subsequent curves rather than fewer curves with unrelated subsequent curves) requiring sudden changes in speed. The alignment should be such that speed changes are minimized. Sudden sharp curves or curves with much lower design speeds than other curves along the road should be avoided. Transition curves help reduce the accident frequency (Elvik and Vaa, 2004).

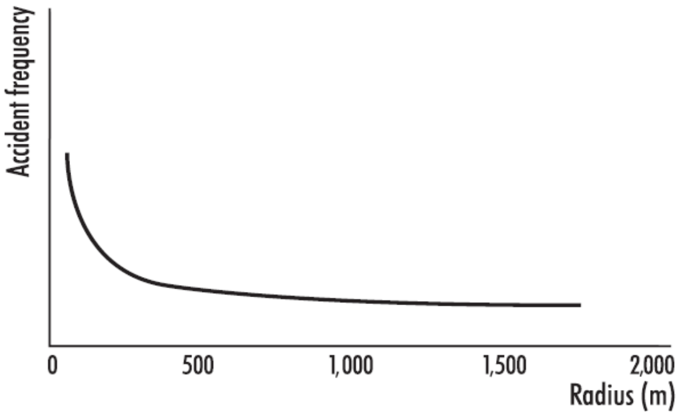
- Curve radius and curvature change rate

  Several studies concluded that the accident rate decreases as the radius of horizontal curves increases, up to a radius of about 400 to 500m after which the accident rate does not decrease anymore (Elvik and Vaa, 2004; Lamm et al., 1999, p12.; Krebs and Kloeckner, 1997, cited in Lamm et al., 1999). It has been found that the accident rate in a sharp curve, located after a straight segment of the roadway, increases as the length of the straight segment increases. Including transition curves in the roadway alignment seems to be safer as it has been shown to decrease the number of accidents by about 10 percent (Elvik and Vaa, 2004). This type of curve makes the transition from a straight segment to the curve in question more moderate and therefore drivers are less likely to make abrupt steering movements.

  On rural roads, accident frequencies are generally seen to increase as curve radii decrease. A convex downward relationship is often found as shown in Figure 1. The increase in accidents is significant when the radius is less than 400m (PIARC, 2003).

  The rate of change of curvature (Curvature Change Rate, CCR) can also provide insight in to the level of safety of a section of road. The curvature change rate is defined as the absolute sum of the angular changes for a roadway section with similar road characteristics divided by the length of this section. Higher curvature change rates are associated with higher accident rates (Krebs and Kloeckner, 1997, cited in Lamm et al., 1999). It was found that road sections with higher CCR have accident rates that were two thirds higher than those with lower CCR. However, it was also found that with increasing CCR, travel speeds decreased, suggesting a potential decrease in accident severity.

Figure 1: Accident frequency and curve radius



Source: PIARC, Road Safety Manual, page 327.

Overall, it can be stated that accident risk and severity decrease with an increase of curve radius. For a given curve radius, the accident risk increases with the length of the preceding tangent. Furthermore, the difference between the accident risk of curves with small radii and curves with large radii decreases with an increase in the curve density (Nielsen et al., 1998)

Vertical alignment

Besides increased wear and tear, steep gradients affect both the safety of heavy goods vehicles and their mobility. Sections with steep gradients and extended lengths of roadway do not allow all vehicles to operate at the same speed level. Speed variations along a road have a direct impact on road safety; the greater and less expected the variations, the higher the probability of collisions. On upgrades and steep downgrades (where heavy goods vehicles are forced to travel more slowly to avoid speeding and potential loss of control), head-on collisions occur as a result of the passing needs of vehicles driving behind slow moving vehicles. Run-off-the-road accidents most often take place on steep downward grades, where drivers are likely to lose control of their vehicle due to excessive speed. Accident frequency increases with grade percent, at a rate of 1.6% for each grade percentage (Harwood et al., 2000).

Beside the impact of steep gradients on speed, the vertical alignment also contributes to the so called ‘optical distortion’. This phenomenon makes curves appear larger than they are; hence drivers choose higher speeds than adequate (combination of horizontal curve and vertical sag).

<u>Accident factors and assumed relationship</u>

Several studies showed that the accident rate on rural roads heavily increases for sections with grades larger than 6 percent (Lamm et al., 1999) and that the accident rate on downward gradients is higher than on upward gradients. For similar roadway stretches, the accident rate on upward gradients is about 7 percent lower than on downward roadway stretches (Elvik and Vaa, 2004).

Sight distance

At any point on a road, the available sight distance must be sufficient for a driver travelling at a reasonable speed to stop his vehicle safely without hitting a stationary object located on his path. Sight distance, which is the length of the road that is visible to the driver, changes continuously along a roadway and is a very important design parameter because it allows the driver to be aware of potential conflicts on his/her trajectory. Sight distance has four generally recognised applications, stopping sight distance, passing sight distance, decision sight distance and intersection sight distance. Stopping sight distance is the minimum distance that the driver needs to stop safely if a stationary object is detected on the road. This is a design parameter based on driver perception/reaction time and braking distance/time. Since it does not account for actual conditions such as inclines etc. it can be viewed as a minimum design criterion. Decision sight distance is a variation on stopping sight distance and allows for a longer driver reaction time to detect and react on an unexpected situation. Passing sight distance is the minimum distance required to overtake safely. Intersection sight distance is the minimum distance required to see a vehicle on an opposing approach when approaching an intersection in order to stop or to avoid a conflict.

In Germany a behaviour based approach called orientation sight distance has been introduced (Lippold et al., 2007). The orientation sight distance supplements geometric parameters used in assessing sight distances with so called psycho-physiological criteria that allow for the extra demand placed on drivers (and their perception reaction times) by conditions on the road. The standard guidelines in Germany now include a standard methodology to check the 3 dimensional alignment of a road during design (Kuhn and Jha, 2010) and this takes into account the constraints mentioned with regards to sight distance and driver reaction/perception.

<u>Accident factors and assumed relationship</u>

Sight distances are reported to have a negative relationship with run off the road accidents and to a lesser extent with head-on accidents. The accident rate decreases as the sight distance increases. The relationship between accident rate and sight distance is not linear since the rate is seen to decrease rapidly until a certain critical distance (Fambro et al., 1997).

- On rural roads, sight distances less than 200 m require a higher attention of drivers, less than 150 m the impact is much higher (Lippold et al., 2007), the critical sight distance is in order of 90-100 m
- Accidents related to passing manoeuvres increase when the sight distance is less than 400-600 m (Lamm et al., 1999).
- Roads with sight distances between the half and full passing sight distance are safety critical, since unsafe manoeuvres may be forced (RAS-L, 1995).
- At unsignalized intersections, right-angle accidents increase when the sight distance is restricted on an approach (especially for right-angle accidents at rural intersections).

Design consistency

The concept of design consistency is described as the conformance of a roadway design with driver expectations (Krammes, 1997). Drivers are likely to make fewer mistakes if the road and traffic conditions are in line with their expectations. Design consistency refers to the roadway geometry and establishes that the alignment should conform to the unfamiliar drivers' expectations (Fitzpatrick et al., 1999). Methods to evaluate the design consistency have been developed and are applied in various countries around the world. e.g. Design Consistency Module in the American Interactive Highway Design Safety Model (IHSDM; Krammes, 1997), Consistency in Portuguese design (Cardoso, 1998). In Germany the guidelines include a check of radii of consecutive curves. In Lippold (1997) high accident frequencies on stretches where the alignment changed from large curves into small curves have been shown. Such combinations are inappropriate. But, also combinations with fewer differences may cause accidents. The investigation resulted in a definition of recommendable, possible, and unusable radii combinations and has been introduced in the German Guideline RAS-L (1995).

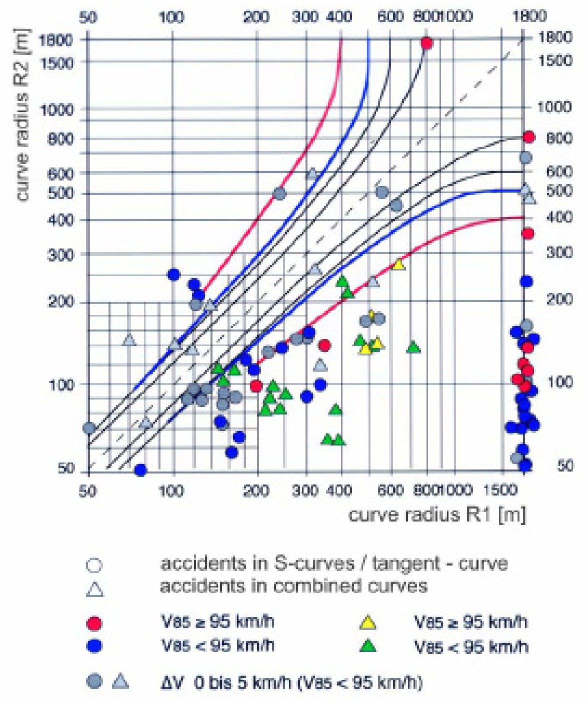
Furthermore, spatial design elements have an important impact on the optical appearance of roads and therefore on design consistency. Some studies (Weise et al., 2002; Zimmermann et al., 2007; Kuhn and Jha, 2010) have worked on specifications on spatial alignment in order to ensure design consistency and to eliminate safety related shortcomings.

Accident factors and assumed relationship

The overall design should not allow for speed changes of more than 15km/h and the design speeds of the different segments should not vary more than 15km/h. The accident rate increases as crest and sag vertical curves become sharper. Larger average radius of curvature on a roadway section and larger ratio of an individual curve radius to the average radius for the roadway present cause higher accident rates (Fitzpatrick et al., 1999).

In Lippold (1997) it has been figured out that the radii ratio of consecutive curves has an important impact on road safety. Significantly the accident frequency for single accidents increased if the ratio increases (Figure 2).

Figure 2: Single accident frequency and radii of consecutive curves



Source: Lippold (1997).

Traffic control devices

Providing the road user with adequate information (visual, audible and tactile) along the roadway can assist the driver in making the right decisions and in avoiding a serious accident. There are several traffic control devices that aim at warning and guiding drivers. For instance, rumble strips along the roadway have shown to decrease run off road accidents which are often due to driver fatigue (Perrillo, 1998; Charlton et al., 2005). Edge and centre lines on the pavement provide drivers with directional guidance, especially during conditions with poor visibility (Charlton et al., 2005).

Accident factors and assumed relationship

- Curve warning signs

  Studies dealing with the effect of signs such as curve warning or recommended speed in curves do not seem decisive as to their effect of reducing accident rate, according to Elvik and Vaa (2004). Tignor (1999), in contrast, reported a 20 percent decrease in accidents with the implementation of curve warning signs. Painting guardrails and background or directional marking in curves have also been found to decrease the accident rate by 20 to 40 percent (Elvik and Vaa, 2004).

- Markings and delineation

  Elvik and Vaa (2004) suggest that road markings such as edge lines, centre lines or raised pavement markers do not seem to decrease the accident rate when they are considered separately. They do seem to have a positive effect on safety, however, when they are combined. Combinations of edge and centre lines were found to account for a decrease in accidents of more than 20 percent.

- Guidance

  Shoulder rumble strips, which warn the driver about the proximity to the edge of the lane, seem to have a highly significant impact in the reduction of run off the road accidents. Elvik and Vaa (2004) report a 30 percent reduction of run-off-road accidents due to shoulder rumble strips. Rumble strips are also used to warn the driver of special circumstances such as the impossibility to overtake. Another element that is meant to alert the driver about the risk of running off the road is the profiled lane marking. A decrease in the total number of accidents was observed on sites with a combination of centreline and edge line profiled lane marking (Hatfield et al., 2009).

Cross sectional elements

Lower accident rates on roads with appropriate roadside conditions are related to greater error margin available to drivers. If a driver loses control over the vehicle, having a hard surface along the road usually provides enough space for manoeuvring safely. Hence, it is less likely to hit an obstacle, turn over, or end up on the opposite lane.

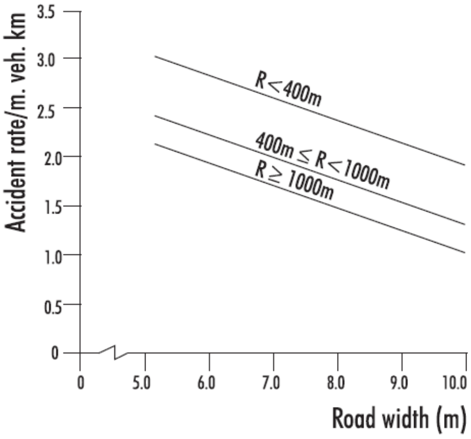
Accident factors and assumed relationship

- Lane/road width

  In horizontal curves, the radius followed by a vehicle's front wheels is larger than the radius of its rear wheels, which increases the width swept (as compared to the situation in a tangent). This additional width is negligible in the case of passenger vehicles but can be significant with long articulated vehicles, and increases with the decrease in curve radius. Moreover, the difficulty stemming from changes in direction in a curve increases the risk of encroachment outside the traffic lane (PIARC, 2003). As a result, road width often needs to be increased in horizontal curves. The required width depends on the curve radius, operating speed and vehicle's characteristics.

  Krebs and Kloeckner (1977) showed that increasing road width reduces accident rates. This relationship applied to the three radius categories they considered is shown in Figure 3).

Figure 3: Accident rates in curve and road width



Source: PIARC, Road Safety Manual, page 337

Elvik and Vaa (2004) state that an increase of 1 to 3 meters in road width reduces the number of accidents in rural roads. Lamm et al. (1999) report reductions in accident frequency with increasing lane width but suggest that accident severity might be increased due to increasing speeds. Table 1, based on a USA study conducted by Zeeger et al. (1990), shows accident reductions that can be expected from traffic lane/shoulder widening in curves.

Table 1: Accident reduction (%) due to lane or shoulder widening

		ACCIDENT REDUCTION (%)		
WIDENING (m)		WIDENING OF		
TOTAL	PER SIDE	LANES	PAVED SHOULDERS	UNPAVED SHOULDERS
0.6	0.3	5	4	3
1.2	0.6	12	8	7
1.8	0.9	17	12	10
2.4	1.2	21	15	13
3.0	1.5		19	16
3.6	1.8		21	18
4.2	2.1		25	21
4.8	2.4		28	24
5.4	2.7		31	26
6.0	3.0		33	29

Source: PIARC, Road Safety Manual, page 337

- Emergency/Hardened shoulders

  On rural roads, shoulders should be clear of objects and stabilized, in order to facilitate recovery of encroaching vehicles. The quality of shoulders in curves deserves special attention, given that the probability of encroachment is higher at these locations. Drop-offs between lane and shoulder increase the risk of loss of control. Hallmark et al. (2006) studied 55-60 mph (about 89-97 km/h) roadway sections and reported that a drop-off deeper than 5.7 cm is statistically related to accident occurrence.

  Rural roads with hard shoulders show a lower accident rate than rural roads without hard shoulders (Elvik and Vaa, 2004). It seems that a rather wide shoulder reduces the accident risk. Nevertheless, there is still no consensus from the different studies as to the optimum width of the shoulder. According to Zeeger et al. (1992), sealing shoulders reduces the number of accidents by 5%.

Service and equipment

The roadside area and equipment to a certain extent determines the outcome of the accident. The existence of obstacles in the roadside area influences the severity of an accident. More than 25 percent of the fatal accidents in Sweden involve a fixed object on the roadside. Single vehicle accidents involving a ditch or embankment account with more than 22 percent of fatal run off road accidents, according to a study in Canada (OECD, 1999). In the event of an accident, guardrails and crash cushions are means to reduce the severity of the crash.

Accident factors and assumed relationship

- Clear roadside area

  The road verge slope and the distance to obstacles also have effects on the likelihood of an accident and its severity; the steeper the slope of the terrain along the road the more likely a vehicle running off the road will have a serious accident (Elvik and Vaa, 2004).

  Steep side slopes are another kind of roadside obstacle that should be avoided. The maximum gradient that can be safely travelled by errant vehicles is in the order of 1:3 to 1:4. The angle between shoulder/slope and slope/adjacent land should also be smoothed.

