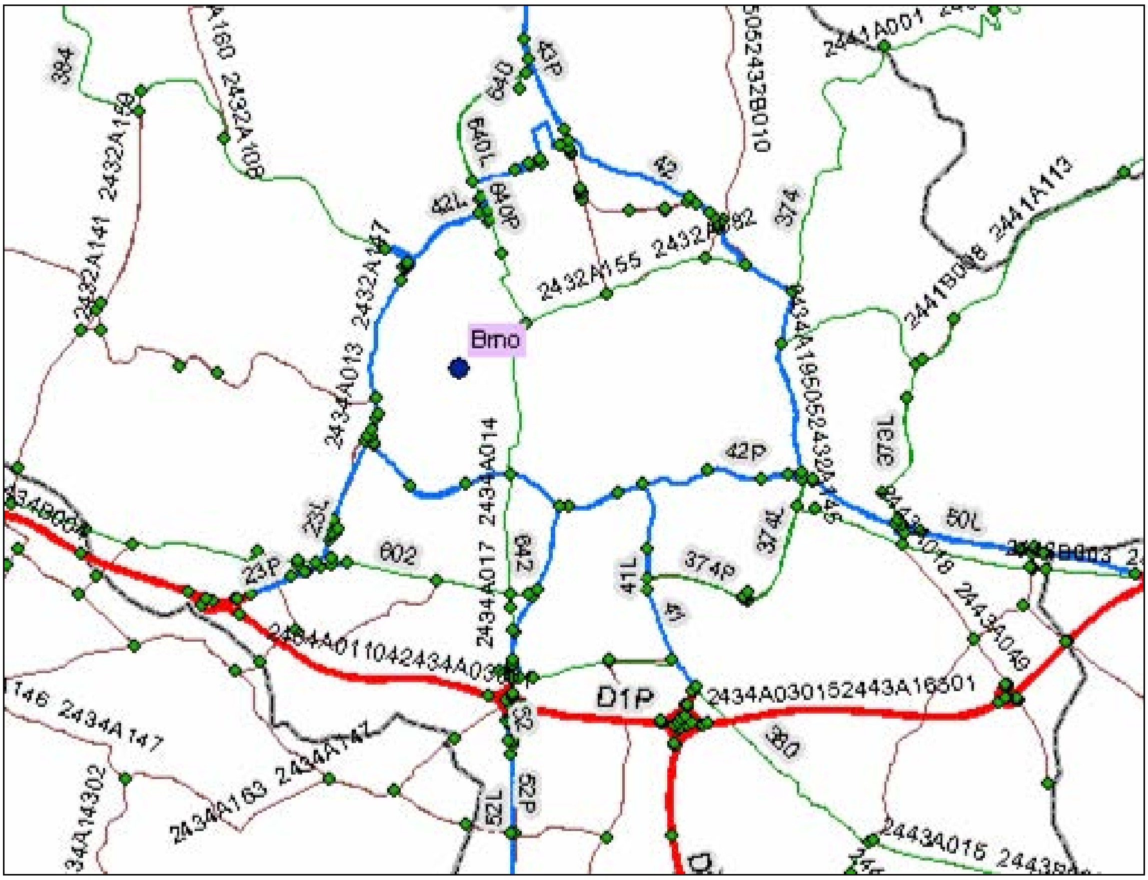
PIARC

ROAD ACCIDENT INVESTIGATION GUIDELINES FOR ROAD ENGINEERS



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1. WHAT IS A ROAD ACCIDENT INVESTIGATION (RAI)

1.1. Definition

A Road Accident Investigation (RAI) is a set of procedures carried out on existing roads which includes:

- a collection of information about accidents and about all the facts linked to them, about road and traffic parameters and other related circumstances (e.g. driver behaviour and his/her impairment, weather and light conditions, etc.)
- an assessment of the accident distribution on the road network, on the particular road or road section/location
- a detailed data analysis of accidents and their circumstances in the targeted spots/sections of roads by using collision diagrams
- a determination of the road related deficiencies and elaboration of suggestions for their suppression or treatment

Carrying out the RAI requires a certain amount of accident and the accompanying data according to the road engineer's given task. A typical task is to draft a preference list of improvement interventions or of black spot treatments.

The purpose of the RAI is to help road engineers detect the amount of road infrastructure deficiencies that influence an accident's occurrence, and to guide them in the implementation of appropriate improvement measures.

The RAI is based on findings compiled in the Road Safety Manual (PIARC, 2003), and upon particular later developments as described in Chapter 4, 5, and 6 of Part 2 of this manual.

1.2. Road Accident Investigation (RAI) and Road Safety Inspection (RSI)

RAI and RSI both deal with existing roads. Given that the RSI procedure doesn't require any data input, the investigators need expert qualification and experienced in road safety. Their evaluation of the "risk features" of the road and its environs is not only an identification of the hazardous situation, but also draws attention to locations that need more detailed investigation based on accident data analysis(RAI).

RAI is thought to be the last step in a road safety improvements system as shown in FIGURE 1.

NEW ROADS ◀ ▶ EXISTING ROADS

ROAD SAFETY IMPACT ASSESMENT	**ROAD SAFETY AUDIT**	**ROAD SAFETY INSPECTION**	**ROAD ACCIDENT INVESTIGATION**
strategic comparative analysis of the impact on safety performance	**project review identifying road/traffic safety concerns**	**site review of hazardous conditions, failures and deficiencies**	**Accident assessment linked to real road traffic conditions**

PREVENTIVE ◀ ▶ REACTIVE

FIGURE 1: ROAD SAFETY IMPROVEMENT SYSTEM

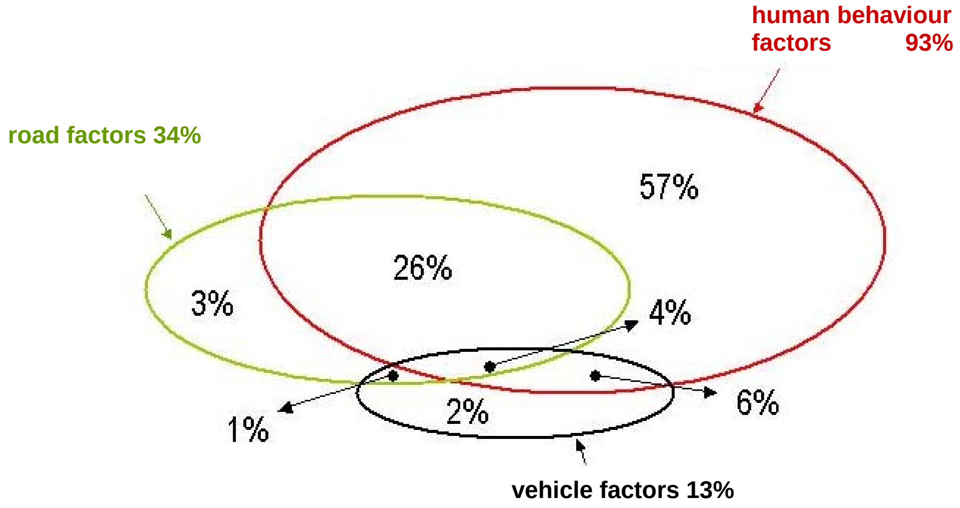
RAI, compared with other procedures shown in FIGURE 1, is a reactive tool. It reflects the real occurrence and distribution of accidents and their circumstances and has a high potential for identification of tailor-made safety measures and their implementation. The quality and the level of details of the relevant data are the prerequisite for the application of appropriate countermeasures.

2. THE ROAD – A SIGNIFICANT FACTOR IN THE SAFETY SYSTEM

There is consensus forming among the general public due in part to emphatic reinforcement of the accident statistics by traffic authorities that the human element is the key causal factor of road accidents occurrence.

Drivers and other road users basically determine their movements on the road due to a sense of obligation to adapt their behaviour to existing traffic regulations and rules, to road surfaces, to traffic and weather conditions in accordance with their driving skills and health status. Furthermore, human behaviour itself is influenced by a myriad of elements related to the individual and their ability, skill and experience, current physical and psychical state, and perception of the actual traffic and road conditions.

A large number of in-depth accident investigation studies provide a more complete picture of the real accidents causes. One example is shown in **FIGURE 2**.



(Source: PIARC Road Safety Manual, 2003)

FIGURE 2: ACCIDENT CONTRIBUTING FACTORS

This diagram depicts the link between individual areas of the road safety system. It indicates the important role of the road itself, particularly its pivotal interaction with human behaviour.