  Zegeer et al. (1992) reports significant accident reductions due to width increase of the obstacle-free zone. According to the Roadside Design Manual[1], dangerous obstacles in the obstacle free zone should be removed; if that is not possible then they should be repositioned; if impossible, then they should be made less dangerous (made traversable or by means of breakaway supports); and if none of the previous solutions is viable, traffic should be shielded from the obstacle by installation of a safety barrier or a crash cushion.

- Protective devices

  The number of fatal and injury run off road accidents is significantly reduced when guardrails are placed along embankments. Crash cushions, meant to absorb energy in the event of a crash, reduce the number of fatal and injury accidents (Elvik and Vaa, 2004).

- Drainage

  Ditches, gutters or channels not only have to provide adequate drainage of run-off water but also they have to be designed to avoid extra accident risks. The depth and slope of these elements are important. Flatter ditches or gutters are preferred to steeper ones. Deep ditches when compared to shallow ones present 20 percent higher injury accident rates (Lamm et al., 1999).

Road surface

The required steering and braking distances are related to the friction coefficient between the road surface and the vehicle tyres. The accident risk increases as skid resistance decreases. The risk is higher under wet surface conditions and at sites where friction requirement is high (e.g. intersections, horizontal curves, downhill slopes).

Accident factors and assumed relationship

- Friction coefficient

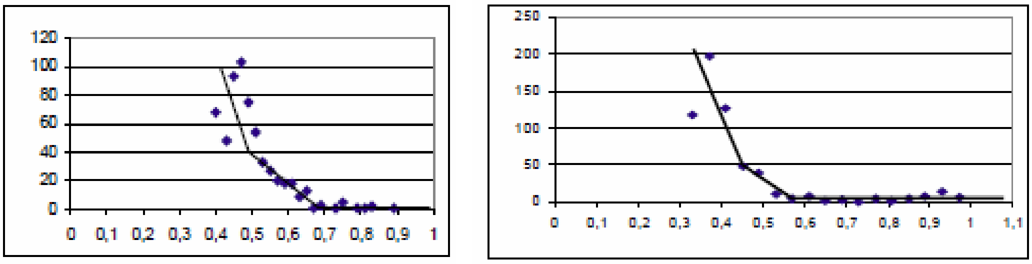
  Studies show that the accident rate on dry roads is lower than on wet roads (Elvik and Vaa, 2004) and in general that the accident rate increases where the skid

[1] AASHTO (1996). Roadside Design Guide, American Association of State Highway and Transportation Officials. Washington, D.C.

resistance is low. Wet pavement conditions increase the risk of accidents especially on horizontal curves and on downward or upward slopes (PIARC Road Safety Manual, 2003).

Research showed that the relation between accident risk and skid resistance surface characteristics are not linear, and side friction coefficient, CAT (x axis) for example affecting accident risk (y axis) only when the coefficients are lower than 0.7 (see Figure 4) and macro texture (HS) affecting accident rates when HS is below 0.55 (Caliendo and Lamberti, 2001).

Figure 4: Accident rate as a function of pavement friction (left) and macro texture (right)



Source: Caliendo and Lamberti, 2001

Table 2 provides a summary of the most important relationship between head-on and single vehicle accidents and design parameters found in this review.

Table 2: Overview of accident factors and their relationship to traffic safety for head-on and single-vehicle accidents

Accident factors	**Relationship**	**Indicators**
Curves	More accidents take place in curves with small radii than in curves with large radii. Sections with a high curve density are safer than straight sections with occasional sharp curves. Large curvature changes are associated with higher accident rates.	Curvature change rate
		Curve density
		Curve radius
Design consistency	Speed reduction from approach tangent to curve. Large average radii of curvature (road sections) and large ratios of individual curve radii to average radii result in high accident rates.	Speed
		Average radius of curvature
		Curve radius ratio
Vertical alignment	Gradients higher than 6% are associated with higher accident rates.	Gradient
Sight distance	Sight distances and accidents are linked in a way that - up until a certain critical distance - accident rates decrease as sight distances increase.	Sight distance Stopping sight distance Passing sight distance Decision sight distance Intersection sight distance
Traffic control devices	Rumble strips as well as edge and centre line markings are responsible for a decrease in accident rates. Electronic traffic control systems such as Variable Traffic Signs adapt speed limits due to current weather and/or traffic conditions.	Curve warning signs
		Marking and delineation
		Guidance

Accident factors	Relationship	Indicators
Cross section	Increasing the lane width (temporarily) reduces the number of accidents. Rural roads with hard shoulders show lower accidents rates.	Lane/road width
		Emergency/hardened shoulders
		Shoulder drop-off
Roadside area and equipment	Larger obstacle-free zones produce fewer numbers of accidents. Protective devices reduce both the number of fatal and injured accidents.	Clear roadside area
		Protective devices
Road surface	Accident rates increase where the road surface skid resistance is low.	Friction coefficient

4.2 Rear-end collisions

Rear-end crashes occur when the front of a moving vehicle impacts the rear of the vehicle ahead. They are also known as shunts or nose to tail accidents. These crashes are more likely to occur in urban areas and on roads with high traffic flow. They typically result in minor injuries to occupants but severe injuries and even fatalities are possible if the speed differences between involved vehicles are high. They are a crash type associated with junctions very frequently but may also result from stop-start conditions on major roads or where vehicles encounter stationary traffic in queues, resulting from congestion in front. Severe rear-end collisions may occur where important differences in car and truck speeds are common, such as in steep and long grades.

This type of crash can also result where vehicles have very different braking performances. Heavy goods vehicles and motorcycles have significantly greater breaking distances than cars. This has the consequence that a car braking sharply may be struck by these vehicle types from behind whereas another car would have stopped before striking it.

Typically shunts can result in injuries to the spine of those involved. This damage can range from fairly minor whip-lash to major damage to bones and hard tissues.

The accident factors that are investigated in this section are:

- Weather
- Signalised junctions
- Visibility/lighting
- Road design and complexity
- Signing and marking
- Road surface
- Inattention
- Inappropriate speed
- Tailgating
- High central brake light
- Various proximity warning systems
- Vehicle type

Detailed description of accident factors

Weather conditions

On icy and wet/slippery roads, rear-end accidents are more common as braking performance is substantially reduced.

Accident factors and assumed relationship

Yan et al., (2005) reported that rear-end collisions were more than three times more likely for wet roads compared to dry roads.

Signalized junctions

An American study (Yan et al., 2005) found that at signalised junctions in Florida, the most common accident is a vehicle hitting the rear of another vehicle. Additional awareness is required of the range of responses that drivers in front can make to signal changes.

Accident factors and assumed relationship

The introduction of traffic signal controls and enforcement of traffic signal controls has been observed to increase the number of rear-end collisions (Elvik et al., 2004).

Yan et al. (2005) showed in an analysis of rear-end accidents at signalised intersections in America, that there are sets of road environment, vehicle and human risk factors associated with shunt accidents specifically at controlled junctions:

- number of lanes (Odds ratio: 0.9 of 6 lanes v. 2 lanes)
- divided/undivided highway (OR 0.9 of undivided v. divided)
- accident time, (OR 0.5 night v. day)
- road surface condition (OR 3.3 wet v. dry)
- urban/rural (OR 1.2 urban v. rural)
- speed limit (OR 4.6 55mph v. 25mph)
- vehicle type (OR 1.1 van v. car)
- driver age (OR 0.5 – 0.7 for age groups <75 v. <26)
- alcohol/drug use (OR 149.6 alcohol v. no influence, OR 99.8 drug v. no influence)
- driver residence (OR 1.3 – 1.7 for non local v. local)
- gender (OR 0.9 female v. male)

Sight and visibility/lighting

Several studies have investigated the relationship between sight distances and road accidents.

LAMM et al. (1999a), e.g., determined high accident rates for sight distances shorter than 100 m, above 150 m no further positive effect was determined.

An American study showed that 3% of rear end accidents were due to limited sight and visibility (McGehee, Mollenhauer and Dingus, 1994).

Accident factors and assumed relationship

In Yan et al. (2005), it was shown that light trucks are 18% more likely to be struck than passenger cars. One explanation for this is that it is difficult to see what is happening on the road in front of a light truck from behind, and so a driver in a vehicle behind a light truck may not get any pre-warning of hazards ahead (Abdel-Aty and Abdelwahab, 2004).

Elvik et al. (2004) showed that the number of rear end collisions reduced by around 41-54% with the addition of lighting on unlit roads. Based on studies in the U.S.A, United Kingdom, Denmark, Germany, Sweden and the Netherlands, Elvik et al. (2004) found that increasing the level of lighting reduced nighttime injury accidents by 8 to 32 percent.

Yan et al. (2005) suggested that the presence of both horizontal and vertical curves doubles the risk of a rear end collisions compared to a straight road.

Weise et al. (2002) have shown that average speed is higher in curved crests with grade change than in curved crests with grade switch.

Road design and complexity

Increasing the complexity of the road environment (more lanes, higher traffic flows and divided carriageways) increases the risk of a rear end accident (Yan et al. 2005).

Accident factors and assumed relationship

Kim et al. (2007) also showed that ‘junctions with road shoulders had more rear-end collisions than those without shoulders’.

Signing and marking

Rear-end collisions can be reduced by the advance warning of risky situations such as junctions. If the driver is expecting a risky situation, he can prepare for it and therefore reduce sudden unexpected responses (Elvik et al. 2004).

Accident factors and assumed relationship

No information available.

Inattention

Rear-end accidents often occur at junctions when one vehicle pulls out failing to notice the vehicle in front not pulling out (PIARC, 2003). These collisions are generally of low severity and therefore little research is devoted to this accident type. An American study (Elvik and Vaa, 2004) found that 63% of rear end collisions were caused solely by lack of driver attention, and an additional 16% were caused partly by lack of attention.

Impairment of the driver at fault may also play a major part in fatal rear end shunts (Clarke et al. 2006). Nearly 9% of shunt crashes which resulted in fatalities involved an impaired driver in a UK study. Potentially driving tired may also result in increased involvement in rear end crashes.

Accident factors and assumed relationship

No information available.

Tailgating and inappropriate speed

Tailgating and inappropriate speed also lead to rear-end collisions away from junctions (Lynam, 2007) if some unexpected external factor (road condition, reduced visibility or actions of another road user) requires the vehicle in front to brake suddenly. Hofmann (1966) showed that driver’ abilities at judging the speed of the vehicle in front is relatively poor. Various ITS systems exist which use signs to warn drivers of stationary traffic ahead (e.g. MIDAS Motorway Incident Detection and Automatic Signalling in the UK). Analysis has estimated that MIDAS results in a 13% reduction in injury crashes where it is used (Tucker et al. 2006).

Accident factors and assumed relationship

A higher flow of traffic generally leads to reduced headway between vehicles which can decrease the chances of a driver being able to avoid a vehicle in front in an emergency stop situation. Khattak (2001) reported that a majority of rear-end accidents in America occurred during the peak times 7:00–9:00 a.m. and 3:00–6:00 p.m., when traffic flows are at their highest.

Vehicle type

There is some evidence from a study of work related crashes (Clarke et al. 2005) that light goods vehicles are involved in excessive rear-end shunts on rural A roads and to a lesser but still significant extent on rural motorways. The motorway incidents frequently occurred in congested conditions and there was often an element of fatigue involved.

Accident factors and assumed relationship

Company car drivers have a tendency to cause shunts through inattention and tailgating between 08:00 and 09:00 in the morning. Lorry and light goods vehicle drivers were involved in excessive shunts whilst working during the same morning peak hour (08:00-09:00) but also between midnight and 01:00. These shunts were thought to be caused by excessive speeds but also close following, and these did result in some fatalities on motorways. Table 3 provides a summary of the relevant accident factors that play a role in rear end collisions.

Table 3: Overview of accident factors and their relationship to traffic safety for rear-end collisions

Category	**Accident factors**	**Relationship**	**Indicators**
Overall	Weather	Rain, snow and ice reduce braking capability causing more rear-end collisions into stationary or slow moving vehicles	Historic weather data
Infrastructure	Signalised junctions	At newly introduced signalised junctions the most common collision is a rear-end collision	Presence/absence
	Visibility/lighting	Reduced visibility leads to lack of warning about hazards ahead, not allowing drivers to prepare in advance.	• Sight distance • Time of day
	Road design and complexity	More complex roads lead to more rear collisions, as drivers have to concentrate on the road rather than vehicles ahead.	
	Signing and marking	Rear-end collisions can be reduced by early warning of risky situations such as junctions	
Maintenance	Road surface	Roads with a lower skid resistance result in longer braking distances	Skid resistance/Friction coefficient
Human factors	Inattention	Many rear-end collisions are caused by lack of attention at junctions, by drivers not noticing that the vehicle in front has not pulled out	Gaze data
	Inappropriate speed	Inappropriate speed and tailgating lead to rear-end crashes away from junctions when one vehicle has to complete an emergency action to an event. There is insufficient time and space for the vehicles behind to react	Speed surveys
	Tailgating		Headway, flows
In-vehicle technology	High central brake light	Early warning system for vehicle behind	Prevalence
	Various proximity warning systems	Early warning system for driver	Prevalence
Vehicle	Vehicle type	Light goods vehicles and company car drivers more likely to be involved in rear-end collisions	Vehicle type distribution

4.3 Lateral collisions

Lateral collisions (also called right-angle or side impact crashes) arise when the front of one vehicle impacts into the side of another at an angle of about 90°. This crash type arises mainly at junctions since the kind of conflict that results in a lateral collision typically occurs between vehicles during the movements required to negotiate T-junctions or cross-roads. Since these kinds of collisions frequently involve a crash between a fast moving vehicle and a slow or almost stationary vehicle, most of the energy is transferred through a part of the vehicle which may offer little protection to occupants. This crash type causes disproportionate levels of severe injuries, especially when the striking vehicle is larger or is travelling at high speed. One study indicates that 15-40% of lateral collision crashes can produce 25-40% of fatal and serious injury crashes, (Laberge-Nadeau et al., 2009).

The Safe Systems approach to safety indicated that the posted speed should be kept to 50km/h or less where there are junctions on a route where side impacts crashes are possible.

In Europe, a significant proportion of injury road crashes occur at junctions. A much higher proportion of urban crashes occur at junctions than do rural crashes (Elvik and Vaa, 2004), but it should be noted that this may be an effect of larger under reporting of less severe crashes which occur in rural areas. As discussed below, junction type has been found to affect the types of crashes that occur and also the resulting severity. Junctions can be at-grade such as crossroads and T-junctions; or merging junctions such as roundabouts; or grade separated interchanges, which keep vehicles moving in different directions segregated.

These grade separated junctions are used mostly on busier multi-lane and divided roads since they tend to be expensive to implement. Accidents at junctions occur due to excessive speed and angle conflicts between vehicles (Lynam, 2007). In particular, these crashes are frequently caused by vehicles going straight across a junction where they assume they have priority (Ryan et al., 1988). Other problems can result when a driver fails to stop on a minor arm because he does not see the traffic on the major arm, miss-judges speeds of traffic on the major arm, or he fails to realise that there is a junction.

17.5 fatalities per million inhabitants in the EU-12 occurred at junctions on all road types in 2006, which is a total of 5,168 (in 2006, or latest available year) (SafetyNet, 2008). This constituted around 21% of all traffic accident fatalities in these countries.

The accident factors that are investigated in this section are:

- Speed differential
- Junction type
- Consistency
- Intersection control
- Warning systems
- Visibility
- Distance between junction
- Driver age
- Vehicle type

Detailed description of accident factors

Speed differential

Many safety problems at junctions result as a consequence of drivers' difficulty in judging the speed and distance of other traffic, particularly at priority junctions (Department for Transport, 2010). Increased speed of traffic makes the drivers' tasks more difficult whilst negotiating a junction and also increases the energy of an impact should it occur.