Many spots or road sections that have similar features show a high frequency of accidents. This means that ***the particular road environment instigates inappropriate driver responses or provides misleading stimuli to driver perception that creates confusion, and/or delayed reactions.*** To identify and examine these locations and to characterize the safety deficiencies is a challenge for road engineers. The mere appearance of an accumulation of accidents with similar characteristics offers excellent guidance as to where to apply appropriate traffic engineering treatments that create self-explanatory roads and forgiving roadsides. These are the most suitable way to increase the safety of all road users. The availability of accident data offers a greater concentration of safety improvement intervention options than does conducting a Road Safety Inspection, where the understanding of recent accident history is unnecessary.

3. ACCIDENT DATA

3.1. Need of data

The availability of road accident data is a prerequisite for each efficient road safety management system. Identification and definition of the relevant problem together with knowledge of the data and parameters describing this problem is essential for its successful solution. Comprehensive, up-to-date, accident data is needed for recognition of the scope of road safety problems and for raising public awareness. Reliable and relevant data enable the identification of the contributory factors of the individual accidents, and an unveiling of the background of the risk behaviour of the road users. It offers the best way to explore the prevention of accidents, and ways to implement measures to reduce accident severity.

Accident data is a crucial element for any road safety intervention. But it is not only the description of the accident circumstances that are needed. Contributing factors like road and traffic characteristics, vehicle parameters, and information about the people involved in the accident have to be registered as well.

3.2. Data parameters and their quality

To effectively analyse, compare and make informed conclusions from the data it is necessary to fulfil the following basic requirements:

- Accuracy (to exactly describe the individual parameters)
- Complexity (to include all features within the given system)
- Availability (to be accessible to all users)
- Uniformity (to apply standard definitions)

The last parameter (uniformity) is of vital importance for comparisons. Even on the national level it is important that the local and regional definitions comply with national ones. There are different databases that often exist within one country. These databases may be managed by:

- police
- road administration
- hospitals / health system
- insurance companies

An agreement on national standards and definitions is desirable among all the relevant subjects (although this is not the case even in many developed countries), because it facilitates comparison of data and ensures its accuracy.

A similar approach should be followed at an international level. Although international comparisons are not at all the core activity of the road engineer, they are important for the definition of national road safety policies, including those relevant to the work of road engineers.

International databases provide:

- a comparison picture of national accident data
- a ranking of countries
- an indication of the urgency of international support
- information on development and progress
- better identification of weak areas in the safety system
- differences in the safety levels of users and roads

Given the usefulness of international comparisons, national standards that reflect the international agreements should be developed. This could be achieved by adopting international standards, or to develop conversion coefficients allowing production of comparable datasets. One example of international standardisation is given in the "Glossary for Transport Statistics" which has been agreed to among UNECE, EUROSTAT and ECMT[1].

Another aspect to be emphasised when working with accident data is the great amount of underreporting. Not all accidents are reported. There are, of course, many intentionally unreported accidents. But also due to the fact that each database (police, hospital, road administration, insurance company) has its own requirements on what and how to report, only a careful comparison of the different sources can give a "true" picture.

The fourth chapter of the PIARC Road Safety Manual describes the framework for data collection, the content of the accident files, methods of data gathering and other data options. Data is usually collected into a road accident report form. It is a pre-printed, standardized form where the required information is required. Police officers are the ideal data collectors, as they usually are one of the first to be called to an accident site.

It is quite evident that such complex monitoring of accidents and traffic systems and their maintenance is very expensive. Therefore, it is difficult for many countries to develop and operate such systems to provide road engineers and decision makers with all the relevant and necessary information. ***Nevertheless, even a minimal amount of information can offer the road engineer the ability to identify safety deficiencies in the road environment, and to design possible countermeasures.***

Three levels of data sets are considered:

- minimum data
- road and traffic data
- additional data

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[1] UNECE - United Nations Economic Commission for Europe (www.unece.org)
EUROSTAT - The Statistical Office of the European Communities (www.ec.europa.eu/eurostat)
EMCT – The European Conference of Ministers of Transport (www.cemt.org)

3.3. Minimum data

A minimum set of data can provide road engineers with relevant information necessary for basic accident causation investigation. The minimum data can be identified as follows:

- accident identification
  (a unique number-based system)
- time
  (the date, hour, minute, day of week)
- location
  (see part 4)
- accident type
  (see part 6)
- vehicles involved
  (number, type)
- accident consequences
  (fatalities within 24 hours/30days, injuries, material damage)

This elementary set of data can be easily introduced in countries without any accident recording system as an early step for a system based reporting system. It doesn't require huge financial resources, and only limited human input is needed. The existing administrative structure (administration regional governance, health system, etc.) is suitable for involvement.

This key information will enable a basic evaluation of the level of a road's (or road section's) safety in comparison with other roads or sections. This information can direct a road engineer to certain locations which have higher accident frequencies, and provide a basic outline of the possible circumstances and factors that may have led to these accidents. With the aid of additional parameters and features related to the accident site, an estimation of potential deficiencies of the road infrastructure can be determined and elaborated.

Certain locations may offer an obvious link between accident causation and the failure of a road or its surroundings. The procedures developed in RSI can efficiently facilitate the investigation process. A proposal for improvement measures is, then, an obvious result.

3.4. Road and traffic data

This set of data provides road engineers with relevant road infrastructure information linked with the location of the accident and other circumstances and factors contributing to the accident occurrence. Even if these data are available, a complementary site investigation is desirable, and can lead to findings which were not obvious from the accident data analysis.

The set of data can include features as follows:

- road description
  (tangential section, type of intersection, road number, road category, cross section…)
- specific places/objects
  (pedestrian crossing, rail crossing, bridge, tunnel, bus/tram stop, parking place, petrol station…)
- road alignment
  (evident deficiency or not, slope, narrowing …)

- road surface
  (type, permanent state, actual conditions – e.g. snowy, wet, icy surface)
- road signing and marking
  (availability, condition, location, …)
- roadside obstacles
  (tree, column, bridge….)
- visibility conditions
  (clear, limited by alignment, vegetation, obstacles…)
- weather conditions
  (dry, fog, rain, snow…)
- traffic control
  (traffic lights, road signs, policeman)
- position of accident
  (travel direction of involved participants, location - traffic lane, shoulder, roadside, …)
- main causes of accident
  (speeding, overtaking, right of way…)

This level of reporting system can be implemented in countries with a developed road administration that has been introduced to its operation. A link with an existing road inventory database is recommended.

3.5. Additional data

This set of information contains features related to the vehicles and persons involved in the accident. Some of this information can be obtained from other sources as well, e.g. from the central vehicle registry.

Such a complete set of information that also includes road and traffic data enables a more detailed and precise investigation; and excludes the seemingly apparent typical single human or vehicle based failure (e.g. breakdown of vehicle, alcohol or drug impairment…).

The data to be gathered are as follows:

- the driver (category of licence, driver experience, sex, age, nationality, education…)
- impairment of the driver (alcohol, drugs, others…)
- condition of the driver (alert, tired, impulsive, sudden indisposition, suicidal,….)
- use of restraint devices (helmet, safety belt, child seat….)
- condition of the pedestrian (alert, impaired by alcohol/drugs,….)
- behaviour of the pedestrian (proper, faulty, poor estimation of vehicle movement, sudden entry to the road….)
- license plate number
- brand make of vehicle
- vehicle operator (private, commercial, public transport…)
- year of production of the vehicle
- emergency service involvement

4. ACCIDENT LOCATION

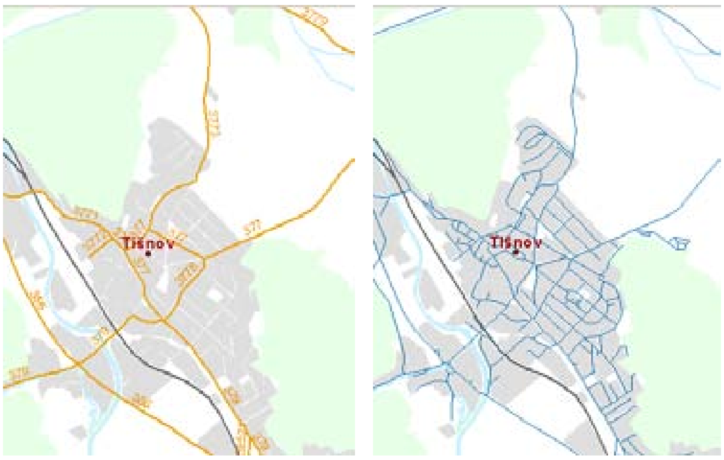
4.1. General introduction

Various road safety studies are aimed at improving the quality of road parameters. The biggest problem when conducting these studies is to determine the exact road accident location. Therefore the availability of a localization method is a crucial element of any road information system. Without reliable knowledge of the accident localisation and without relevant data, the opportunities for solving the local deficiencies are limited.