Accident factors and assumed relationship

Studies have shown that accident rates are reduced at junctions where speed differentials between the joining roads are small, in particular by a reduction in vehicle speeds on the main road (Lynam, 2007). Vision Zero (Tingvall et al., 2000) suggests that the maximum acceptable speed limit in situations where lateral collisions are possible should be 50km/h.

Reductions in speeds can be achieved by manipulating the junction layout (for example, a roundabout layout gives priority to road users on the roundabout regardless of the road type that they emerged from and therefore, in theory, speed differential should be minimal once on the roundabout), by adding intersection control or by introducing warning systems. For example, extending deceleration lanes by approx 30m has been observed to reduce accidents by up to 10% (Elvik and Vaa, 2004).

Channelization at crossroads and to some extent at T-junctions using ghost and physical barriers can reduce crashes. These engineering measures result in greater vehicle path consistency and driver manoeuvre predictability reducing the chance for conflict and helping to re-enforce priority. (Elvik and Vaa, 2004).

Junction Type

Ogden (1996) stated that in general grade separated junctions are safer than at-grade junctions. Accident rates increase with the number of arms and when there is a higher proportion of traffic entering the main traffic stream from the minor road (Elvik et al., 2004). A high number of arms increase the complexity of potential vehicle movements, the number of conflict points and vehicle interactions making the task of negotiating the junction more difficult for drivers.

Accident factors and assumed relationship

Research suggests that accident rates at at-grade junction can be improved by using a merging type of junction such as roundabouts where conflicts are limited to lower speeds and reduced angle of merging movements (Lynam, 2007 and SWOV, 2002). Merging junctions such as slip roads or acceleration and deceleration lanes should have longer lengths (Walmsley & Summersgill, 1998) and level on and off ramps (SWOV, 2002) and have wide edges (Hamilton & Kennedy, 2005 and SWOV, 2002). At non-merging junctions, such as T-junctions, increasing the carriageway width has been observed to reduce accidents (SWOV, 2002).

Elvik and Vaa (2004) have shown that:

- Accident rate at junctions is higher for 4+ arms than 3 arms
- Roundabouts reduce numbers of accidents by 10-40%
- Changing cross road to grade separated results in an estimated reduction in accidents of ~50%
- There is no reduction in accidents when changing a T junction to a grade separated junction, although the investigation of Meewes (2002, 2003) showed that the accident cost rate of grade separated junctions is about one third less than the ACR of T-junctions.

Consistency

It has been shown that it is important to use the same junction type along a particular route or road type where possible, consistently, so that junction types are not unexpected, and appropriate behaviour is encouraged (SWOV, 2002).

Intersection control

Intersections without controls have a higher rate of older driver fatalities (Zhang et al., 2000) than controlled junctions.

Accident factors and assumed relationship

A Meta-analysis of studies where intersection controls were introduced showed that the number of accidents at crossroads reduced by 30% and at T-junctions by 15% (Elvik et al., 2004). The number of rear end accidents increased; however these are generally of lower severity.

Warning systems

Early warning signs and systems for bends and junctions can allow the driver to be better prepared for and more alert to a potential change or hazard. Engineering measures such as coloured road surfacing, high friction surfacing or rumble strips act as alerting devices. Transverse yellow bar markings with exponentially increasing frequency can be used to reduce speeds and increase awareness of hazards (Hamilton et al., 2005).

Accident factors and assumed relationship

Removal of traffic signals and introduction of a stop sign at intersections in Philadelphia resulted in a 24% reduction in collisions from the expected number (Persaud et al., 1997). Vehicle activated signs on the approach to junctions and bends were shown to reduce mean speeds by 3-6mph and substantial accident reductions were recorded in a UK study (Winnett and Wheeler, 2003).

Visibility

Good visibility at junctions appears to have inconsistent results: in general better visibility at roundabouts appears to reduce accidents, however reducing sight lines by planting obstacles on the central island reduced speeding through junctions in one study (Elvik et al., 2004).

Accident factors and assumed relationship

It is estimated that reducing the gradient near intersections could reduce the number of injury accidents by 17% (Elvik and Vaa, 2004), by increasing visibility and making it easier to stop or start. Straightening lateral curves also improves sight conditions and allows road users more reaction time. Elvik and Vaa (2004) found that increasing sight lines does not appear to affect injury accidents but reduces damage only accidents by approximately 15%.

Distance between junctions

Studies have shown that as the distance between junctions increase, the number of crashes per junction decrease.

Accident factors and assumed relationship

Junction frequency was found to be the most influential factor affecting head-on and lateral collision rate in a Spanish investigation into accident prediction modelling on rural roads (Padillo et al., 2003). Walmsley & Summersgill (1998) and SWOV (2002) suggest that the number of junctions should be kept to a minimum where possible. However, adding major junctions (roundabout or light-controlled) seems to increase accident rates only slightly (Lynam, 2007).

Driver age

A review of the literature on side impact crashes (Chipman, 2004) has shown that older drivers are involved in more crashes at junctions per distance driven than younger drivers.

Accident factors and assumed relationship

Older drivers (over 60 years old) were observed to be more likely to be at fault in an accident at a junction than younger drivers (taking into account different mileage and driving patterns of older drivers; Preusser et al., 1998), due, speculatively, to a reduction in vision, reaction time and judgement (Chipman, 2004).

Vehicle type

The relationship between the size of the striking and struck vehicle affects the severity of injuries sustained by the vehicle occupants.

Accident factors and assumed relationship

Analyses of injuries (Chipman, 2004) sustained in frontal and lateral collisions concluded that collisions involving a small (mini) and a large vehicle (e.g. SUV) resulted in more severe head and torso injuries that those involving two similar vehicles. An American study (Gabler et al., 1998) showed that 60% of fatalities in side impact collisions were the results of a light van or truck, which make up around 30% of the vehicle population.

A summary of the factors influencing lateral collisions is given in Table 4.

Table 4: Overview of accident factors and their relationship to traffic safety for lateral collisions

Accident factors	Relationship	Indicators
Speed differential	The number of accidents is smaller at junctions where the speed differential between joining roads is lower. Slower speeds mean that negotiating the junction is easier and injuries are less severe should an impact occur.	• Speed limit differential • Vehicle speed distributions
Junction type	Grade separated junctions are safer than at-grade junctions. More complex junctions (higher number of arms) result in more lateral collisions.	• Junction type • Junction complexity – number of arms • Deflexion angle on roundabouts
Consistency	Similar junction types should be used along a route where possible, so as not to be unexpected and to encourage appropriate behaviour	Index of consistency
Intersection control	Junctions where intersection controls were introduced showed a marked decrease in accident number.	Rate of junctions with controls
Warning systems	Warning systems such as signs and different surfacing will prepare the driver for potential hazard	Presence/absence
Visibility	Good visibility at junctions reduces accidents in general, although improving visibility can increase speeds.	• Sight distance • Time of day • Weather
Distance between junction	As the distance between junctions increases, rates of junction accidents decrease.	Junction frequency
Driver age	Older drivers (60+) are more involved in collisions at junctions than younger drivers (<60).	Driver age distribution
Vehicle type	A large difference in size of vehicles involved in a collision results in higher severity injuries than those when similar vehicles collide.	Vehicle type distribution

5 State-of-the-Art databases and information systems

5.1 SafetyAnalyst

In April 2001, the Federal Highway Administration (FHWA) entered into a contract with Midwest Research Institute (MRI) to plan and develop a set of software tools for safety management of specific highway sites, known as SafetyAnalyst. The software incorporates computerized analytical tools that correspond to the main steps in highway safety management for site-specific improvements:

- Network screening
- Diagnosis and countermeasure selection
- Economic appraisal and priority-ranking
- Evaluation

The basic purpose of SafetyAnalyst is to use available data to review the entire roadway network under the jurisdiction of a particular highway agency and identify and prioritize those sites that have promise as sites for potential safety improvements and, therefore, merit further investigation. Module 1 (Network Screening) makes use of information on roadway characteristics and safety performance to identify those sites that are the strongest candidates for further investigation.

Database structure

SafetyAnalyst provides a range of capabilities based on data availability. Many of the data elements required are readily available to highway agencies, but some effort to assemble other data elements may still be needed. A preliminary list of desired data requirements gives the following variables and characteristics (levels).

A. Traffic Accident Data

- Accident location (milepost, link/node/offset, segment/offset, GPS coordinates)
- Date (day/month/year)
- Day of week
- Time (at least to the nearest hour)
- Accident severity (Fatal/Injured/Property Damage Only)
- Tow-away indicator (yes/no)
- Relationship to junction (at intersection/intersection-related/driveway-related/at railroad-highway grade crossing/grade-crossing-related/ramp/speed-change lane/not related to junction)
- Light condition
- Weather
- Pavement surface condition
- Number of vehicles involved
- Accident type (based on type object struck for single-vehicle accidents and manner of collision for multiple-vehicle accidents)
- Initial direction of travel (for at least Vehicles 1 and 2)
- Intended manoeuvre (for at least Vehicles 1 and 2)
- Driver age (for at least Vehicles 1 and 2)
- Vehicle types involved (for all involved vehicles)
- First harmful event
- Most harmful event
- Object struck
- Ran-off road indicator (yes/no)

- Pedestrian indicator (yes/no)
- Bicycle indicator (yes/no)

B. Roadway Segment Inventory Data

- Segment location (beginning and ending points; linkable to accident data)
- Segment length
- Area type (rural/urban)
- Basic number of lanes
- Auxiliary lanes (TWLTL/passing lane/climbing lane/other auxiliary lane)
- Median type
- Median width
- Lane width
- Shoulder type
- Shoulder width
- Access point density
- Average daily traffic (ADT)
- Peak hour volume/design hour volume
- Percent heavy vehicles
- Speed (85th percentile or posted speed)

C. Intersection Inventory Data

- Intersection location (linkable to roadway segment and accident data)
- Area type (rural/urban)
- Number of legs
- Type of traffic control (signalized/two-way STOP/all-way STOP/two-way YIELD/uncontrolled)
- Number of through lanes on major road (includes shared lanes)
- Median type on major road
- Median width on major road
- Left-turn lanes on major road
- Right-turn lanes on major road
- Number of through lanes on minor road (included shared lanes)
- Median type on minor road
- Median width on minor road
- Left-turn lanes on minor road
- Right-turn lanes on minor road
- Traffic volume (ADT) on major road
- Peak hour volume/design hour volume on major road
- Traffic volume (ADT) on minor road
- Peak hour volume/design hour volume on minor road
- Turning volumes

D. Interchange Ramp Inventory Data

- Ramp location (linkable to mainline roadway segment and accident data)
- Area type (rural/urban)
- Ramp length
- Ramp type (diamond/loop/outer connection/directional/semi directional)

- Type of connection at either end (mainline acceleration lane/mainline deceleration lane/mainline weaving area/C-D road/other ramp)
- Speed (85th percentile, posted, or advisory speed)

E. <u>Other Data Files</u>

- Horizontal curve data
- Grade and vertical curve data
- Railroad-highway grade crossing inventory data

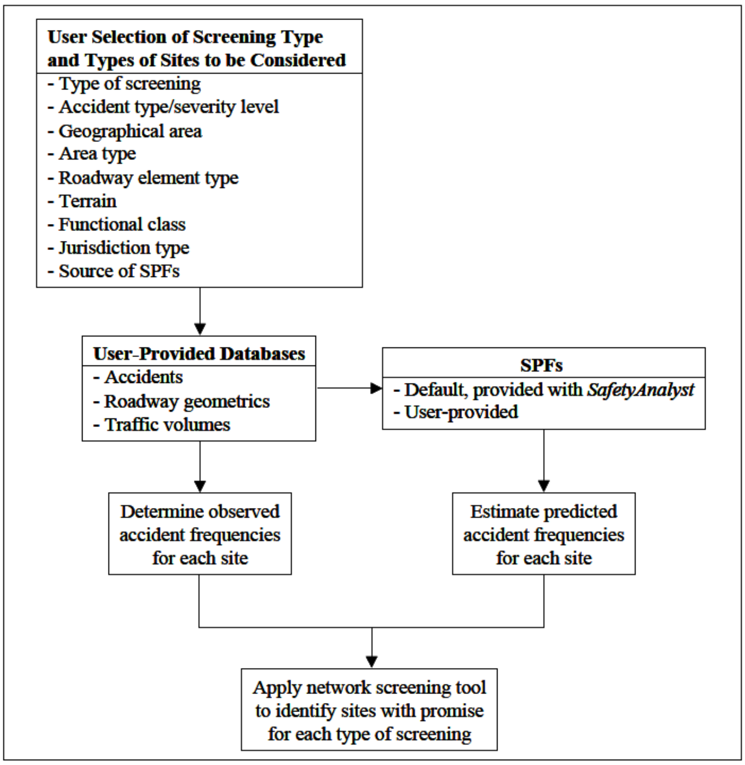
F. <u>Cost Data</u>

- Average cost of safety improvement projects where available disaggregated as far as possible
- Average cost of accidents of different severities

<u>Output</u>

SafetyAnalyst is built on the concept of conducting screening based on expected accident frequencies. Expected accident frequencies can be estimated from so called safety performance functions (SPFs), which often take the form of negative binomial regression relationships to predict accident frequencies from traffic volumes and roadway characteristics. The Empirical Bayes (EB) method provides a means to combine SPFs predictions and observed accident frequencies into a single estimate of the expected accident frequency, so that the observed accident history of a site can be considered in the estimation process.

Figure 5: Combination of different data sources and methodologies for network screening



Source: SafetyAnalyst, White Paper for Module 1, page 11

The variables mentioned above are being used to calibrate the safety performance functions and calculate estimates of accident frequencies for different sites. Those values are needed to identify high risk sites and hazardous road sections.

5.2 MOLASSESS

The MOLASSES (Monitoring of Local Authority Safety Schemes) database was initiated by the County Surveyors' Society (CSS) in 1991 in an attempt to encourage more monitoring of safety engineering work undertaken by highway authorities. In 1993 TRL agreed to take over and have been in charge of its operation since that time. The data in MOLASSES is supplied voluntarily by local authorities and contains 'before' and 'after' on several thousand schemes.

The objectives of the MOLASSES project are fourfold:

1. Develop a central computer database for building up information about the effectiveness of safety engineering schemes implemented by local authorities within the UK.
2. Compile data received on schemes into the database.
3. Provide information for CSS reports and for individual authorities
4. Provide software for data transfer and record keeping.

Molasses was closed down in 2007 as there was very little data being input by local authorities and the historic data was becoming out of date. A new database called UK Morse was started around the same time, but as yet has little information available.

Database structure

When an authority or agency agrees to contribute to MOLASSES, it is asked to provide information on schemes when they are implemented. A standard scheme report form is used for this purpose (see Figure 6). Subsequently, authorities and agencies are asked to provide 'after' accident information on schemes that they have submitted. This is done on a retrospective, 3-year after, basis. Three years is considered to be a suitable time-period because it is long enough for a statistically reliable 'after' record to be analysed, but short enough to assume important factors, such as vehicle flow will not have changed too much.

Although each authority or agency is requested to supply the 'before' and 'after' accident data, it is in fact the police who initially collect these data. The details of each road accident are recorded on a STATS 19 form. This is a standard form that defines the information the police must record at each personal injury accident involving at least one vehicle at the highway. The national STATS 19 database supplied by the police forces is held in a central database. Each local authority incorporates data for its own area into a local database; this may also include further information and checks on these data made locally after they have been submitted to the national database. Scheme accident data are provided by local authorities from these local databases.

Schemes entered into the MOLASSES database are classified by the type of treatment installed at a site. To make a provision of information on treatments simpler and quicker, the MOLASSES input form provides a set of treatment codes which describe the treatment types employed at specific sites. The treatment codes can describe modifications to a site in great detail, ranging from completely new features to relatively minor changes to existing installations. The coding system allocates treatments into several major categories:

- Signalized junction
- Roundabout
- Priority junction
- Bend
- Pedestrian facility
- Cycle scheme
- Link
- Route
- Area-wide scheme

Output

The schemes included in MOLASSES cover a wide spectrum of different types. Schemes may include treatments from more than one treatment category and sometimes, therefore, will appear more than once, depending on how many categories they cover. A number of different measures have been developed to assess schemes within the MOLASSES database.

These are:

- Percentage change in accidents per annum
- Average annual accidents saved
- Expenditure per accidents saved per annum
- First year of return

Figure 6: MOLASSES Database input form

Section 1: Details of Agency Supplying Information

1.1 Name of person to contact:________________

1.2 Name of agency:________________

1.3 'Phone number of agency:________________

1.4 'Fax number of agency: ________________

1.5 Address of agency:

____

____

____

____

1.6 Your reference number for this scheme/group of schemes:________________

1.7 Type of agency (Please tick one box):

1 DETR..........................

2 Regional Council.............

3 County Council..............

4 London Borough..............

5 Metropolitan District........

6 District Council ....

7 Borough Council...........

8 Private consultant ....

9 TRLab..............................

10 Agent (please specify area)..

0 Other (please specify).........

____

Section 2: Type of Scheme(s)

Please answer all the following questions where relevant

2.1 Number of sites covered by this report:____(if not single site scheme)

2.2 Category of safety scheme or plan (please tick **one** box):

1 Single site scheme..

2 Group of individually tailored schemes..

3 Mass action plan, one treatment only..

4 Route action plan..

5 Area scheme..

6 Traffic calming scheme..

7 Other, please specify and complete all questions that appear relevant

____

2.3. Existing site type (please tick **one** box):

	No of approaches 3	4	5+	
Signal controlled jct	1	2	3	Pedestrian refuge......16
Priority junction	4	5	6	Zebra crossing.........17
Conv roundabout	7	8	9	Pelican crossing........18
Mini-roundabout	10	11	12	Traffic sig X phase....19
Grade sep intersection	13	14	15	Cycle crossing.........20
				Bend....................21

Other (please describe) 22 ________________

Section 3: Location of Site(s)

3.1 Grid references (if available):________________

3.2 Route number(s):________________

3.3 Place name:________________

3.4 Further details of location (if necessary for identification):________________

____

____

Section 4: Site characteristics

4.1 Please estimate the following and tick box if appropriate:

(i) AADT (Average Annual Daily Total) veh flow

1 Less than 5,000....................

2 5,000 to 9,999....................

3 10,000 to 19,999....................

4 More than 19,999....................

(ii) Pedestrian flows:

1 Very light...............

2 Light...............

3 Medium...............

4 Heavy...............

4.2 Is the site(s) in a built-up area ?: Yes/No (delete as appropriate)

4.3 Enter lowest speed limit on any part of the site(s) (mph): _______

4.4 Enter highest speed limit on any part of the site(s) (mph): _______

Section 5: Treatment details

5.1 Please summarise your diagnosis of the problem:

____

____

____

____

____

5.2 Total works costs for all site(s): £_____

5.3 Source of funds (tick box):

Highway Authority Revenue : Yes No If Yes, approximate percentage: ___ %

Central Government Funding: Yes No If Yes, approximate percentage: ___ %

Other: Yes No If Yes, approximate percentage: ___ %

(please specify)________________

5.4 Please give a brief description of the treatment:

____

____

____

____

____

5.5 Please specify the type of accident(s) at which the treatment is aimed (TARGET accs)

Please tick all boxes that apply.
1 Vehicle/pedestrian conflict......
2 Cyclists..............................
3 Motorcyclists..........................
4 Overshoot ....
5 Restart..................................
6 Shunt, both vehicles moving.....
7 Shunt, both vehicles stationary..
8 Loss of control on a bend.........
9 Loss of control not on a bend.....
10 Overtaking............................

11 Stopping ....
12 Changing lane.......................
13 Turning right.......................
14 Turning left..........................
15 U-turn.................................
16 Excessive speed....................
17 Other (please specify):.........

5.6 Please tick the appropriate boxes to indicate the treatment(s) used in the scheme:

Examples of how to use these treatment codes:

Example 1: Addition of a separately signalled right turn at a set of signals would be coded as 1.2.5

Example 2: Introduction of road humps and new surfacing on a link would be coded as 7.1 and 7.6

Example 3: An area-wide scheme that included all the features described for link schemes would be coded as 9.0-9.9

Example 4: An area-wide scheme that included all the features decribed for link schemes, and general schemes, would be coded as 9.0-9.35

1 Signalised junction
1.1 New signals..........................
1.2 Modifications to signals........
1.2.1 Addition of ped phase/stage..
1.2.2 Mods to ped phase/stage....
1.2.3 Addition of early cut-off......
1.2.4 Modification of early cut-off.
1.2.5 Separately signalled right turn
1.2.6 Closely associated secondary signals.......................
1.2.7 Geometric improvement (inc refuges).....................
1.2.8 Conspicuity improvement....
1.2.9 Timing/linkingimprovement.
1.2.10 Red light cameras................
1.2.11 Gantry signals....................
1.2.12 Right turn ban....................
1.2.13 Anti-skid surfaces.............
1.0 Other (please specify).........

---

2 Roundabout
2.1 New conventional roundabout.
2.2 New mini-roundabout............
2.3 Modifications to conv rdbt.....
2..3.1 Entry geometry..................
2.3.2 Circulatory geometry..........
2.3.3 Exit geometry....................
2.3.4 Signing...............................
2.3.5 Visibility...........................
2.3.6 Yellow bar markings..........
2.3.7 Signalise.............................
2.3.8 Anti-skid surfaces..............
2.3.0 Other (please specify) ....

2.4 Modifications to mini-roundabout
2.4.1 Entry geometry..................
2.4.2 Circulatory geometry..........
2.4.3 Exit geometry.....................
2.4.4 Signing..............................
2.4.5 Visibility...........................
2.4.6 Yellow bar markings...........
2.4.7 Signalise............................
2.4.8 Anti-skid surfaces..............
2.4.0 Other (please specify) ....

---

3 Priority junction
3.1 Geometric improvement........
3.1.1 Right turn ban...................
3.2 Central refuges in side-road..
3.3 Visibility............................
3.4 Signing...............................
3.5 Road markings.....................
3.6 Anti-skid surfaces...............
3.0 Other (please specify) ....

---

4 Bend
4.1 Re-alignment........................
4.2 Visibility.............................
4.3 Safety fence.........................
4.4 Signing................................
4.5 Kerbing...............................
4.6 Anti-skid surfaces.................
4.7 Speed camera technology ....
4.0 Other (please specify) ....

---

5 Pedestrian facility
5.1 New zebra.......................
5.2 New pelican.....................
5.3 Modifications to zebra..........
5.3.1 Conspicuity.......................
5.3.2 Relocation.........................
5.3.3 Safety barriers...................
5.4 Modifications to pelican.........
5.4.1 Conspicuity.......................
5.4.2 Relocation.........................
5. 4.3 Safety barriers..................
5.4.4 Signal linking....................
5.4.5 Split pelican.......................
5.5 Pedestrian refuges.................
5.6 Promontory..........................
5.7 New puffin............. ....
5.8 Anti-skid surfaces.................
5.0 Other (please specify) ....

---

6 Cycle schemes........................

7 Link calming
7.1 Road humps.........................
7.2 Chicanes - 1 way working...
7.2.1 Chicanes - 2 way working...
7.3 Plateaux...............................
7.4 Four-way give-way...............
7.5 Gateways..............................
7.6 Surfacing..............................
7.7 Sheltered parking.................
7.8 Throttles/narrowings.............
7.9 Rumble strips.......................
7.10Thumps.........................
7.11Cushions........................
7.0 Other (please specify)..........

Link general
7.20 Carriageway markings.........
7.21 Surfacing.........................
7.22 Signing ....
7.23 Signs and markings..........
7.25 OtherTrafficRegulationOrders
7.26 New lighting ....
7.27 Improved lighting ....
7.28 Publicity..........................
7.29 Drainage..........................
7.30 Central reservation barrier....
7.31Anti-skid surfaces...............
7.32Speed camera technology.....
7.33 Speed limits.......................
7.34 Island channelisation..........
7.35 Safety fencing....................
7.99 Other (please specify) ....

Please turn over:

8 Route calming
8.1 Road humps....................
8.2 Chicanes - 1 way working..
8.2.1 Chicanes - 2 way working..
8.3 Plateaux..........................
8.4 Four-way give-way.............
8.5 Gateways...........................
8.6 Surfacing...........................
8.7 Sheltered parking................
8.8 Throttles/narrowings...........
8.9 Rumble strips......................
8.10 Thumps.........................
8.11 Cushions.........................
8.0 Other (please specify)..........

Route, general
8.20 Carriageway markings.........
8.21 Surfacing...........................
8.22 Signing ....
8.23 Signs and markings...........
8.24 Parking restrictions ....
8.25Other TrafficRegulationOrders
8.26 New lighting........................
8.27 Improved lighting ....
8.28 Publicity............................
8.29 Drainage.............................
8.30 Central reservation barrier...
8.31 Anti-skid surfaces..............
8.32 Speed camera technology....
8.33 Speed limits.......................
8.34 Island channelisation..........
8.35 Safety fencing....................
8.99 Other (please specify) ......

9 Area-wide traffic calming
9.1 Road humps.........................
9.2 Chicanes - 1 way working..
9.2.1 Chicanes - 2 way working..
9.3 Plateaux..........................
9.4 Four-way give-way..............
9.5 Gateways...........................
9.6 Surfacing...........................
9.7 Sheltered parking................
9.8 Throttles/narrowings............
9.9 Rumble strips.......................
9.10 Thumps..........................
9.11 Cushions.........................
9.0 Other (please specify)..........

Area-wide general
9.20 Carriageway markings.........
9.21 Surfacing...........................
9.22 Signing ....
9.23 Signs and markings...........
9.24 Parking restrictions ....
9.25 OtherTrafficRegulationOrders
9.26 New lighting ....
9.27 Improved lighting ....
9.28 Publicity.............................
9.29 Drainage.............................
9.30 Central reservation barrier...
9.31 Anti-skid surfaces..............
9.32 Speed camera technology...
9.33 Speed limits........................
9.34 Island channelisation..........
9.35 Safety fencing.................
9.99 Other (please specify)........

Section 6: Evaluation of effectiveness:

6.1 "Before" period start date: ______________

6.2 "Before" period end date: ______________

6.3 Date of completion : ______________

6.4 "After" period start date: ______________

6.5 "After" period end date : ______________

6.6 Total "before" accidents for all sites covered by this report:______

6.7 Total "before" **TARGET** accidents (ie; the particular accidents at which the treatment is aimed. Please use the appropriate numbers from Question 5.5 if possible), if known:______

6.8 Total "after" accidents for all sites covered by this report:______

6.9 Total "after" **TARGET** accidents:______

6.10 Apparent overall percentage change in accidents,ie: ((average annual after/average annual before)x100)-100 ________ %

6.11 How would you rate the effectiveness of the scheme on a scale from 1, very effective, to 5, not at all effective ? (please circle the appropriate number):

1 2 3 4 5

6.12 Please give any brief general appraisal of the effectiveness of the scheme(s), drawing attention to any difficulties it would be helpful to warn others about (continue on a separate sheet if necessary):

Section 7: Additional comments:

We would be interested to know about additional comments you may have, please put them here (continue on a separate sheet if necessary):

5.3 HSIS – Highway Safety Information System

The Highway Safety Information System (HSIS) is a multistate database that contains crash, roadway inventory, and traffic volume data for a select group of US States. HSIS is operated by the University of North Carolina Highway Safety Research Center (HSRC) and LENDIS Corporation, under contract with FHWA.

The Highway Safety Information System uses data already being collected for the management of the highway system, for the study of highway safety. It is a roadway-based system that provides quality data on a large number of accident, roadway, and traffic variables. The data are acquired annually from a select group of States, processed into a common computer format, documented, and prepared for analysis. HSIS is used to analyze a large number of safety problems, ranging from the more basic "problem identification" issues to identifying the size and extent of a safety problem to modelling efforts that attempt to predict future accident frequencies from roadway characteristics and traffic factors.

Database structure

All of the selected States maintain basic crash files, roadway inventory files, and traffic files. In addition, individual States also collect other types of data. Depending on the particular problem being studied, files from one or more States may be used by the analyst. The following table indicates the files that are available.

Figure 7: File types available in HSIS by states

	CA	IL	ME	MI	MN	NC	OH	UT	WA
Crash	x	x	x	x	x	x	x	x	x
Roadway Inventory	x	x	x	x	x	x	x	x	x
Traffic Volume	x	x	x	x	x	x	x	x	x
Curve and Grade		x						x	x
VIN		x		x		x	x		
Intersection	x				x				
Interchange/Ramp	x		x	x					x
Guardrail/Barrier				x					

Crash - Contains basic accident, vehicle, and occupant information on a case-by-case basis. Typical data include type of accident, type of vehicle, sex and age of occupants, fixed-object struck, accident severity, and weather conditions.

Roadway Inventory - Contains information on roadway cross-section and the type of roadway. Data include the number of lanes, lane width, shoulder width and type, median width, rural/urban designation, and functional classification.

Traffic Volume - Contains annual average daily traffic (AADT) data. Additional data on hourly volumes and percentage of trucks is also available in selected States and/or locations.

Roadway Geometrics - Contains horizontal curve and vertical grade information. Data include degree of curve, length of curve, percent grade.

Vehicle Identification Number (VIN) - Contains VIN data decoded using the VINDICATOR program. Data include make and model, body style, body type, curb weight, and wheelbase.

Intersection - Contains information on highway intersections. Data include traffic control type, inter-section type, signal phasing, and turn lanes.

Interchange/Ramp - Contains information on highway interchanges. Data include interchange type and ramp characteristics.

Guardrail/Barrier - Contains an inventory of guardrail. Data include guardrail type, post type, rail height, and terminal type.

Two generic variable tables have been developed for all the States. The first table lists the crash-related variables for each State side-by-side and the second table lists the roadway-related variables. The purpose of developing these tables was to give the ability to the HSIS data requester to compare between States the availability of variables.