Each road accident relates to a specific location in the road network. Each road location is described by road number and stationing data uniquely related to each road network.

A reference localization system provides a link between individual files (road accidents, road parameters, road equipment). To link these files, localization methods have to be identical or at least compatible, and thus, to enable files conversion between methods.

In urban areas, the precise road accident localization may be performed by a digital map set, for example by StreetNet, which is used in the Czech Republic (see Figure 3). This map set comprises the entire road network including local roads and streets. It also contains general traffic information (traffic prohibitions, one-way traffic, etc.). Moreover, there is information related to roads (number, class and type), cities, streets, etc.



a) Road map (rural areas) *b) StreetNet (urban areas)*

FIGURE 3: COMPARISON OF URBAN AND RURAL AREAS MAP SETS

An accurate localization system should enable the:

- exact localization of road feature according to localization data stored in the database
- storage of recorded data to the appropriate location in the database

Each reference localization system has to provide identifiable results in both lanes and directions.

An **accident blackspot** is a term used in road safety management to denote a place where accidents are concentrated. Without a precise localization of road accidents, road administrators are not able to find, and effectively treat the accident blackspots on their road network. Inaccurate localizations mean misguided identifications and result in the loss of financial means and time. The effective evaluation of implemented countermeasures can also be influenced.

The Road Safety Manual (part 4.1.4) describes different accident location methods as follows:

- node network (may be applied in rural areas)
- stationing (may be applied in both rural and urban areas on the main road network)
- main junctions – (see FIGURE 3)
- GPS (may be applied in both rural and urban areas where a sufficient GPS signal is available)

4.2. Route – km post; stationing

Stationing is the traditional and most commonly used method for road location identification. Road stationing is similar to a node system. They both identify location with distance between known points. This method uses values assigned to road sections. Each road has an original station (zero point) – the distance from this point defines each location. Distances are indicated by km post markers.

If the distance between posts is too long, as it is often the case in rural areas, there may be certain problems with the localization of road accidents. A sufficient density of stationing posts is, therefore, of immense importance. The markers should be typically placed every 200 meters at main roads, and at 500 meters on other roads.

Disadvantage of this system is its burdensome inadaptability to infrastructural changes that result in a change of the road length (e.g. bypasses).

Therefore, police staff at road accident departments should have some sort of stationing review to keep it updated every year. Review should cover all roads in the relevant area with the values of stationing at every orientation point.

4.3. Node network

The method is based on nodes that are usually placed at junctions. A unique number is attributed to them. Node systems are defined as a network of nodes and the sections between them. Sections are simple linear elements with defined stationing. Each node is connected with at least one other node. Each location may then be identified by the distance between nodes and the stationing direction. The simple network can be displayed as a web with nodes at junctions. Other objects and locations along the road (bridges, channels, borders, etc.) may be also considered as nodes. They can facilitate the localization in case of long distances between adjacent nodes. Nodes may also contain information about traffic volume.

A node localization system contains the following items:

- Node number
- Administration unit number
- Crossing road numbers
- Municipality number
- Node characteristic

- Adjacent node numbers

4.4. GPS

The use of GPS (Global Positioning Systems) is the fastest and most accurate way of obtaining reliable data about accident locations. GPS is also the cheapest way to identify accident locations. GPS is the cheapest method of accident registration in those countries which have existing accident data collection programs.

This method is suitable for safety analysis issues – road accident locations and accident blackspots can be easily identified. For road accidents visualisation, digital geographic localization can be performed. Different background maps can be conveniently used. Localization has to be performed at the road accident location immediately after the accident occurrence when the causes and circumstances can be examined more precisely. For these purposes, mobile Geographic Positioning System (GPS) devices that have sufficient accuracy to obtained location data should be used. The data can be then transfered into a PC.

This method uses localization in geographic coordinates. GPS offers the fastest and cheapest localization method; hence, its advantages are getting wider recognition and greater use.

Localization application should contain the following features:

- loading data from GPS to application
- manual typing of the localization to a map
- data visualization in form of a map
- export of localization data to a text file

GPS localization systems have to be used on site – no results will be filed without following the procedures exactly. The only method of post-processing is with the input of coordinates from the map background.

During GPS localization of road accidents the following basic data is recorded:

- cause of road accident
- location of road accident
- distinction between rural and urban areas

The following data is recorded in detail:

- municipality
- street
- house number
- traffic direction
- lane type
- road type
- road number and stationing

5. ACCIDENT DATA ASSESSMENT

Even the minimum set of data enables the evaluation of the safety level of a road network, and the ability to discover a spot or section with a higher occurrence of accidents. Again, the procedure is well elaborated in Chapter 5 of the PIARC Road Safety Manual, where several methods of identification of the road safety deficiencies are described.

High-frequency accident occurrence locations (blackspots) are emphasised as the first step of the road safety improvement programmes. These blackspots have a significantly high potential for accident reduction, and a high cost-effectiveness ratio, too.

Several methods using accident frequencies, accident rates and accident severity are demonstrated to detect road deficiencies.

Accident data basically can be used in two ways:

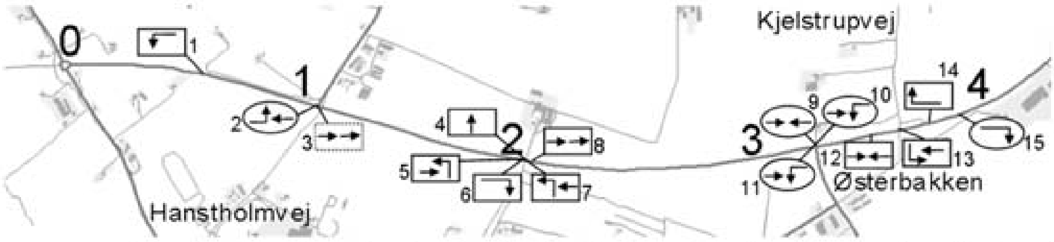
- To determine the common characteristics of accidents in order to elaborate the effective countermeasures.
- To identifyy the locations, ttogether with the traffic volume data, where the probability of accidents is significantly higher than average (so-called black spots).

In the first case, we have to produce very simple frequency tables, from which we can have an overview about the most frequent characteristics of road accidents.

Some very simple examples:

- If the number of night-time accidents is outstandingly high, it is very probable that the night-time visibility is insufficient for the investigated location;
- If the number of accidents on wet road surface is outstandingly high, it is very probable that the skid resistance of the road surface is inappropriate at the investigated section, etc.

The next Figure 4 shows an extended collision diagram and the before mentioned accident frequency table.
From the table we can observe the timely distribution of road accidents, the type of accident (we do not know the meaning of the code numbers in this case, but the small figures give us a good starting point), the weather conditions (clear or raining), the road surface conditions (dry or wet), the light conditions (light or dark) and the influence of alcohol. It can be seen clearly, that at location 2, for example, the accidents occurred only in the 9th and 10th months of the year. For locations 3 and 4, the prevaling characteristic is that almost all accidents occurred on a wet road surface. In location 2, accidents in the darkness are the primary characteristic; and in locations 0 and 1, the influence of alcohol is registered quite often.
These tables and common characteristics of accidents compilations are very simple, yet effective tools in the elaboration of countermeasures.



No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year	03	03	03	02	03	04	04	04	02	02	04	02	03	03	03
Month	5	9	10	10	9	9	10	10	1	8	5	6	12	10	5
Day	7	1	5	6	2	1	3	1	4	5	5	7	6	6.	6
Hour	6	12	22	02	05	23	11	22	18	10	9	4	11	01	05
Type	012	410	198	031	660	032	650	140	241	410	410	241	660	011	023
Whether	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Rain	Rain	Rain	Dry	Dry	Rain	Dry
Road	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Wet	Wet	Wet	Dry	Wet	Wet	Wet
Light	L	L	D	D	D	D	L	D	D	L	L	L	L	L	D
Alcohol	Yes	Yes	Yes	Yes	-	Yes	-	-	-	-	-	-	-	-	-

…to identify local accident patterns that "drown" in the average for the whole road section
(Source: Sørensen M., TØI, RIPCORD-ISEREST, WP6)

FIGURE 4: EXTENDED COLLISION DIAGRAM.

In the second case we need traffic volume data as well for the evaluation. For this purpose the most used accident rates are as follows:

- accident density (A_d):

$$A_d = \frac{A}{L.T}\left(\frac{accident}{kmyear}\right)$$

where:

L: the length of the investigated road section or road network (km)
A: the number of accidents occurred on the section or network with length "L".
T: the number of years.

This rate is typically calculated yearly. In some countries so-called accident frequency maps are produced on the basis of the accident density in order to show the most dangerous parts of the network. The problem is that this rate does not take into account the traffic volume; therefore it has a high value in case of high traffic volume also.
The other well-known relative number is the

- accident rate (A_r):

$$A_r = \frac{A.10^6}{365.AADT.L.T}\left(\frac{accident}{10^6\,vehiclekm}\right)$$

where:

AADT: annual average daily traffic (vehicle/day)

In most cases this rate is also calculated yearly.
From theoretical point of view this rate is the most accepted as a measure (the approach) of the accident risk. This rate is based on the concept, that there is a linear relationship between the number of accidents and the traffic volume.
The relationship between traffic volume and accidents can be expressed as follows: (Elvik and Vaa, 2004):

$$A = a.Q^b$$

where:

A : number of accidents
Q : measure of traffic volume
a, b : constants

If b = 1, 1% increase in traffic volume is associated with a 1% increase in the number of accidents.
For injury accidents b = 0,911 (Fridstrøm, 1999), which means that there is a nearly linear relationship between the frequency of accidents and the traffic volume (Knoflacher, H.; Kern, U., 1979), at least within the interval of the usual traffic volumes. Based on this relationship it can be said that increased traffic volumes are basically connected with increasing accident numbers and vice versa.
The EuroRAP programme uses the accident rate in order to produce risk maps and to assess the safety level of roads. There are a lot of discussions about which rate is better for this purpose, the accident density or the accident rate. In the first case, we have to introduce countermeasures independently of the traffic volume, in the second one; we take into account not only the number of accidents but the traffic volume too.
Of course, there are combined methods as well, which take into account both mentioned indicators.
The PIARC Road Safety Manual gives a very good overview about the existing methods to identify the black spots. What is more, the Manual describes the advantages and disadvantages of the existing methods, it gives a very detailed comparison of them, and it helps the practical work of the road safety engineers with so-called calculators.
It is of a basic importance to differentiate between sections and intersections, like in case of the critical accident rate method.
The PIARC Road Safety Manual deals with the accident prediction models too, it gives details, among others, about the empirical Bayesian method as well, which can be assessed as the best one from a methodological point of view. It takes into account the random nature of road accidents, and improves the accuracy of the estimated potential for improvement. Its only disadvantage is the relative complexity.
For developing countries, the application of more simple methods can be suggested. For developed countries, the usage of the best practice guidelines can be proposed, which will be elaborated in the framework of RIPCORD-ISEREST project in the near future.

Other examples of network safety assessment are described in Appendix 1 - Network safety management (Germany) and Appendix 2 - Assessment of road sections safety (the Czech Republic). Both of them are based on the calculation of accident costs and they primarily reflect the accident severity.

6. TYPES OF ACCIDENTS

The accident type describes the manoeuvre or conflict situation (e.g. a collision between a vehicle and a pedestrian crossing the road) which resulted in the accident. Only the conflict situation, which led to the accident, plays a role in determining the accident type. Whether and how the road users collided (so called "kind of accident") is not of relevance when determining the accident type. Nor do incorrect actions on the part of road users, i.e. the "accident cause", play a role when determining the accident type.

Classifying accidents according to their common features into several groups facilitates and defines the investigation process. Therefore, groups of accidents according to their occurrence and the types of collision are identified and used in accident analysis. The following list represents the accident types used in the Czech Road Accident Typology, which is based on the Austrian version. Accidents are divided into the following 10 types:

- Single vehicle accidents
- Road accidents of vehicles driving in the same direction on the road section
- Road accidents of oncoming vehicles on the road section
- Road accidents of vehicles entering a junction from the same direction
- Road accidents of vehicles entering a junction from opposite directions
- Road accidents of vehicles entering a junction from neighbouring lanes
- Road accidents of vehicles and pedestrians
- Road accidents with standing or parked vehicles
- Road accidents with animals and rail vehicles
- Other road accidents

Most other countries use similar typology of accident types with different number of accident types considered. For example in Germany, the typology contains somewhat less basic accident types - seven (see below with relevant definitions):

- **Driving Accident**
  An accident in which the driver loses control of the vehicle because he or she was driving at a speed which was inappropriate for the layout, the cross-section, the incline or the conditions of the road, or because he or she did not realise how the road was laid out or that there was a change in the cross-section until it was too late. Driving accidents are not always "one-party accidents" in which the vehicle leaves the road. They can also result in a collision with other road users.

- **Turning-off Accident**
  Turning-off accidents are those triggered by a conflict between a vehicle turning off a road and a road user travelling in the same or the opposite direction. This can happen at junctions and intersections with roads, at field tracks or cycle tracks, or at entrances to properties/car parks.

- **Turning-into/Crossing Accident**
  An accident triggered by a conflict between a vehicle which is obliged to give way, turning into a road or crossing the path of other traffic, and a vehicle which has right of way, is referred to as a "turning-into/crossing accident". This can happen at junctions and

intersections with roads, field/cycle tracks and railway crossings, or at entrances to properties/car parks.

- **Crossing-over Accident**
  An accident is triggered by a conflict between a pedestrian crossing the road, and a vehicle, provided the vehicle had not just turned off a road. This rule applies irrespective of whether the accident occurred at a site without any special pedestrian-crossing facilities or at a zebra crossing, a light-controlled crossing or similar installation.

- **Accident caused by Stopping/Parking**
  An "accident caused by stopping/parking" is an accident triggered by a conflict between a vehicle in moving traffic and a vehicle which is parked (parking) or has stopped (is stopping) on the road. Such accidents include accidents in which the moving traffic conflicted with a vehicle manoeuvring into/out of a parking position. It does not matter whether stopping/parking was permitted.

- **Accident in longitudinal traffic**
  An "accident in longitudinal traffic" is an accident triggered by a conflict between road users moving in the same or opposite directions, provided the conflict is not the result of a manoeuvre that corresponds to another accident type.

- **Other Accidents**
  These accidents are all those which cannot be assigned to any other accident type.
  The basic groups are subsequently divided according to the relevant conflict events into more detailed categories, using the graphical symbols for easier understanding. See Appendix 3: Road Accidents Typology, where the Czech typology is shown, or Figure 5 with a German example of more detailed categories of stopping/parking accidents.

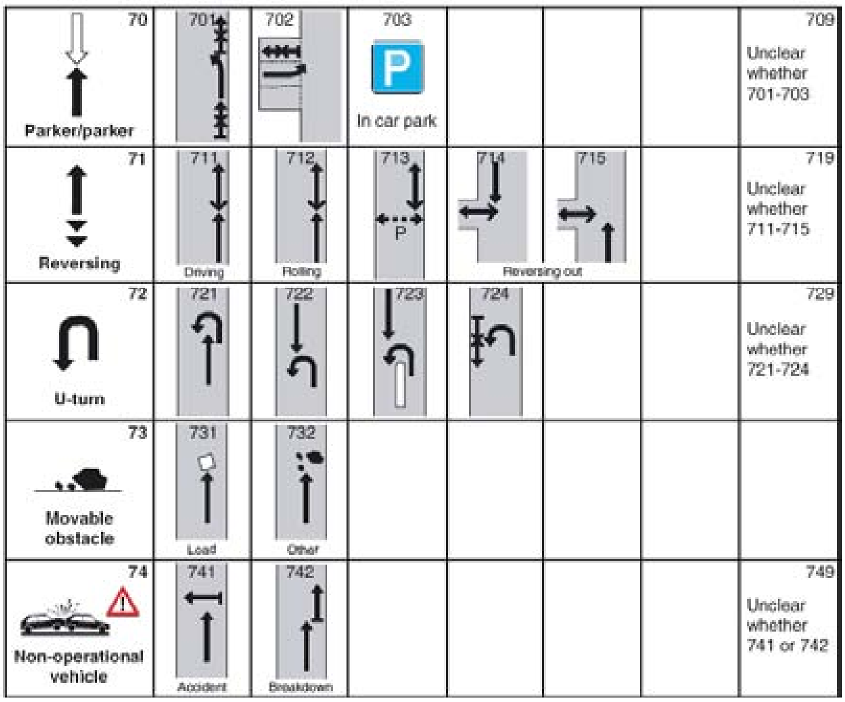


FIGURE 5 : TYPOLOGY OF STOPPING/PARKING ACCIDENTS

The other example is from New Zealand, where the number of accident types is 15 (A – Q). These types are further divided into 7 typical accident movements (see FIGURE 6)