Table 5: Accident, vehicle and occupant files of HSIS

I. TIME VARIABLES										
GENERIC VARIABLE DESCRIPTION	**VARIABLE NAME**	**IL**	**MN**	**UT**	**ME**	**MI**	**CA**	**NC**	**WA**	**OH**
ACCIDENT DATE	ACC_DATE (A)	x	x		x		x	x	x	x
DAY OF WEEK	WEEKDAY (A)	x	x	x	x	x	x	x	x	x
MONTH OF ACCIDENT	MONTH (A)	x		x	x	x	ACC_DATE	x	x	
ACCIDENT YEAR	ACCYR (A)	x	x	x	x	x	x	x	x	x
HOUR OF OCCURRENCE	HOUR (A)	x	x	x	x	x	x	x		x
DAY OF MONTH	DAYMTH (A)	x	ACC_DATE	x	x	x		x	x	

II. ENVIRONMENT VARIABLES										
GENERIC VARIABLE DESCRIPTION	**VARIABLE NAME**	**IL**	**MN**	**UT**	**ME**	**MI**	**CA**	**NC**	**WA**	**OH**
SURFACE ROAD CONDITION	RDSURF (A)	x	x	x	x	x	x	x	x	x
LIGHT CONDITION	LIGHT (A)	x	x	x	x	x	x	x	x	x
WEATHER CONDITION	WEATHER (A)	x	x	x	x	x	x	x	x	x

III. ACCIDENT RELATED VARIABLES										
GENERIC VARIABLE DESCRIPTION	**VARIABLE NAME**	**IL**	**MN**	**UT**	**ME**	**MI**	**CA**	**NC**	**WA**	**OH**
ACCIDENT/COLLISON TYPE	ACCTYPE (A)	x	x	x	x	x	x	x	x	x
ACCIDENT CASE NUMBER	CASENO (A)	x	x	x	x	x	x	x	x	x
INVESTIGATING AGENCY	AGENCY (A)	x		x	x	x		x	x	
ACCIDENT SEVERITY	SEVERITY (A)	x	x	x	x	x	x	x	x	x
HAZARDOUS MATERIAL	HAZMAT (V)		x				x	x	x	x
NUMBER OF VEHICLES INVOLVED	NUMVEHS (A)	x	x	x	x	x	x	x	x	x
SEQUENCE OF EVENTS	EVENT (V)		x	(A)		x		x	x	x
DRIVER PHYSICAL CONDITION	PHYSCOND (V)	x	x		x		x	x		x
TYPE OF OBJECT STRUCK	OBJECT (V)		(A)	(A)	(A)	x	x	x	(A)	x
ACCID CONTRIB FACTORS	CONTRIB (V)		x	x	x		x	x	x	x

IV.VEHICLE INFORMATION VARIABLES										
GENERIC VARIABLE DESCRIPTION	**VARIABLE NAME**	**IL**	**MN**	**UT**	**ME**	**MI**	**CA**	**NC**	**WA**	**OH**
VEHICLE NUMBER	VEHNO (V)	x	x	x	x	x	x	x	x	x
VEHICLE TYPE	VEHTYPE (V)	x	x	x	x	x	x	x	x	x
VEHICLE YEAR	VEHYR (V)	x	x	x		x	x	x	x	x
VEHICLE DAMAGE AREA	DAMAGE (V)		x	x				x		x
VEHICLE DAMAGE SEVERITY	DAMSEV (V)		x			x		x	x	x
TOWAWAY/TOWED	TOWAWAY/TOWED (V)	x	x				(A)	x		x
VIN CODE	VIN (V)	x		x		x		x		x

V. DRIVER INFORMATION VARIABLES										
GENERIC VARIABLE DESCRIPTION	**VARIABLE NAME**	**IL**	**MN**	**UT**	**ME**	**MI**	**CA**	**NC**	**WA**	**OH**
DRIVER AGE	DRV_AGE (V)	x	x	x	x	x	x	x	x	x
DRIVER SEX	DRV_SEX (V)	x	x	x	x	x	x	x	x	x
DRIVER SAFETY EQUIPMENT	DRV_REST (V)	x		x		x		x	x	x
HELMET	HELMET (V)					x			x	(O)
DRIVER EJECT	DR_EJECT (V)			x		x			x	
DRIVER INJURY INFORMATION	DRV_INJ (V)	x	x	x	x	x	x	x	x	x
DRIVER INTENT	MISCACT1 (V)	x	x	x	x	x	x	x	x	x
DRIVER SOBRIETY	SOB_TEST (V)	x		x			x	x	x	(O)
DRIVER ALCOHOL PERCENT	DRV_BAC (V)	x		x				x		
DRIVER VIOLATIONS	VIOL (V)		(O)	x		x	x			

VI.OCCUPANT (NON-DRIVER) INFORMATION										
GENERIC VARIABLE DESCRIPTION	**VARIABLE NAME**	**IL**	**MN**	**UT**	**ME**	**MI**	**CA**	**NC**	**WA**	**OH**
OCCUPANT AGE	AGE (O)	x	x	x	x	x	x	x	x	x
OCCUPANT SEX	SEX (O)	x	x	x	x	x	x	x	x	x
OCCUPANT POSITION IN VEHICLE	SEATPOS (O)	x	x	x	x	x	x	x	x	x
NO. OF OCCUPANTS IN ACCIDENT	NUM_OCCS (V)	x	x	x	x	x	(A)	x		x
OCCUPANT EJECT	EJECT (O)	x	x	x		x	x	x	x	x
OCCUPANT SEVERITY	INJ (O)	x	x	x	x	x	x	x	x	x
OCCUPANT SAFETY EQUIPMENT	REST1 (O)	x	x	x		x	x	x	x	x

VII.ROADWAY VARIABLES (FROM ACCIDENT REPORT)										
GENERIC VARIABLE DESCRIPTION	VARIABLE NAME	IL	MN	UT	ME	MI	CA	NC	WA	OH
ROUTE NUMBER	RTE_NBR (A)	x	x			x	x	x	x	x
MILEPOST	MILEPOST (A)	x	x	x	x	x	x	x	x	x
COUNTY	COUNTY (A)	x	x		x	x	x	x	x	x
TYPE OF ACCD LOCATION	LOC_TYPE (A)	x	x	x	x	x	(V)	x	x	x
ROUTE TYPE	RTE_TYPE (A)	x					(V)			x
ROAD ALIGNMENT	RD_CHAR1 (A)		x	x	x	x		x	x	x
URBAN/RURAL POPULATION CODES	POP_GRP (A)	x	x			x	x	x		x
FUNCTIONAL CLASSIFICATION	FUNC_CLS (A)	x	x						x	x
ROAD DEFICIENCY	RD_DEF (A)	x		x		x	x			
TRAFFIC CONTROL DEVICES	TRF_CNTL (A)		x	x	x	x	x	x	(V)	(V)

VIII.PEDESTRIAN/BICYCLIST INFORMATION										
GENERIC VARIABLE DESCRIPTION	VARIABLE NAME	IL	MN	UT	ME	MI	CA	NC	WA	OH
LOCATION OF PED/BIC ACCIDENT	LOC_BIKE (A)		x				LOC_TYP (V)	x	x	
PEDESTRAIN ACTION	PEDACT (V)	x	MISCACT1				MISCACT1	x	x	MISCACT1

I. LOCATION/LINKAGE VARIABLES

GENERIC VARIABLE DESCRIPTION	VARIABLE NAME	IL	MN	UT	ME	MI	CA	NC	WA	OH
DISTRICT	DISTRICT (R)	x	x			x	x		x	x
COUNTY	COUNTY (R)	x	x	x	x		x	x	x	x
ROUTE NUMBER	RTE_NBR (R)	x	x	x	x	x	x	x	x	x
BEGINNING MILEPOST	BEGMP (R)	x	x	x	x	x	x	x	x	x
ENDING MILEPOST	ENDMP (R)	x	x	x	x	x	x	x	x	x
SECTION LENGTH	SEG_LNG (R)	x	x	x	x	x	x	x	x	x

II. ROADWAY CLASSIFICATION

GENERIC VARIABLE DESCRIPTION	VARIABLE NAME	IL	MN	UT	ME	MI	CA	NC	WA	OH
FUNCTIONAL CLASS	FUNC_CLS (R)	x	x	x	x	x	x	x	x	x
FEDERAL AID/ ROUTE TYPE	FED_AID (R)	x	x	x	x	x	x		x	
RURAL/URBAN DESIGNATION	RURURB (R)	x		x	x	x	x		x	
ACCESS CONTROL	ACCESS (R)	x	x	x	x		x	x	x	x

III. ROAD ALIGNMENT

GENERIC VARIABLE DESCRIPTION	VARIABLE NAME	IL	MN	UT	ME	MI	CA	NC	WA	OH
HORIZONTAL CURVE DEGREE	DEG_CURV (C)			x		(R)			x	x
HORIZONTAL CURVE DIRECTION	DIR_CURV (C)	(R)		x					x	x
HORIZONTAL CURVE RADIUS	CURV_RAD (C)	(R)							x	
HORIZONTAL CURVE DEFLECTION ANGLE	CURV_ANG (C)								x	
VERTICAL CURVE GRADE DIRECTION	DIR_GRAD (G)			x					x	x
PERCENT OF GRADIENT	PCT_GRAD (G)			x					x	x
TERRAIN TYPE	TERRAIN (R)			x		x	x	x	x	

IV. CROSS SECTION ELEMENTS										
GENERIC VARIABLE DESCRIPTION	**VARIABLE NAME**	**IL**	**MN**	**UT**	**ME**	**MI**	**CA**	**NC**	**WA**	**OH**
SURFACE WIDTH	SURF_WID (R)	x	x		x	x	x	x	x	x
SURFACE WIDTH (ROAD2)	SURF_WD2 (R)		x				x		x	
LANE WIDTH	LANEWID (R)	x	x	x		x	x			
LEFT SHOULDER WIDTH	LSHLDWID (R)		x		x	x	x	x	x	x
LEFT SHOULDER WIDTH (ROAD2)	LSHL_WD2 (R)		x			x	x		x	x
RIGHT SHOULDER WIDTH	RSHLDWID (R)	x	x		x	x	x	x	x	x
RIGHT SHOULDER WIDTH (ROAD 2)	RSHL_WD2 (R)		x			x	x		x	x
RIGHT PAVED SHOULDER WIDTH	PAV_WIDR (R)			x		x	x			
LEFT PAVED SHOULDER WIDTH	PAV_WDL (R)			x		x	x			
MEDIAN WIDTH	MEDWID (R)	x	x	x		x	x	x	x	x
SURFACE TYPE	SURF_TYP (R)	x	x	x	x	x	x	x	x	x
SURFACE TYPE (ROAD2)	SURF_TY2 (R)		x				x		x	
LEFT SHOULDER TYPE	LSHL_TYP (R)		x		x	x	PAV_WDL	x	x	
LEFT SHOULDER TYPE (ROAD2)	LSHL_TY2 (R)		x			x	PAV_WDL2		x	
RIGHT SHOULDER TYPE	RSHL_TYP (R)		x	x	x	x	PAV_WIDR	x	x	
RIGHT SHOULDER TYPE (ROAD 2)	RSHL_TY2 (R)		x			x	PAV_WDR2		x	
MEDIAN TYPE	MED_TYPE (R)	x	x	x	x	x	x	x	x	x
PARKING LANE WIDTH	PRKLN_WD (R)	x								
SHOULDER CONDITION	SHLD_CON (R)	x								
ROADWAY RIDEABILITY	PAVECOND (R)	x		x				x		x
NO. OF LANES	NO_LANES (R)	x	x	x	x	x	x	x	x	x
CURBS	CURB1 (R)	x	x	RSHL_TYP	RSHL_TYP LSHL_TYP	RSHL_TYP LSHL_TYP	x	RSHL_TYP LSHL_TYP	RSHL_TYP LSHL_TYP	
CURBS (ROAD2)	CURB2 (R)	MED_TYPE	x	MED_TYPE		RSHL_TY2 LSHL_TY2		MED_TYPE	MED_TYPE RSHL_TY2 LSHL_TY2	
RIGHT OF WAY	ROW (R)	x	x	x		x		x		

V. ROAD FEATURES										
GENERIC VARIABLE DESCRIPTION	VARIABLE NAME	IL	MN	UT	ME	MI	CA	NC	WA	OH
INTERSECTION TYPE	INT_TYPE (I)	x	x			x	x			
INTERSECTION DESCRIPTION	TYPEDESC (I)		x				x			
INTERSECTION NO. OF LEGS	NBR_LEGS (I)		x			x	TYPEDESC			
INTERSECTION SIGNAL CONTROL	TRF_CNTL (R)	x							x	
RAILROAD CROSSING NUMBER	RAIL_NBR (R)		x							
RAILROAD CROSS RIDEABILITY	RR_CRX (R)	x								
YEAR ROAD CONSTRUCTED	RD_YEAR (R)	x								

VI. TRAFFIC CONTROL/OPERATIONS										
GENERIC VARIABLE DESCRIPTION	VARIABLE NAME	IL	MN	UT	ME	MI	CA	NC	WA	OH
ONE/TWO-WAY OPERATIONS	ONEWAY (R)	x	x	x	x	x			x	
TOLL FACILITY	TOLL (R)			x			x			
NO PASSING ZONE CODE	PASSING (R)					x				
TRUCK ROUTE	TRK_RTE (R)	x	x		x	x		x		

VII. TRAFFIC DATA										
GENERIC VARIABLE DESCRIPTION	VARIABLE NAME	IL	MN	UT	ME	MI	CA	NC	WA	OH
AVERAGE DAILY TRAFFIC VOLUME	AADT (R)	x	x	x	x	x	x	x	x	x
SPEED LIMIT	SPD_LIMT (R)	x		x	FIFTY	x		x		x
ADT GROUPS	AADTGRP (R)			x						
DESIGN SPEED	DESG_SPD (R)		x	x			x		x	
PERCENTAGE TRUCK	PCT_TRK (R)	x		x				x	x	
% COMM VEHS IN PEAK PERIOD	PEAK_TRK (R)			x				x		

5.4 GIDAS – Database

GIDAS (German In-Depth Accident Study) is one of the largest accident studies in Germany. It is a cooperation project of the Bundesanstalt für Straßenwesen BASt (Federal Highway Research Institute Germany), Forschungsvereinigung Automobiltechnik e.V. FAT (The Research Association of Automotive Technology) which is represented by the companies Ford, VW, Daimler, BMW, GM, Porsche, Autoliv, TRW, JCI. Furthermore, the Medical University Hannover and the Technische Unversität Dresden are involved.

Data for the GIDAS project are collected in the cities Hannover and Dresden. The project was started in July 1999. Per year about 2.000 accidents are recorded. The headquarters of police, rescue services and fire departments report all accidents to the GIDAS team. Based on a sample plan they decide which accidents will be collected and recorded in detail.

A team to record accident data consists of two technicians, a doctor, and a coordinator. Specially equipped vehicles provide the team with the necessary equipment like cameras and measurement tools. A scaled sketch of the accident location is built based on photogrammetry technique.

Figure 8: GIDAS – vehicles at TU Dresden

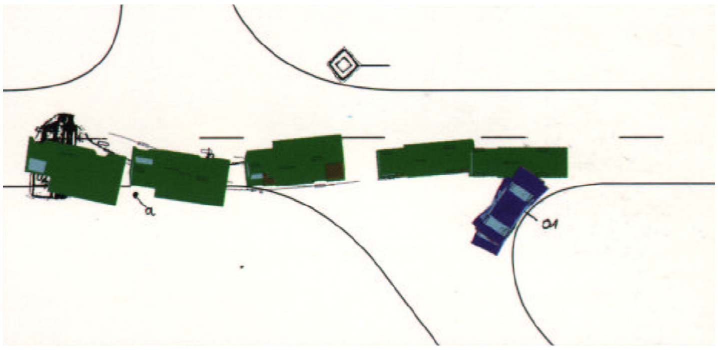
Usually the following data are collected:

- Environmental conditions,
- Road design,
- Traffic control,
- Accident details and cause of the accident,
- Crash information e.g. driving and collision speed, Delta-v and EES, degree of deformation
- Vehicle deformation,
- Impact contact points for passenger or pedestrians,
- Technical vehicle data, and
- Information relating to the people involved e.g. weight, height etc.

In addition, more detailed vehicle measurements are collected the next day and additional information about treatments and injuries are received from the hospitals.

With the help of professional software and based on these data and known physical principles, accident reconstructions are generated together with the impact event. Furthermore, the accidents are graphically visualized.

Figure 9: GIDAS – Graphically output of accident reconstruction



All in all, between 500 and 3.000 details per accident are collected and stored in the GIDAS-Database. These data are used for various aspects of analysis. Legislators study the data to identify and quantify future needs for legislation. The automotive industry and BASt use the data to compare real accidents and crash tests in order to recognize structures causing injuries. Furthermore, the statistical data is also used for developing crash test programs, for supporting and validating computer simulations, recognizing and assessing potential areas of future safety developments and evaluating vehicle safety performance in real world accident situations. Concerning road engineering, the data are used to learn more about accident severity and road equipment or obstacles. Analysis results help to improve guidelines and measurements to increase safety. A main focus is on obstacles and the improvement of constructional measures. For example, results have been taken as a basis for an obstacle crash tests guideline.

Overall, the GIDAS project cooperates with international projects, so that the data collected and analysed are used for comparison. A standardized method for collecting crash injury data was developed in STAIRS (Standardization of Accident In-Depth Research Studies; http://ec.europa.eu/transport/roadsafety_library/publications/stairs_finalreport.pdf).

5.5 Road Database of the TU Dresden

The Institute for Road Design of the Technische Universität Dresden has been working in the field of road safety and road engineering for decades. The results of studies were used to improve and develop road design guidelines in order to make roads safer.

Research studies done by the Institute are often focused on the relationship of road design and driver behavior and their impact on road safety. This kind of research requires a database with qualified data about road design, behavior of drivers and accident data. For this reason the Institute for Road Design has developed its own database and collected road data and road related data for years.

In general, the following data categories are distinguished:

- Road Design,
- Traffic,
- Accident, and
- Driver behavior.

Today, road design data are collected with the special measurement vehicle UNO which is equipped with a modern GPS supported positioning system and digital roof cameras. This allows an accurate and fast capture of road design and road environmental characteristics. Several analysis tools have been developed in order to calculate road design parameters and measure further characteristics by using photogrammetry for image analysis. Other data were taken from external databases such as the federal road data base (SIB) or accident databases maintained by the police (e.g. EUSKA).

Unlike other databases the road database of the Institute for Road Design contains quite precise data about the geometric design. For example, geometric parameters are based on the trajectory recorded by the measurement vehicle UNO. Special software developed by the institute allows the calculation of road design parameters for the horizontal alignment. Other geometric parameters such as road width or road equipment are taken from the digital images.

Data about driver behavior are normally measured with two different methods: tracking or stationary. Various techniques such as radar, laser or light beam are used to collect data about speed or lateral position. Stationary measurement methods collect data at a certain spot while tracking allows investigating behavior for whole stretches of roads. However, because collecting behavioral data is quite expensive, these data are only measured for selected stretches.

All data stored in the database are referenced by coordinates and can be visualized in GIS-programs. The geo-reference of data sets allows assigning the data to external sources. This is because most data from external sources are referenced by the classic network system based on nodes and chainage. The combination of both the data collected with the measurement vehicle and external data tremendously increases the possibilities for in-depth-investigations.

Figure 10: TU Dresden - Images taken every 10 m by the front cameras

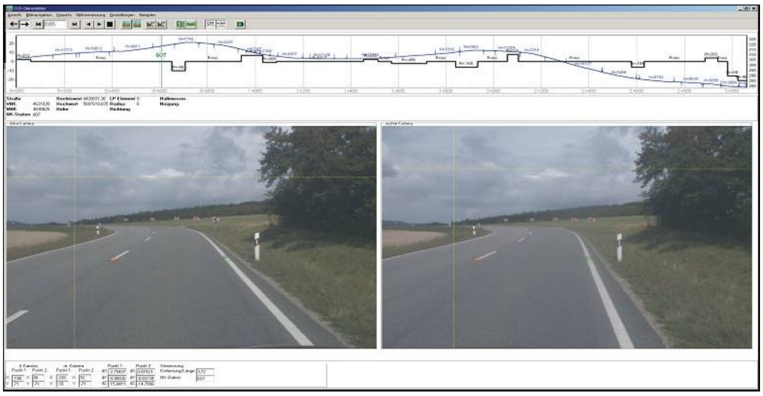


Figure 11: TU Dresden - Fully designed horizontal and vertical alignment based on the positioning system trajectory

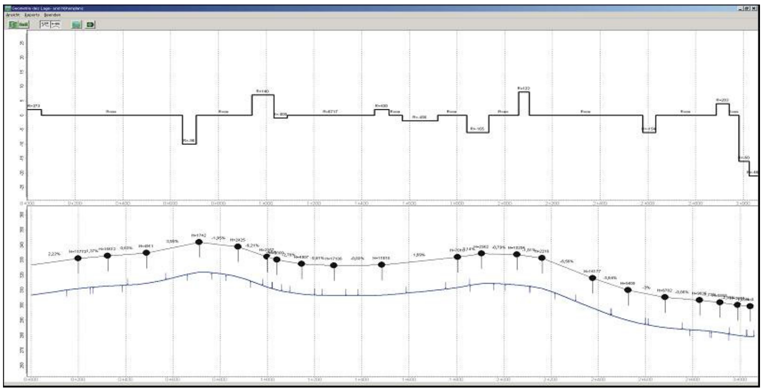


Figure 12: TU Dresden - Combination with external data such as accident data

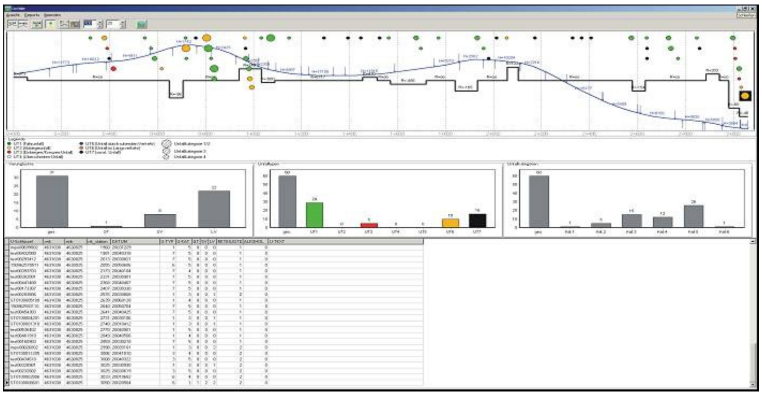


Table 6: TU Dresden - Overview of stored data and their sources

Category	**Internal**	**External**	**Data**	**Parameter**
road design	x		horizontal alignment	tangent, curve, clothoid as single elements with parameter and length
road design	x		vertical alignment	tangent, vertical curve with parameter and length, grade
road design	x		cross section	number of lanes, lane width
traffic		x	traffic flow	ADDT with heavy vehicle rate
driver behavior	x		velocity	single data and statistical values derived from these data (min, max, mean, …)
driver behavior	x		lateral position	single data and statistical values derived from these data (min, max, mean, …)
accident	x	x	accident characteristics	date, time, weather and road conditions, number of involved vehicles/ persons, accident type, accident category, number of fatalities, seriously/ slightly injured persons, accident description, dwi

5.6 ASB – German Road Information Bank Protocol

In 1992, the German Federal Ministry of Transport, Building and Urban Development introduced a protocol (general instructions) for a road database (ASB – Instructions for the Road Information Bank) containing a common structure for road networks and infrastructure objects. Over the years, the ASB protocol was updated several times to meet changing requirement profiles of infrastructure and road users.

The ASB protocol includes several parts:

- Network data
- Inventory data
- Building data
- Road equipment data
- Traffic data
- Road condition data
- Miscellaneous data
- Environmental data
- etc.

With these parts the ASB protocol gives a framework how to organize and hold data. It is a theoretical description of data structures and not an actual database nor does it include or prescribe software or analysis tools. The federal states are responsible to developing, filling and maintaining the database. Based on the ASB such a database will provide a standard inventory of the road network, featuring common definitions and descriptions of the variables in the database. However, the quality and complexity of data can be different across states in Germany because it depends on the level of enforcement by the individual state authorities. Some may choose to collect all variables, others some and others none; the way in which it is collected and the ultimate quality could also differ.

However, the main objective of ASB is to define a basis for data structuring in order to support authorities and decision makers with appropriate and accurate data concerning both the road and road environment. These objectives are mainly:

- Optimization of the existing road network by analysing and evaluating traffic and infrastructure data
- Maintenance of high traffic levels by targeting road condition and facility management despite an ongoing increase in individual and commercial traffic
- Comprehensive and continuous data collection
- Evaluation of road safety measures and development of short and middle-termed rehabilitation programs.
- Minimization of environmental impacts
- Improvement of road safety
- Improvement of design element of alignment, junctions, cross-section

As mentioned the federal authorities are responsible for road data collection and maintenance. It depends on their own activities how and for which purpose the information database is used. It is the intention to develop road network inventories in all German states based on the ASB. Once filled, there will be a central database of all primary roads (but excluding municipal and local roads). Such a database will ultimately support several road and safety engineering applications including:

- Analyses for road planning, rehabilitation planning, and road safety
- Operation and maintenance of roads
- Road inspection

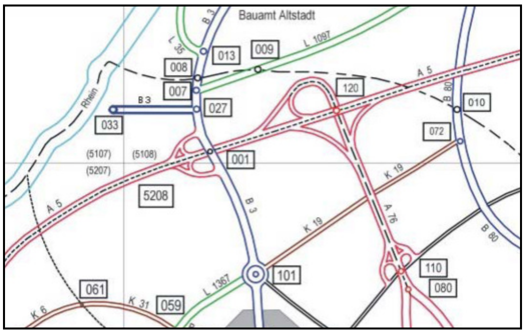
Database structure

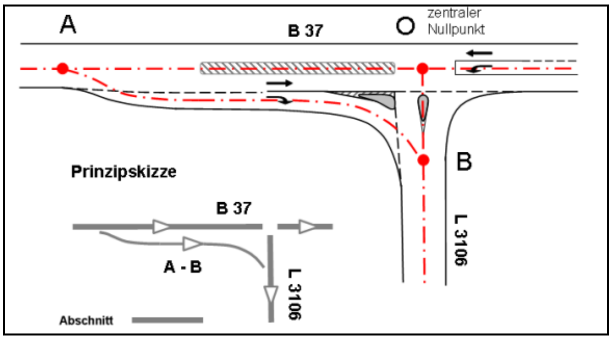
In the Instructions for the Road Information Bank (ASB), the general structure of the roads and their essential information are defined in Part 1: Network data. The road network includes motorways, federal highways, regional roads and county/district roads. Each road is sub-divided into sections based on the road network structure with nodes as basic elements. Nodes are generally at-grade and grade-separated junctions of classified roads. Road sections all have a uniquely numbered node on either end.

Furthermore, a section has a chainage that starts at the first node and ends at a second node which thus also defines the direction. With the section and its chainage an explicit system is given to describe any position. The name of a certain section is given by its dedicated nodes.

Figure 7 shows parts of the German road network. Each node is named by a seven digit number e.g. 52080101. The first four digits are derived from the grid square number of the topographical map (scale 1:25,000) and the last three digits come from the counter within the grid square. For example a section of the road K 19 is determined by the nodes 52080101 and 5108072. In this case, road K 19: starts at node 52080101 and ends at node 5108072. The road name is K 19 5208101 – 5108072

Figure 13: Road Network map with nodes and sections (ASB Version 2.01)



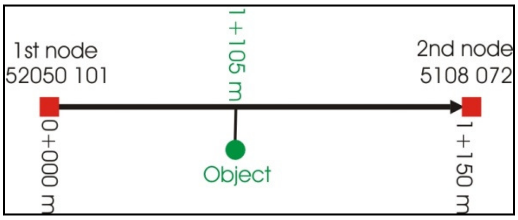


Beside these regular nodes there are exceptions for nodes for roundabouts, motorway ramps etc. At junctions with a more difficult geometric design (e.g. separated turning lanes, grade-separated ramps) sub-nodes are used in order to describe the traffic flow relations. Here the main node (so called “0”-node) includes also sub-nodes which are additionally attributed by a letter. Thereby, the zero node remains the main node and is mostly given by the intersecting point of the main road axis. Sub-nodes characterise additional connections between the main road axis such as turning lanes or ramps on motorways.

Based on this simple system a unique and explicit structure has been developed which is attributed to all sections of classified roads in the German road network. All further data are referenced to this system and are therefore clearly allocated.

Figure 8 shows an example for the referencing system: Each object gets the general section name based on both nodes (here: from 52080 101 to 5108 072). Within the section the distance related to the first node gives the position (here: 1+105 m). Finally, the relative position of the object to the road axis (left or right) indicates the road side. Often the distance between the object and road axis is given in order to set the location more exactly.

Figure 14: Scheme of the ASB referencing system (Version 2.01)



Objects of the Road information bank

Beside the general road structure the ASB further proposes a framework to store data about additional attribute or objects. This framework structure makes it possible to manage numerous linked road data to certain road sections. To collect and maintain these data is a task of the federal authorities.

This description only shows an overview of the general content of data. Each object is characterised by numerous attributes that describe the object position related to the road section as well as further properties of the object itself. Further details can be found in the German guideline ASB Version 2.01.

The inventory data characterize roads concerning their:

- Design and Construction
  - Geometric elements of horizontal and vertical plan
  - Geometric elements of cross-section
  - Material properties
- Significant impacts on traffic flow
  - Function of traffic lanes
  - Constraints of traffic
- Relation to the environment
  - Operation facilities
  - Resting facilities
  - Noise protection
  - Drainage system

The ASB defines and describes the following road inventory data groups:

- Junctions
- Geometry of horizontal and vertical design
- Geometry of cross-section design
- Constructional design
- Road facilities
- Road safety facilities
- Environment and nature

Below the several objects for each inventory group are listed which are defined in the road information bank.

Junctions

- Lanes
- Road furniture
- Safeguarding equipment for animals
- Section chainage signs
- Elements of drainage system
- Safeguarding systems like guardrails, concrete barriers, crash cushions
- Pedestrian Parapets (EN 1317-6)
- Road and traffic signs
- Trees

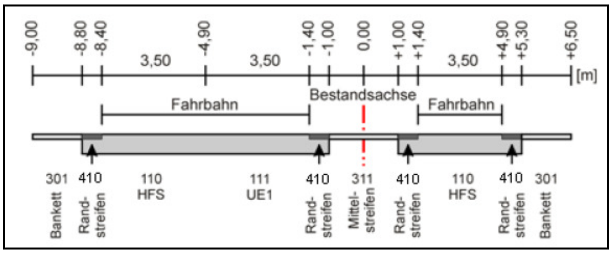
Geometry of horizontal and vertical design

- Horizontal alignment
    - Design element type (radius, clothoid, straight line)
    - Design parameters (radius, clothoid parameter, length)
    - Curve direction (left/ right related to section direction)
    - Direction of design tangents
- Vertical alignment
    - Altitude,
    - Altitude reference system
    - Vertical grade
    - Design element type (crest, sag, straight line)
- Design parameter (radius of vertical curve)

Geometry of cross section design

- Cross section
    - Position to road design axis (e.g. distance)
    - Type of lane (e.g. main traffic lane, overtake lane)
    - Lane width
    - Type of shoulder
    - Type of surface (e.g. gravel, paved, planted, unplanted)
    - Surface area
    - Owner (e.g. responsible road authority)
    - Level of detail
    - Standard design cross section type (regarding the German design guidelines).

Figure 15: Example of cross section (ASB 2009)



Constructional design

In general the constructional design is related to layers. Each layer is characterised by homogeneous material and function and is described by its length, width and thickness.

- Layer
    - Layer type (e. g. surface, binder, base, sub-base)
    - Material (e. g. asphalt, concrete)
    - Binding agent
    - Thickness
    - Incomplete construction
    - Date of construction
    - Design and construction class (regarding the German guidelines)
    - Drill core

Road facilities

- Roundabouts,
    - Type (size of roundabout, number of lanes)
    - Driveable centre
    - Diameter
    - Design of centre
    - Owner
- Other facilities,
    - Building of road authorities
    - Other facilities like stockyard, telecommunication
    - Rest areas
    - Special facilities (e.g. police station, customs)
    - Road furniture
    - Technical buildings (e.g. Noise protection systems)
    - Supply facilities (e.g. pipes)

Road safety facilities

- Safeguarding systems for vehicles
  - Guardrails
  - Concrete barriers
  - Crash cushions
  - Emergency, acceleration and braking lanes
- Safeguarding systems for pedestrians
- Road markings
- Road Signs (e. g. traffic signs, guiding signs, other signs)
- Obstacle

Environment and nature

- Protected areas (e. g. national parks, reserves, areas with special protection)
- Road trees (e. g. single trees, tree lined roads)
- Areas for compensation of road facilities

Output

The Instructions for the Road Information System ASB provides both the national governments and civil engineers with the necessary data to do in-depth investigations concerning infrastructure. To evaluate different types of measures, one has to know in detail what the components of the system under surveillance are. The more information are available, the better and more realistic the output of the model equations which are being used.

6 Current road and traffic data in Europe

Indicators based on the following data categories have been identified in Task 2.1 of the detailed Work Plan as relevant in order to comprehensively answer traffic safety related questions:

- Road (Design) parameters: The inter-dependencies between road design and accidents are the primary focus of RISMET and the literature review in chapter 4. The road infrastructure itself is a mechanism that can be altered and can bring about changes in traffic performance (described by traffic flow, behaviour and congestion data) and in safety levels (described by accident, hospital and in-depth data).