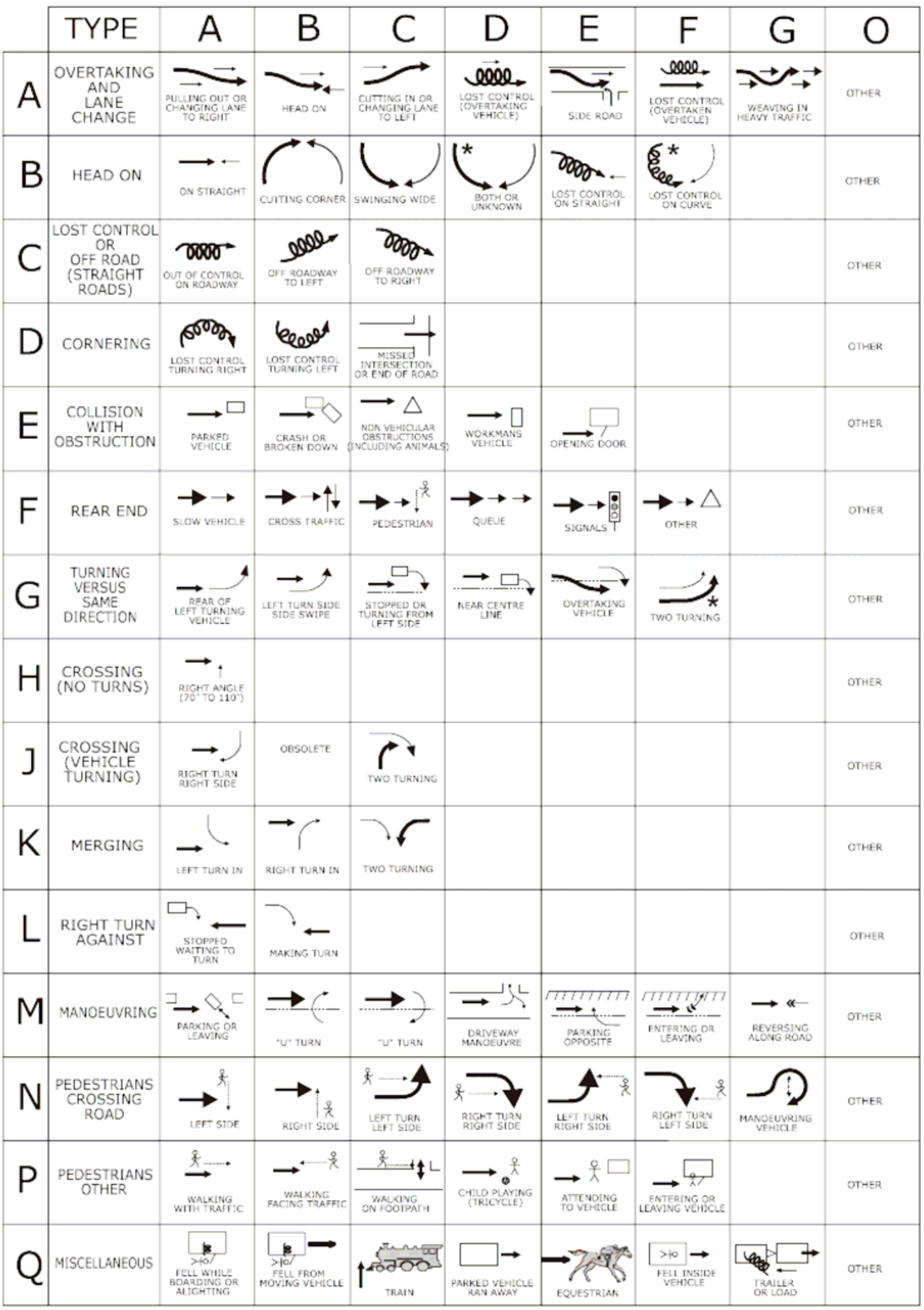


FIGURE 6 : EXAMPLE OF VEHICLE MOVEMENT CODES USED IN NEW ZEALAND

The frequent occurrence of road accidents of the same or similar type at a certain location on road network may have the same or similar contributory factors. When asking the question of what leads drivers to take risks or to make mistakes at such locations, unsuitable road configuration may be discovered. Poor road geometry, e.g. characterised by optical and psychological illusions, may significantly affect the accident rate. A simplified overview of some possible deficiencies, which may contribute to road accidents, and possible types of measures to improve the road safety of black spots, are showed in Appendix 4.

7. COLLISION DIAGRAMS

7.1. Introductory examples

Creation and usage of collision diagrams is a very simple and efficient tool when conducting road accident analysis. Collision diagrams show important road accident patterns with graphic symbols (see Appendix 5) displayed in (or next to) a traffic scheme (see Figure 7 and Figure 8). Collision diagrams provide a broader understanding of the number of accidents and common contributory factors at analysed locations, without supplying extensive text comment. If the same or similar accident patterns are found with the help of collision diagrams, it is then possible to identify the suitable countermeasures.

Collision diagrams are also a very illustrative tool for the comparison of the accident frequency before and after the implementation of a particular road safety measure. The minimum length of the "before-and-after" period considered in any 'before/after' analysis should be at least 3 years.

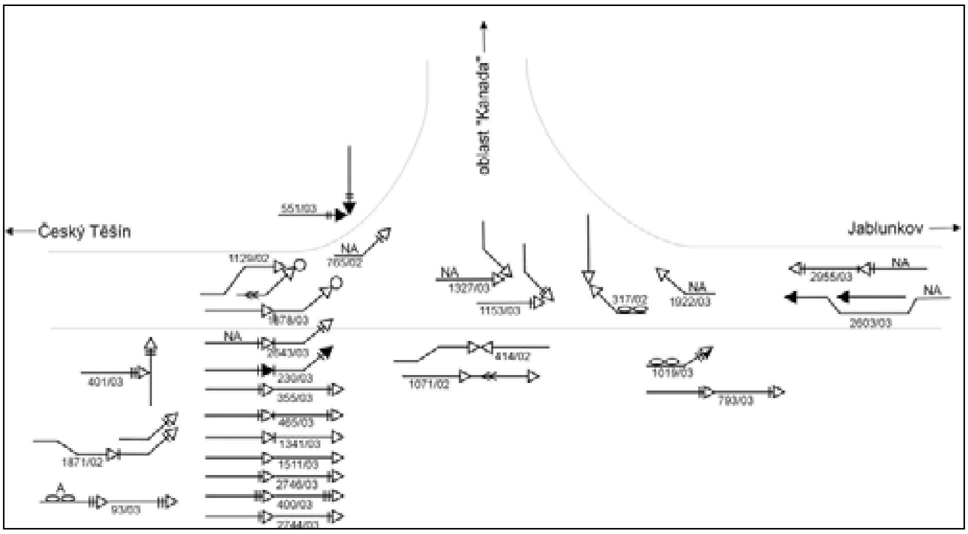


FIGURE 7 : EXAMPLE OF COLLISION DIAGRAMS (THE CZECH REPUBLIC)

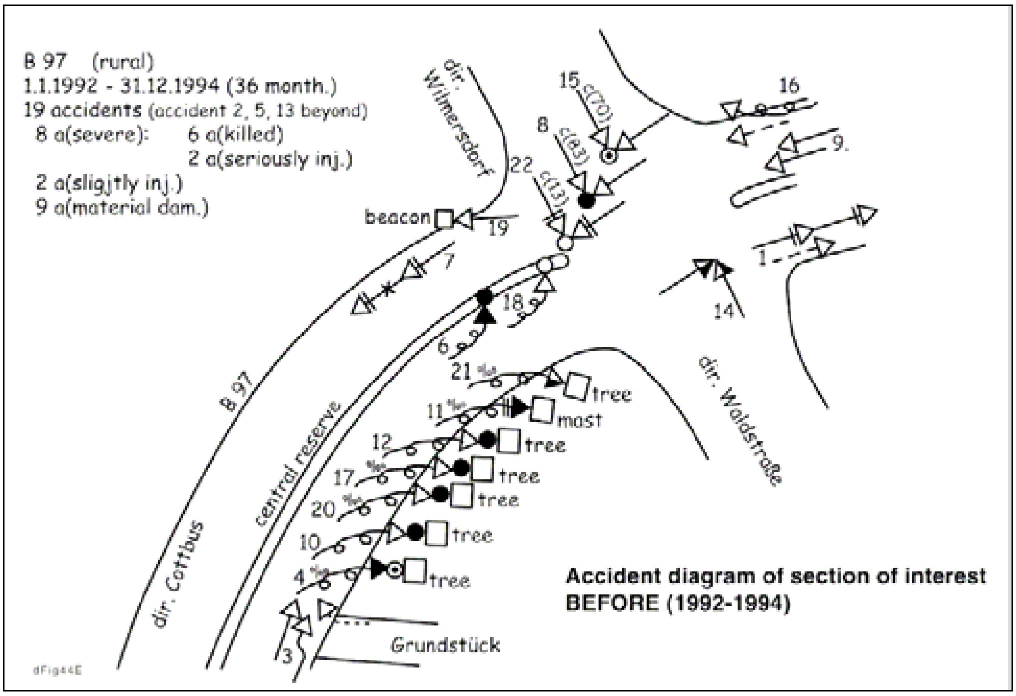


FIGURE 8 : EXAMPLE OF COLLISION DIAGRAMS (GERMANY)

7.2 Fundamentals for creating collision diagrams

Collision diagrams are usually drawn in a scheme at a scale of 1: 200 (or 1: 500). The scheme should contain all important local characteristics, especially those relevant to the movement and manoeuvres of pedestrians and vehicles. If there were changes in the geometry, or traffic organization or management at the site during the investigated period, it is necessary to display them as well.

Symbols for road accidents are marked according to the type of conflict, based on the Road Accident Typology Catalogue (see Appendix 3). The shape of the arrow shows the actual or intended direction of the road user's movement, which corresponds with the direction of travel immediately before the accident.

However, collision diagrams not only display those road users who participate in the accident, but all of those who influence the road accident in any way. It is also suitable to indicate; e.g.:

- a pedestrian, who hesitated before crossing the road and caused a rear-end accident, yet remained uninjured
- all the vehicles which participated in an overtaking manoeuvre that caused the oncoming driver to swerve into a roadside ditch.

When displaying those indirect participants in collision diagrams, specific patterns and features will gradually become clear at the analysed location. The less road accidents shown in the scheme; the more important is the supplemental information.

The movements of accident participants after the collision are usually unimportant, e.g. it is unnecessary to mark a vehicle which began skidding after the collision and then struck a parked vehicle on the other side of the road. The collision diagram would not be clear if the whole accident event was marked in it.

The road accidents that contain the similar conflict situations are summarized into groups, even though it is impossible to mark the accident exactly at the site it occurred.

Collision diagrams should also contain the important road signs, street names, road numbers, road destinations and local characteristics (buildings, vegetation, slopes, embankment, traffic islands, trees, etc.). Road details (road and pavement borderline, tram and bus stops, refuge islands, tram tracks, etc.) should only be marked if they affected the course of the movement of pedestrians or vehicles. Traffic guiding facilities are considered only when they have direct relation to the accidents.

The participant who caused the road accident and was identified by the police investigation may not be specifically marked in the diagram, because legal aspects of road accidents are not essential for this analysis. However, the following issues may be marked:

- whether the accident participant was unaware of the need to give the right of way or,
- whether the accident participant failed to comply with a traffic light

It is recommended that a table or a list accompanying the collision diagrams containing additional information on road accidents be made. To keep it clear, the road accidents should be numbered chronologically, and these numbers should be displayed in the collision diagrams, as well as on copies of the accident report. In this manner, it is later easier to find additional information in a particular road accident record (police accident report, special circumstances, etc.). Using the collision diagrams may be an effective tool, not only for single blackspot solutions (e.g. horizontal curves or junctions), but also for road section analysis.

It is important for the analysis that collision diagrams are created for greater time durations (usually at least for three years), and contain all the road accidents that are available from the statistics. In general, the longer time the period considered, the clearer is the accumulation of the accident type patterns and the appearance of the factors contributing to the origin of the road accidents. If the road geometry or other conditions of the road traffic changes during the period considered in the analysis, these changes must be accounted for in the diagrams.

When selecting the suitable time period for the safety analysis, frequency of road accident occurrence at the investigated site has to be taken into account, as well. Collision diagrams can be created and successfully analysed for shorter periods than the recommended three years where road accidents are available in greater frequencies, and there is only a small variation in their types (prevailing accidents of one or two type groups).

8. EVALUATION OF COLLISION DIAGRAMS FOR SAFETY IMPROVEMENTS

8.1. General introduction

Collision diagrams provide a comfortable, yet fast and brief overview of the substantial characteristics of accidents that have occurred at a particular site or road section. The main principle governing how to identify deficiencies in road design that contribute to accidents is to search for common accident patterns in the analysed collision diagrams. The more often that the pattern is repeated in the diagrams, the greater the probability is that the identified problem or shortcoming in the infrastructure is crucial to the solution. This relationship is also valid vice versa – the more varied and differentiated the accident characteristics are, the lower the chances are that the next accident can be avoided with the help of traffic engineering measures only.

The basis for the accident analysis is the accident type classification made according to the road accident typology catalogue. It is also necessary to involve other characteristics in the analysis, e.g.:

- a greater number of road accidents in wet conditions (or other difficult adhesion conditions),
- a greater number of road accidents at night or dusk,
- accidents that involve only certain vehicle types (exclusively or predominantly motorcycles, heavy vehicles, busses,....),
- accidents that involve specific types of road users (beginners, elderly people, children, foreigners.....),
- accidents that occur during a certain time period (e.g. at darkness, dusk, in winter, summer, at sunrise, sunset, on a certain day of the week, etc.).

Detailed observation of the accident site and traffic monitoring at the site after the collision diagrams are drawn are vital. The accumulation of accident types substantially reduces the range of possible deficiencies which the road engineer must focus on during the site visit.

If the contributory factors related to road geometry are not clear from the analysis of the collision diagrams, detailed accident reports should be studied and all available additional information of the accident circumstances should be assessed. In case the mechanism of the accident origin is still unclear, an expert analysis need be carried out. According to experience, this is true in about 5% of cases; in other cases collision diagrams and information obtained from accident reports are sufficient enough to analyse the investigated location.

8.2. Practice Example

This is a black spot wherein pedestrians are involved. From the collision diagrams it is possible to easily find that most accidents occur when pedestrians are approaching the crosswalk from the right side, and most of accidents occur when the surface is wet. The analyst's task now is to investigate and observe this black spot in the appropriate accident conditions, i.e. at the time when the surface is wet; and develop a hypothesis about the reason why the pedestrians who approach from the right side are more at risk than those who approach from any other direction. Explanation may include for example:

- water drainage on the right side of the pavement is poor, so pedestrians concentrate on negotiating the puddle; rather than paying attention to oncoming cars,
- the speed in one direction may be higher than that in the opposite direction, which in combination with poor adhesive characteristics or road grade may lead to accidents during rainstorms,
- the placement of the pedestrian crossing may be problematic for motorists in one driving direction (i.e. placement behind instead of before an intersection), causing accidents in combination with the poor visibility of crosswalk markings during rainstorms.

8.3. Before/after graphic comparison

If there are some road safety measures implemented on a certain blackspot based on road accident analysis, the trends in road accident frequency have to be monitored further, and evaluated. It is necessary to find out, with the help of before/after analysis, if the measure really helped to reduce the number of road accidents (or accident consequences). The road accident analysis should be carried out once again after a certain period of at least one year after the measure has been implemented. The effects of the implemented measures are found through comparisons of the collision diagrams of the black spot before and after the implementation of the measure (see FIGURE).