- Accident data: Injury accidents and property damage are distinguished in this category (see table 7). For road safety inspections, e.g., the number of accidents within a defined road section within defined period of time is used a selection criteria. CARE, for instance, is a Community database on road accidents resulting in death or injury that comprises detailed data on individual accidents as collected by the Member States (http://ec.europa.eu/transport/road_safety/specialist/statistics/).

- Risk and Exposure Data (for accident data): The availability and quality of risk exposure estimates in the EU Member States has been investigated before by the SAFETYNET project and was characterised as to vary significantly, related both to the exposure measures used and the characteristics of the respective collection methods. The most widely available indicators are population, vehicle fleet, road length, fuel consumption, driver kilometres and vehicle kilometres. The less available indicators are: person kilometres, number of trips and time in traffic. Five of the six generally available indicators were regarded as at least partially compatible with CARE: population, driver population, vehicle fleet, road length and vehicle kilometres (http://erso.swov.nl/safetynet/content/wp_2_risk_exposure_data_red_.htm).

- Hospital data: Hospital data, e.g. based on Emergency Department visits or Hospital Discharge Registers, is a complementary source of accident injury data. Its added value to police based data is more accurate information on the injury outcome (diagnoses, severity) as well as a possible of the assessment of the assumed under-reporting of traffic accidents by the police (especially for bicyclists and pedestrians). A challenge for the increased use of hospital data in road safety in most EU countries is the missing linkage of hospital records with the police records, e.g. by personal identifiers. EU level sources of hospital data e.g. are the EU IDB (https://webgate.ec.europa.eu/idb/).

- In-depth data: In-depth analysis of fatal and serious accidents greatly improves the understanding of the accident triggering sequence of events. From a road administrator's point of view these are important elements that may be used for supporting safety interventions decisions, both at the micro and the macro levels. Figure 17 provides an overview about the data requirements for the in-depth analysis of accidents. A standardized method for collecting crash injury data was developed in the STAIRS project (Standardization of Accident In-Depth Research Studies; http://ec.europa.eu/transport/roadsafety_library/publications/stairs_finalreport.pdf).

- Road behaviour: Speed, inattention, following distances etc., are characteristics of road user behaviour that can be modified by road infrastructure and design. Being also main causes of car crashes, road user behaviour indicators are expected to strongly correlate with accident indicators. The availability of road user data in the EU was documented also by the SAFETYNET project, accessible via ERSO (http://erso.swov.nl/safetynet/content/wp_3_safety_performance_indicators.htm).

- Traffic (Congestion) data: Traffic volume measures such as vehicle kilometres are part of the risk and exposure data mentioned above. An indicator used to monitor inter-urban congestion is the "average vehicle delay", derived from the differences between observed journey times and a reference journey time, weighted by traffic flows for observed road network. Congestion in urban areas is measured by "average person journey time per mile". The regular occurrence of congestions may also be accompanied by the increased share of certain types of accidents, like rear end collisions, in the respective road section is made (Campbell and Knapp, 2005; Mackenzie, 2008).

- Weather data: Weather conditions like rain, fog, snow and black ice, low sun, hard wind, and high temperatures have an obvious impact on the road conditions, the road user behaviour and consequently on the crash rate. Road infrastructure and design measures such as porous asphalt and the introduction of slipperiness warning systems have been introduced as a response to increase road safety under adverse weather conditions. Weather conditions as an accident factor are discussed in chapter 4.2 (Rear-end collisions).

As the RISMET focus is on tools for the safety management of road infrastructure, it is the relationship between accidents and road design parameters that is predominately dealt with in the literature review in chapter 4; where relevant behavioural, traffic and weather considerations are described. A proposal of relevant road design indicators that could quantify this relationship for various design factors is summarized in chapter 7.

Aspects related to behaviour (e.g. speed, inattention, following distances) and exposure (volume, type etc) are indirectly dealt with since they are one (of many) contributing factors. The categories in depth and hospital data are alternative sources to enhance the quality of registered accident data. These are not yet generally used in any of the common (and even less common) road safety engineering tools. The availability of data for each of the categories listed above – based on the results of survey among ten countries – is summarised in the following section.

Questionnaire

In line with the ambition to develop suitable road safety engineering evaluation tools we also examined the availability of data in Europe that are considered relevant for that purpose. A questionnaire was developed to show what information is collected on certain road safety categories in the different countries and how this information is made available. Main road safety categories and sub-categories were defined and multiple data providers were allowed to be named for each sub-category. Also, extending the list of sub-categories was encouraged in order to ease the assignment of data providers to a sub-category (see annex for an example of a completed questionnaire and table 7 for the main and sub-categories covered).

Questionnaires were responded from Germany (GE), Hungary (HU), Lithuania (LT), the Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Slovenia (SI), Sweden (SE), United Kingdom (UK) and Austria (AT). For each data provider (i.e. data source) the following multiple-choice items had to be specified:

Availability
Public: Data is already being published by the data provider and/or interested people/parties are entitled by law to ask for this information.
Non-public: Data provider has the right to prohibit dissemination of data.

Spatiality
National level: Data available for the whole of a country (e.g. population of inhabitants) or the entire road network (e.g. motorways, all A-level roads etc.).
Regional level: Data available for federal states, counties, parts of the primary or secondary road network (road sections).
Local level: Data available for municipalities, short road sections (several hundred meters) or road sites (e.g. pedestrian crossings, roundabouts, junctions etc.).

Data scale
Aggregated: Merged data in order to ease analysis efforts or investigate relationships for higher-level entities.
Disaggregated: Data set is on the lowest possible level.

Operational level
Operational: The data set can be worked with/used
Raw data: Data have not yet been prepared (diagnosis of outliers, missing values etc.)

Purchase of data possible
Yes: Data are available for sale.
No: It is not possible to acquire data.

Quality
Good: collected reasonably consistently in all areas, are generally considered accurate (although there may be under-reporting), and are a key source of road safety evidence.
Sufficient: e.g. not available for all areas, not providing enough information, but still have some useful features and help provide a fuller picture of road safety.
Poor: possibly incomplete, inaccurate or not up-to-date, and so are not currently used.

Results

In table 7 an overview of the basic availability (yes/no), type of availability (public/non public) and operational level of data (raw/operational) is given by sub-categories and country. For the standard sub-categories (S) - only a few countries added extra categories of their own - the following summary of results can be given for the ten questionnaires received:

- Data availability (yes/no) by categories is best for basic exposure, injury and weather data (about 90% non-grey cells in table 7), medium for in-depth data (70%), data on road user behaviour (78%), hospital data (80%), and least for infrastructure (66%) and vehicle data (50%).
- Among countries data availability (yes/no) ranges between about 50% (SE) and 90% (LT, UK, AT).

Table 8 provides a more aggregated view on data characteristics by country – by means of the average categorization of data providers within a country across all sub-categories.

Table 7: Availability and operational level of data in eleven European countries by road safety categories

Basic availability: grey = no data or no answer given. Type of availability: public = P, non public = NP, semi public = SP. Operational level: orange = contains raw data. Pre-defined sub-categories are indicated by "(S)" (Standard) as opposed to non-standard sub-categories that have been added by single respondents.

Main category	Sub-category	GE	HU	LT	NL	NO	PL	PT	SI	SE	UK	AT
Exposure	Population (S)	P	P	P	P	P	P	P	P	P	P	P
	Traffic volume (S)	P/NP	P/NP	NP	P	P	P	P	P/NP	P	P	P/NP
	Traffic performance (S)	P/NP	P	P	P	P	P				P	P
	Intersection counts				P							
	Road links				P/NP							
	Traveller kilometers				P							
	Vehicle Fleet (S)	P/NP	P	P	P/NP	P	P	P		P	P	P
	Vehicle use				P/NP							
	Vehicle kilometers				P							
Road accidents	Injury accidents (S)	P/NP	P/NP	P/NP	P/NP	P/NP	P	P	P/NP	P	P	P/NP
	Property damage (S	P/NP	P	NP	P/NP		P	NP	P		NP	NP
Infra-structure	Cross-section (S)	SP	NP	P	P	NP		NP	NP	SP	NP	NP
	Intersection (S)	SP			P			NP	NP	SP	NP	
	Alignment (S)	SP/NP						NP	NP		NP	
	Speed limits (S)	SP/NP	NP	P	P	P		NP	NP		NP	P
	Road surface (S)	SP/NP	NP	P	P	NP		NP	NP		NP	NP
	Reference populations		NP	P								P
	Road network	SP			P							
Vehicle	Defects (S)			NP		NP		NP			P	NP
Road user behavior	DRL (S)		P	NP		P						NP
	Speed (S)	NP	NP	NP	NP	P	P	P	NP		P	NP
	Seatbelt (S)	P/NP	P	NP	P	P	P	P	NP		P	NP
	Police enforcement (S)	NP	NP	NP	NP	P	NP	P		SP	NP	P
	Police fines				P/NP							
Environ-ment	Weather (S)	P	P	P	P	P	P	P	P		NP	P
Hospital	Inpatients (S)	NP	NP	NP	NP	NP	NP	P		P	NP	NP
	Work accidents (S)		NP	P		P	P	NP		P		P
In-Depth Data	Fatal accidents (S)	NP	P	NP	NP	NP				SP	NP	NP
	Serious accidents				NP							

Table 8: Average categorization of data across all sub-categories by "topic" and country

Germany

Topic	Respondence		
Availability	33% public	67% non/ semi public	
Spatiality	89% national	93% regional	86% local
Data scale	82% aggregated	18% disaggregated	
Operational level	78% operational	22% raw data	
Purchase of data			
Quality	82% good	18% sufficient	0% poor

Hungary

Topic	Respondence		
Availability	56% public	44% non public	
Spatiality	82% national	47% regional	41% local
Data scale	62% aggregated	38% disaggregated	
Operational level	97% operational	3% raw data	
Purchase of data	44% yes	56% no	
Quality	91% good	9% sufficient	0% poor

Lithuania

Topic	Respondence		
Availability	43% public	57% non public	
Spatiality	70% national	30% regional	40% local
Data scale	26% aggregated	74% disaggregated	
Operational level	83% operational	17% raw data	
Purchase of data	13% yes	87% no	
Quality	83 % good	17% sufficient	0 %poor

Netherlands

Topic	Respondence		
Availability	70% public	30% non public	
Spatiality	87% national	87% regional	52% local
Data scale	37% aggregated	63% disaggregated	
Operational level	67% operational	33% raw data	
Purchase of data			
Quality	81 % good	17 % sufficient	2% poor

Norway

Topic	Respondence		
Availability	79% public	21% non public	
Spatiality	67% national	57% regional	47% local
Data scale	47% aggregated	53% disaggregated	
Operational level	83% operational	17% raw data	
Purchase of data	60% yes	40% no	
Quality	90% good	10% sufficient	0% poor

Poland

Topic	Respondence		
Availability	92% public	8% non public	
Spatiality	100% national	83% regional	50% local
Data scale	80% aggregated	20% disaggregated	
Operational level	80% operational	20% raw data	
Purchase of data	38% yes	62% no	
Quality	100% good	0% sufficient	0% poor

Table 8 continued

Portugal

Topic	Respondence		
Availability	55% public	45% non public	
Spatiality	75% national	87,5% regional	31,25% local
Data scale	45% aggregated	55% disaggregated	
Operational level	84% operational	16% raw data	
Purchase of data	50% yes	50% no	
Quality	79% good	21% sufficient	0% poor

Slovenia

Topic	Respondence		
Availability	55% public	45% non public	
Spatiality	95% national	5% regional	5% local
Data scale	45% aggregated	55% disaggregated	
Operational level	55% operational	45% raw data	
Purchase of data	50% yes	50% no	
Quality	95% good	0% sufficient	5% poor

Sweden

Topic	Respondence		
Availability	67% public	33% semi public	
Spatiality	100% national	58% regional	50% local
Data scale			
Operational level			
Purchase of data			
Quality	60% good	40% sufficient	0% poor

United Kingdom

Topic	Respondence		
Availability	65% public	35% non public	
Spatiality	96% national	78% regional	9% local
Data scale	46% aggregated	54% disaggregated	
Operational level	86% operational	34% raw data	
Purchase of data	62% yes	38% no	
Quality	71% good	29% sufficient	0% poor

Austria

Topic	Respondence		
Availability	67% public	33% non public	
Spatiality	50% national	55% regional	39% local
Data scale	42% aggregated	58% disaggregated	
Operational level	76% operational	24% raw data	
Purchase of data	55% yes	45% no	
Quality	81% good	16% sufficient	3% poor

Figure 16: Average characteristics of road safety data in Europe

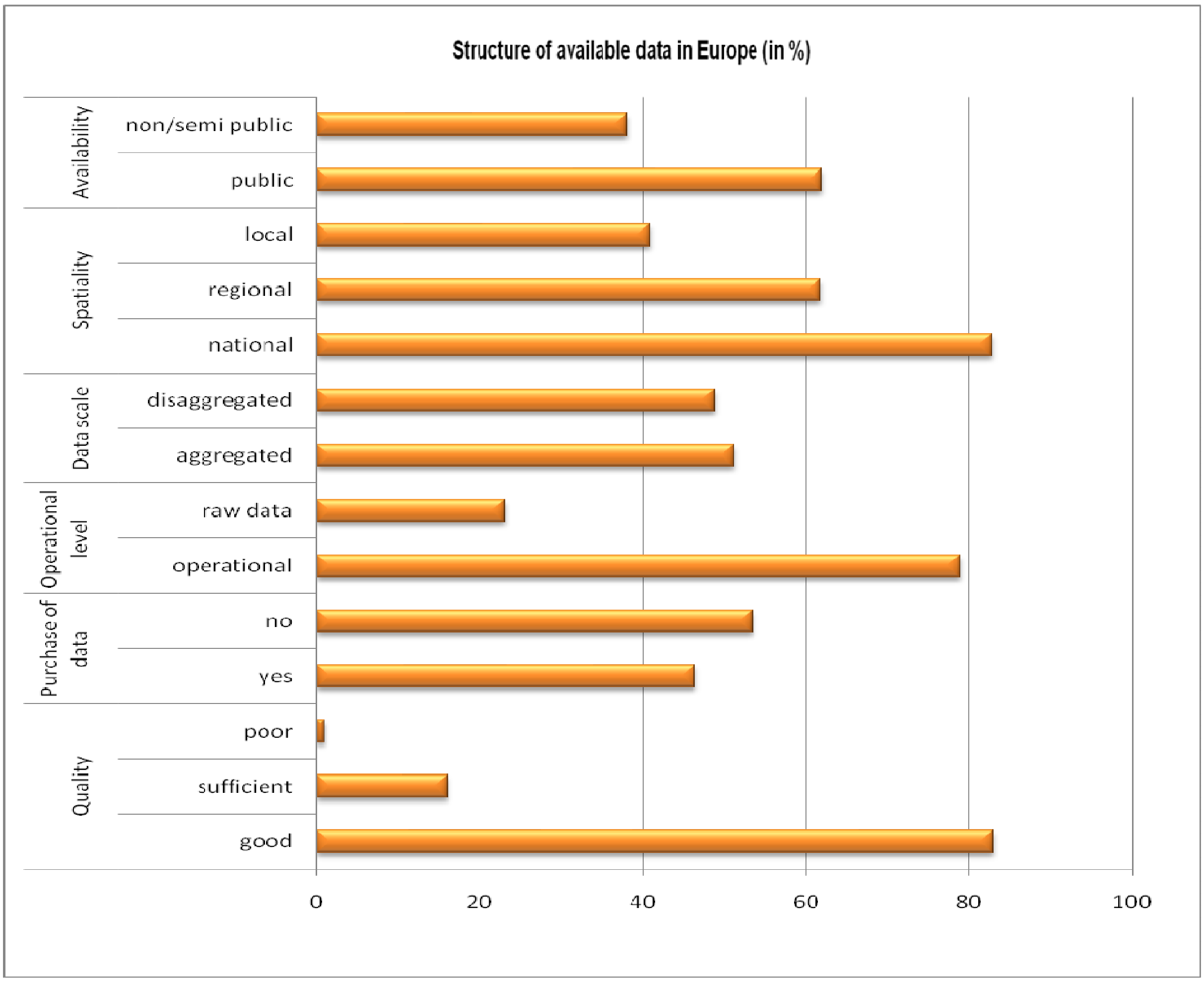


Figure 16 provides an overview of the average characteristics reported by the respondents across data-providers and countries:

- About 83% of all data considered refers to the national level, around 62% is regional, and 41% is local data.
- 62% of the data is indicated as publically available and nearly 80% is said to be on "operational level". Slightly more data sources are available in an aggregated form than at a raw data level.
- Over 80% of the data sources are assessed as of good quality.