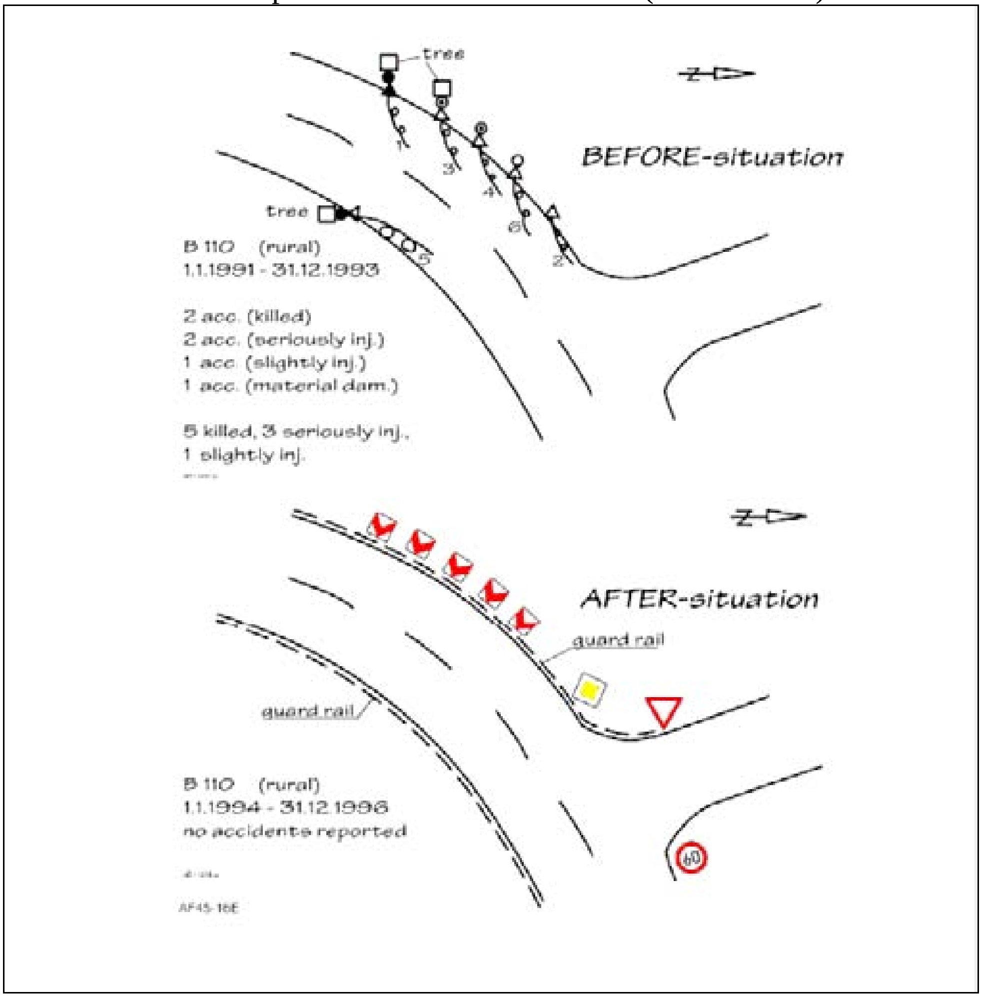


FIGURE 9: EXAMPLE OF BEFORE/AFTER EVALUATION

Appendix 6 shows examples of the use of the collision diagrams for the detection of road deficiencies and their removals. The aim of showing these examples is to demonstrate the usefulness of the collision diagrams for solving black spots in different European countries. Graphic forms may vary slightly in each country, but the principle, background and reasoning remain the same. In any case, collision diagrams are very effective tools, and are an integral part of an accident analysis throughout many countries because they enable the identification of abnormal accident patterns influenced by road design and the appropriate solutions for application.

9. REFERENCES

PIARC: Road Safety Manual, 2003

PIARC: Road Safety Inspection Guideline, Draft, March 2007

PIARC: Road Safety Audit Guideline, Draft, January 2007

Treat, J.R., at al: Tri-level study of the causes of traffic accidents, Final Report, 1979

Andres, J., at al: Metodika identifikace a řešení míst častých dopravních nehod, CDV, 2001

Derriks, H.: Under-reporting of road accidents, 3rd IRTAD Conference, Brno, 2006

EU High-Level Expert Meeting: Infrastructure Safety, Vienna, 2006

Gutoskie, P.: The availability of hospitalised road users data in OECD countries, 3rd IRTAD Conference, Brno, 2006

Mikulík, J.:Global Collission Database Standards: Benchmarking Road Safety Standards, Apeldoorn, 2004

Mikulík, J.: Road Safety Management and Data Systems: PIARC International Road Safety Seminar, Beijing, 2005

Road Safety Audits: PIARC Technical Committee on Road Safety (C13), 2001, Publication 13.02.B.

Proposal for a Directive of the European Parliament and of the Council on Road Infrastructure Safety Management: Brussels, 2007

Ross Silcock (TRL): Road accident data systems, Asian Development Bank

Taroyan, T.: Development of a good practise manual on road traffic data collection, WHO, 3rd IRTAD Conference, Brno, 2006

ANNEX 1: NETWORK SAFETY MANAGEMENT -NSM (GERMANY)

A. Content

By using the Network Safety Management method, it is possible to determine where improvements in the road network due to safety deficits (many/serious road accidents) are required. The result of the safety analysis provides important isolation of possible deficiencies in road design, layout, or condition, and, thus, supplements considerations about road network design from the objective of regional, environmental, and transport planning. The method is not intended to take the place of a fundamental analysis of accident occurrences, or consideration of safety goals with other road-planning objectives within the framework of an economic feasibility study. The method distinguishes between safety analyses for

- road networks that primarily serve a linking function within or outside of urban areas
- road networks in built-up areas limited by roads that primarily serve a linking function

B. Parameters for safety evaluation

- **Rates**

The number and severity of road accidents on a road network section essentially depend on average daily traffic volumes and the traffic composition, the design features (cross section, junction type and form, and alignment), the roadside furnishings (roadside design, traffic signs, protective facilities, traffic installations and markings), the road condition (structure and surface condition), and the roadside environment (lateral obstacles). The quality of the road section is described by accident rates and accident cost rates as related to road safety. Accident rates describe the average number of accidents along a road section with a ‘kilometrage’ of 1 million vehicle km. Accident cost rates describe the corresponding average costs to the economy as a whole, as the result of road accidents which have occurred along this road section with a ‘kilometrage’ of 1000 vehicle km.

- **Densities**

Accident densities respective of accident cost densities describe the average annual number of accidents respective of overall costs incurred to the economy by road traffic accidents that occur over a 1 km length of the road section. The density can be calculated as a ratio of the annual number of accident respective of accident costs and length, or can be calculated as the product of rate and traffic volume of the road section on which the accidents occurred. The density is thus a measure of the (length-specific) frequency at which accidents have occurred during a specific period over a specific road section.

C. Analysis of the existing accident situation

- **Period under review**

Adequately large accident data sets must be available for an analysis of the existing road safety. Basically, it must be aimed, therefore, at making as lengthy a period of review as is possible. The accident occurrence should, however, be as up-to-date as possible, so that peripheral influences resulting from general trends and changes do not have an impact on the informative value. In Germany, experience has shown that a period of 3 years should be scheduled for an appropriate consideration of serious injury accidents (accidents with fatalities or serious injuries) within the framework of road network evaluations.

- **Calculation of accident costs**

For each road section within the network of roads that primarily serve a linking function responsibility within the network of roads primarily used for residential purposes, the annual average accident costs must be calculated. These are the sum of the costs of personal injury accidents and the costs of damage-only accidents. This means that the annual average accident costs can only be calculated depending on the available damage-only accident data on the basis of 2 variants:

(1) Only the personal injury accidents and the serious damage-only accidents are known (general case)

(2) All accidents recorded by the police are known, i.e. also other damage-only accidents

D. Road networks with a linking function

- **Section length**

Road sections should be as long as possible so the safety evaluation leads to informative results. Basically, there are two possible ways of dividing the road into sections:

- on the basis of the network structure
- on the basis of the accident occurrence.

Dividing the road into sections on the basis of the network structure is appropriate if a visualization of the accident occurrence on the road network is not available, or the accident occurrence is to be analyzed in interaction with other influencing parameters (e.g. road improvement standards; accessibility) in the road network (limiting the road sections by network nodes and/or town/city boundaries and/or road sections that are characterized by greatly differing traffic volumes or cross sections). Dividing the road into sections on the basis of the accident occurrence is appropriate if a visualization of the accident occurrence (three-year maps of the serious injury accidents) is available, and no other section demarcations are required on the basis of a joint consideration of various influencing parameters. A section with a number of serious injury accidents, = 3 or less, is combined with a neighboring section. Alternatively, the period under review can be prolonged. This procedure is advisable only for particularly important sections owing to the major complexity and effort involved. Dividing into sections is even appropriate if the influence of the change by 1 serious injury accident leads to a situation in which the accident costs change by less than 20 % on the section under review. In such cases (primarily in urban areas), the number of accidents with minor injury and of damage-only accidents largely determines the result.

- **Safety potentials**

The safety potential of a road section is defined as the difference between the accident cost (number and severity) of those accidents that could be expected if the section has design characteristics that are in accordance with the general design guidelines and the current accident costs. Although, it must be noted that this potential cannot be reached in any individual case of best practice design. The realized safety improvements in the case of reconstruction can be higher as well as lower than the safety potential. The parameter for the safety potential is the difference between the current accident cost density of the section accident cost density within the period under review, and the basic accident cost density. The existing accident cost density is calculated, for a network section, from the average annual accident costs, divided by the section length.