Recommendations

Although the results received from ten country partners are presented here at face value and without claiming full representativity for Europe (or the EU), the overall impression is that national level data (more than regional and local level data) on road safety is usually well accessible, i.e. public, and of good quality. However, there are marked differences in this respect between different road safety categories, with the least availability being reported for infra-structure and vehicle data. These categories, together with single other sub-categories like DRL, indicate the most obvious data-gaps to be closed in view of improving the tools for road safety engineering evaluation in Europe.

In order to increase the validity of this kind of information and ease of information retrieval, a central inventory of road safety related data sources is recommended, e.g. located and maintained by the European Road Safety Observatory (ERSO).

7 Conclusions

Table 9 provides an overview of the factors that in the literature have been found to have a strong relationship with road accidents. Since these relationships exist (and in most cases an effect has been established on the basis of meta-analysis across country boundaries) it is logical that these parameters should be included in any set of data that in future will be used to conduct evaluations of infrastructure based interventions and programmes aimed at improving road safety. A subjective rating scale, based on the reliability of the found relationships and the accessibility to these data has been included. The purpose of such a rating is to develop an initial list of road design criteria (data) that could be essential to using or developing evaluation tools for road infrastructure safety management. Since it costs time and money to collect, analyse and maintain data, especially if it becomes structural (i.e. annually or bi-annually), it is prudent to try and minimise this to those data that are truly essential for such applications and analyses.

Table 9: Summary of relevant factors and indicators for RISMET

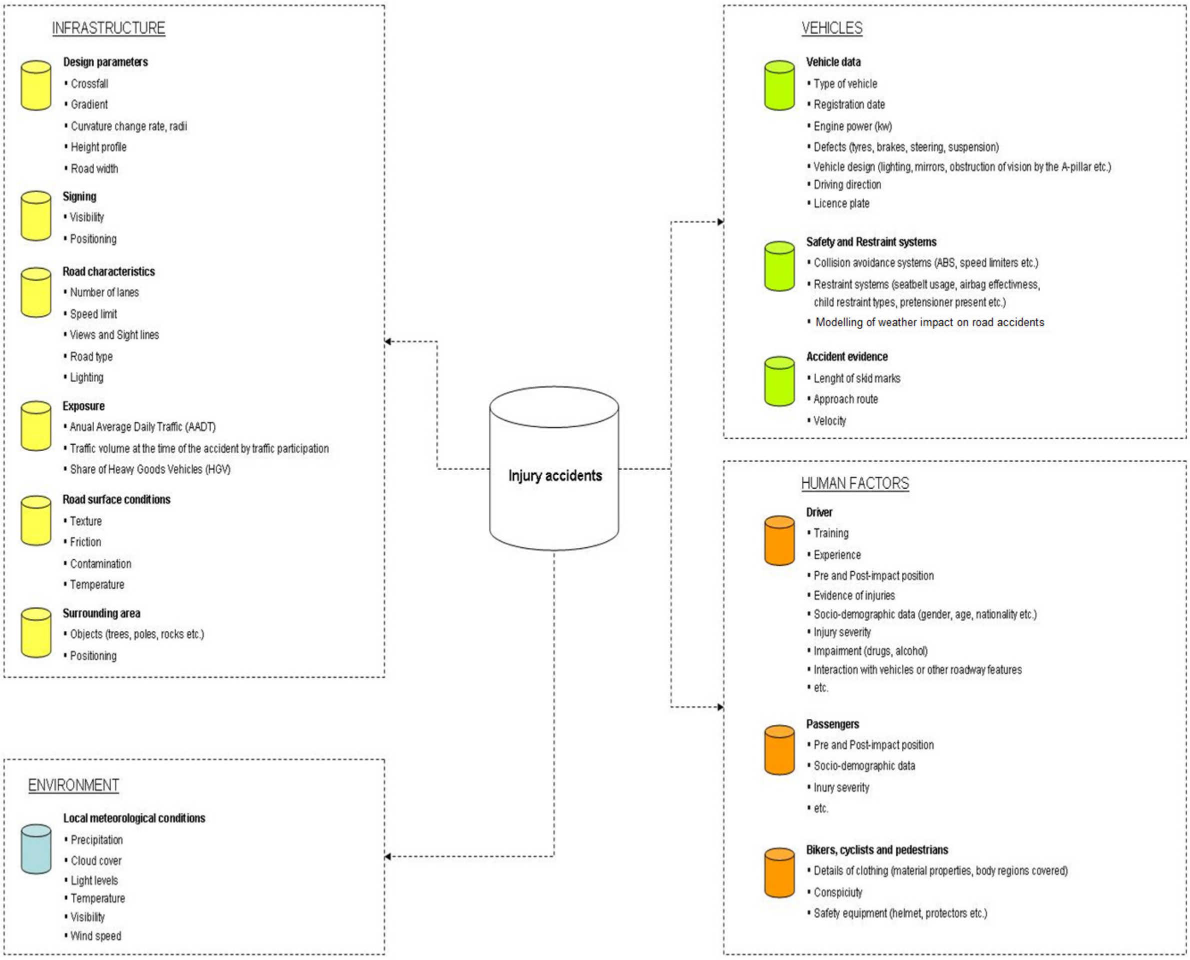
Accident factor	Indicators	Description and unit	Rating 1 = essential 2 = nice to have 3 = minor relevance
Curves	Curvature change rate	gon/km	1
	Curve density	Units/km	1
	Ratio of consecutive curves	%	1
	Curve radius	m	1
Vertical alignment	Gradient	%	1
Visibility	Sight distance	m	2
	Time of day	hrs	2
	Lighting	Present/absent	2
Design consistency	Driven speed (v85)	km/h	1
	Speed limit	Km/h	1
	Average radius of curvature	m	1
	Curve radius ratio (singular curve to average in a section)	m	2
Traffic control devices	Markings (control)	related to comfort/recognition m/km	2 (all markings)
	Curve warning signs	No./km	1
	Delineation	No./km	2
	Guidance devices	Type Unit/km	2
Junction	Signalisation	Present/absent	1
	Adequacy of junction delineation	Good/poor	2
	Junction warning signs	Present/absent	2
	Type of junction	Classification of junctions	1
	Junction arms	Number	1
	Turning pockets	Present/absent	2
	Angle of deflection or quality of (roundabouts)	Good/poor	2

Accident factor	Indicators	Description and unit	Rating 1 = essential 2 = nice to have 3 = minor relevance
	Consistency of intersections	Index of consistency	3
	Access control/ junction frequency	Number of junctions/ accesses per km	1
Cross section	Lane width	Avg/km m	1
	Road width	Avg/km m	1
	Median/Overtaking restrictions	Type (m/km)	1
	Emergency/hardened shoulders	Type Avg/km (m)	1
	Shoulder drop-off	Avg Cm/km	2
	Number of lanes	No/km	1
	Road complexity	Workload of drivers	3
Roadside area and equipment	Obstacles	Type No/km	1
	Distance to obstacles	Average per type m/km	1
	Protective devices (guardrails, crash cushions)	Type m/km	2
	Depth and slope of ditches, gutters, etc.	Type m and %	2
	Road verge slope	Type %	2
Road surface	Friction coefficient IFI (International Friction Index) – combination of friction coefficient measured at 60 km/h and macro texture Skid resistance (relevant to rear end and intersection crashes)	Wet/dry Ice/no ice Snow/no snow Dimentionless/m m Unit	2 2 2
Behavioural factors	Tailgating	Headway	3
	Excess speed	85% speeds	1
	Speed differential	Distributions of vehicle speeds	2
	Attention	Gaze data	3
	Driver age	Age distribution	3
Vehicle fleet	Age of vehicle fleet (should indicate vehicles with safe systems such as ABS, stability control programme etc)	Average age of vehicle fleet	2
	Fleet composition (impact upon rear end collision likelihood – LGVs, company car drivers)	Proportion of high risk groups	2

The development of knowledge concerning how roadway design factors (e.g. curvature, lane width, roadside design) affect the level of safety requires study of not only the failures (i.e. crashes) that occur, but also the successes – the miles of highways with certain design and operational features where the crash rate is either zero or very low. Thus, the database must include linkable files of crash, roadway inventory and traffic flow data. In order to run sophisticated analyses, i.e. modelling accidents and the effects of different road safety measures, all data has to be grouped in a way that characteristics of road objects, road user behaviour and accident data can be queried for each single unit. However, an inventory of road safety data among ten RISMET partners has indicated that the most obvious data-gaps in view of improving the tools for road safety engineering evaluation in Europe exist for infrastructure and vehicle data.

Figure 17 gives an overview on the data requirements of sophisticated road databases. As can be seen from the figure, a holistic approach is needed, with vehicle safety, human factors and highway engineering all taken into consideration.

Figure 17: Data requirements for in-depth analysis of accidents



In many countries, on-the-spot accident investigation teams are employed to gather all or at least most of the above mentioned data. The interest of accident investigation is not only in the consequences of road crashes but also in crash causation, road user behaviour and the effects of road engineering. Much of this information that is necessary to understand these complex issues can only be found at the scene of the crash for a relatively short time after impact. That is retrospective studies cannot be used to obtain perishable accident data such as trace marks on the highway, pedestrian contact marks on vehicles, the final resting position of the vehicles involved and weather, visibility and traffic conditions. Such information is lost during the clearing of the accident scene and it is only by prompt attendance at the scene of the crash that such information can be reliably obtained.

In-depth analysis of fatal and serious accidents greatly improves the understanding of the accident triggering sequence of events. By applying sophisticated statistical methods such as Generalized Linear Models (GLM), results include robust estimates of drivers and pedestrian manoeuvres which enable accident investigators to identify which injury mechanisms are directly related to the road equipment. From a road administrator's point of view these are important elements that may be used for supporting safety interventions decisions, both at the micro and the macro levels.

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Annex: Questionnaire „Current road and traffic data in Europe" (example Austria)

Main category	Subcategory	Data provider	Availability	Spatiality			Data scale	Periodicity	Quality	Operational level	Purchase of data possible	Comments
				National	Regional	Local						
Exposure	Population	EUROSTATS	Public	x			Aggregated	Annual	Good	Operational	No	
		IRTAD	Public	x			Aggregated	Annual	Good	Operational	Yes	By year, country and vehicle type
		Statistik Austria	Public	x			Aggregated	Annual	Good	Operational	No	By sex, federal state, age groups etc.
			Public		x	x	Disaggregated	Annual	Good	Operational	Yes	By sex, age, federal state, educational level etc.
	Traffic volume	ASFiNAG	Public		x		Aggregated	Annual	Good	Operational	No	AADT of motorized vehicles and HGV per road section
			Public			x	Disaggregated	Annual	Good	Raw data	Yes	Hourly traffic by vehicle type at specific toll gantries
		Federal states	Public			x	Disaggregated	Annual	Good	Raw data	No	Automatic counting stations at several A-level roads
		KfV	Non-public			x	Disaggregated	Singular	Good	Operational	Yes	Quarterly traffic by vehicle type, speed, headway etc.
	Traffic performance	ASFiNAG	Public		x		Aggregated	Annual	Good	Operational	No	By vehicle type and road section

Main category	Subcategory	Data provider	Availability	Spatiality			Data scale	Periodicity	Quality	Operational level	Purchase of data possible	Comments
				National	Regional	Local						
Exposure	Traffic performance	UBA	Public	x			Aggregated	Annual	Good	Operational	No	By vehicle type
	Vehicle Fleet	EUROSTATS	Public	x			Aggregated	Annual	Good	Operational	No	By vehicle type, country, year, initial registration etc.
		IRTAD	Public	x			Aggregated	Annual	Good	Operational	Yes	By year, country and vehicle type
		Statistik Austria	Public	x			Aggregated	Annual	Good	Operational	No	By vehicle type, year, sprit, brand name, readmission
			Public		x	x	Disaggregated	Annual	Good	Operational	Yes	By vehicle type, year, engine, brand name, weight, noise level, number of seats etc.
Road accidents	Injury accidents	EU	Non-Public	x			Aggregated	Annual	Good	Operational	No	CARE-Database
		EUROSTATS	Public	x			Aggregated	Annual	Good	Operational	No	Fatalities by country and year
		IRTAD	Public	x			Aggregated	Annual	Good	Operational	Yes	By year, country, severity level, month vehicle type etc.
		KfV	Non-public	x	x	x	Disaggregated	Annual	Good	Operational	Yes	Chainage-corrected data
		Statistik Austria	Public	x			Aggregated	Annual	Good	Operational	No	Injured, fatalities by federal state, county, municipality

Main category	Subcategory	Data provider	Availability	Spatiality			Data scale	Periodicity	Quality	Operational level	Purchase of data possible	Comments
				National	Regional	Local						
			Public		x	x	Disaggregated	Annual	Good	Operational	Yes	By vehicle type, accident type, age, sex, location etc.
	Property damage only	Federal states	Non-public	x	x	x	Disaggregated	Annual	Sufficient	Operational	No	Tirol and Burgenland only
Infrastructure	Cross-section	AIT	Non public		x		Disaggregated	Interval	Good	Raw data	Yes	Motor- and expressways
					x		Disaggregated	Singular	Good	Raw data	Yes	Parts of the Secondary Road Network
	Reference populations	Tele Atlas, Navteq	Public	x	x	x	Disaggregated	Interval	Good	Operational	Yes	Digital Road Map, Intersection cadaster containing information on different road sites
	Speed limits	Tele Atlas, Navteq	Public	x	x	x	Disaggregated	Interval	Good	Operational	Yes	Digital Road Map
		BMVIT	Public		x	x	Disaggregated	Singular	Poor	Raw data	No	Chronology (legal acts) of decreed speed limits.
	Road surface	AIT	Non public		x		Disaggregated	Interval	Good	Raw data	Yes	Motor- and expressways
					x		Disaggregated	Singular	Good	Raw data	Yes	Parts of the Secondary Road Network
Vehicle Data	Defects	Automobilist clubs	Non public		x		Disaggregated	Annual	Good	Raw data	No	
Road user	Daytime Running	KfV	Non-public		x		Disaggregated	Annual	Sufficient	Operational	Yes	Two sites per federal state and

road ERA net

Main category	Subcategory	Data provider	Availability	Spatiality			Data scale	Periodicity	Quality	Operational level	Purchase of data possible	Comments
				National	Regional	Local						
behaviour	Light											road type
	Speed		Non-public		x		Disaggregated	Annual	Sufficient	Operational	Yes	Two sites per federal state and road type
	Seatbelt		Non-public		x		Disaggregated	Annual	Sufficient	Operational	Yes	Two sites per federal state and road type
	Police enforcement	BMI	Public	x			Aggregated	Annual	Sufficient	Operational	No	
Environmental Data	Weather	ZAMG	Public		x	x	Disaggregated	Hourly	Good	Operational	Yes	Precipitation, wind speed, cloud amount, air humidity etc.
Hospital Data	Inpatients	Statistik Austria	Non-public	x	x	x	Disaggregated	Annual	Good	Operational	Yes	Hospital Discharge Register (HDR), individual data made anonymous
	Work related accidents	National Insurance Agencies	Public	x	x	x	Aggregated	Annual	Good	Operational	No	
		EUROSTATS	Public	x			Aggregated	Annual	Good	Operational	No	
In-Depth Data	Fatal accidents	Federal Ministry of Justice/Courts of Justice	Non-public			x	Disaggregated	Annual	Sufficient	Raw data	Yes	Accident cause, course of events, pre and post impact position etc.