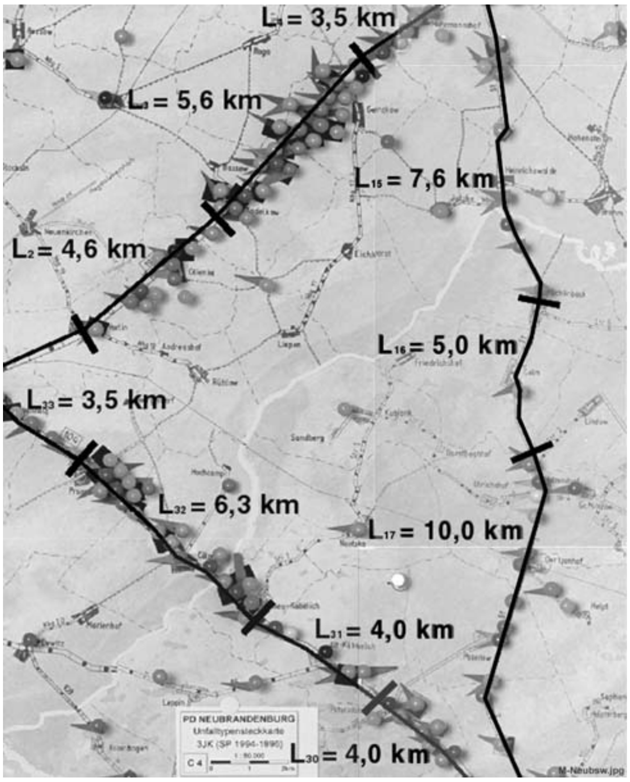


Figure 1- 1: Dividing the road into sections on the basis of accident occurrences (3-year accident type map of serious injury accidents)

- **Basic accident cost rates**

Basic accident cost rates for major urban roads, rural roads and motorway personal injury accidents, serious damage-only accidents, and all damage-only accidents are recorded by the police on an evaluation basis. The basic accident cost density represents the anticipated average annual number and severity of road accidents (represented by the accident costs) per kilometer, which can be achieved by a design of average safety in accordance with the design guidelines of the given average daily traffic. The basic accident cost density can be calculated as the product of the basic accident cost rate and the average daily traffic. If the traffic volume differences within a network section are very large, and there are sufficient accident data for the resulting subsections, the section should be subdivided.

- **Accidents at junctions**

Accidents at intersections that form sections boundaries should generally be assigned to the adjoining sections. A distinction must be made in this case on the basis of how the division into the sections was done:

  - If the road was divided into sections on the basis of the network structure, the accidents should be assigned to the adjoining sections in accordance with the information in the road accident registration sheet.
  - If the road was divided into sections on the basis of the accident situation, the accidents of the intersection should be assigned to the section with the largest (visual) accident density of the serious injury accidents. If necessary, splitting the accident between two adjoining sections would be practical if the accident density of the serious injury accidents is approximately of the same order of magnitude.

If the intersection is an accident black spot involving serious accidents and if the sections adjoining the intersection are (virtually) free of serious injury accidents, it may be advisable to conduct a special analysis on such intersections within the framework of the local accident investigation.

- **Ranking safety potentials**

If the sections of the road network are ordered on the basis of the magnitude of the safety potential, the ranking of those sections in the road network having a particularly high need for improvement and a particularly high improvement potential is obtained. Within a road network a ranking can be formed for the various sub-networks:

  - continuous road segments (rural sections and cross town links),
  - road sections inside or outside of built-up areas,
  - different linking function levels or road authorities.
  - road networks primarily used for residential purposes (areas)
  - demarcation of residential roads

Only the road accidents in an area are the subject of the consideration for evaluation of the road networks in such areas, i.e. not the accidents on major road tangents and, therefore, neither are the accidents at the access junctions of the residential road network to the major roads. Figure 1- 2 shows the network demarcation for a residential road network in the one-year map of all accidents recorded by the police over one year, and the related three-year map of personal injury accidents.

- **Accident cost densities**

The average accident cost density for each residential road network under consideration of the local authority serves to describe the safety deficits in residential areas. The average accident cost density is calculated from the average annual accident costs of an area, divided by the length of the road network in the area. The annual accident costs incurred on average in an area depends, essentially, on the size of the area if all other boundary conditions are the same. Since the intention of the deficiency analysis is not to define urgencies on the basis of area sizes, and since it is intended to determine areas with the greatest danger, the accident cost density provides a suitable criterion.

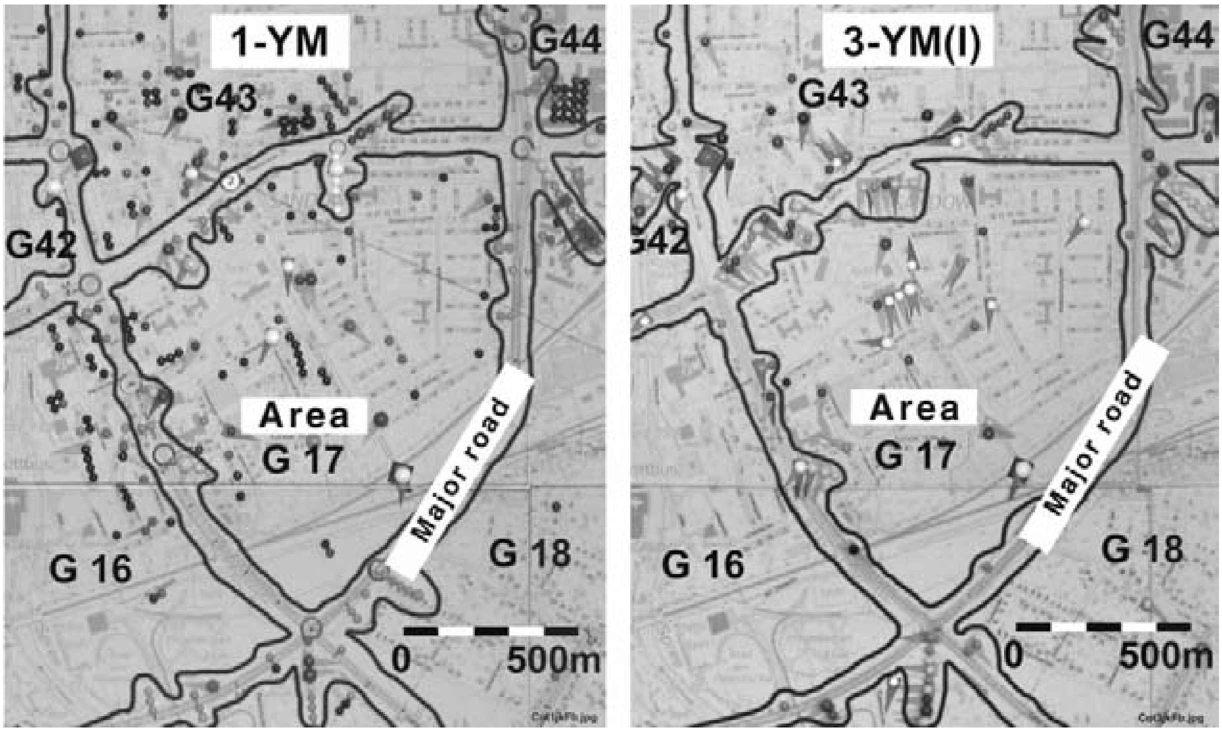


Figure 1- 2: Sections from accident type maps of all accidents that police recorded in one year (1-YM) and of personal injury accidents from three years (3-YM(I)), in addition to demarcation of the accidents in areas, from those on major roads

Recommendation pointers to improvement of road safety in networks

In order to develop suitable measures for road section assignment to huge safety potentials, or for residential road networks with high accident cost densities, a comprehensive analysis of the accident structure should be carried out for the section or network under review. Therefore, it is advisable to determine conspicuous accident locations.

ANNEX 2:
ASSESSMENT OF ROAD SECTIONS SAFETY (THE CZECH REPUBLIC)

Assessment of the unsafe road sections of the road network is currently based on the **Topographic Overview of Road Accidents** (TORA) managed by the Police of the Czech Republic. This overview contains data regarding category I and II roads from the last two years.

An accident site is registered in the TORA according to the GPS road localization method in 10 meter intervals. To carry out the assessment in terms of road accident rates, the road is divided into 250m long sections of 10 m intervals (e.g. km 0.000 – 0.250 + km 0.010 – 0.260 etc.). For these road sections, TORA then summarizes the number of acccident fatalities, of those accidents where there are serious or slight injuries, and accidents with only material damage.

Thus, the economic evaluation of losses from road accidents in the road section is based on the current annual calculation of socio-economic losses.

Example of socio-economic losses from road accidents (2002):

• fatalities	8,099 k CZK	(280 €)
• serious injuries	2,796 k CZK	(95 €)
• slight injuries	301 k CZK	(10 €)
• material damage only (on average)	87 k CZK	(3 €)

Then, the loss total from two years will create a database to hold road localization and total losses statistics which refer to the amount of losses per each 250 m road section at 10 m intervals. The above mentioned procedure allows the annual updating of the classification levels on the basis of road accident rate trends and inflation levels.

A five-level scale has been created for assessment of the road accident rate:

Level 1 – satisfactory road,
Level 2 – slight problems, acceptable without further countermeasures,
Level 3 – intermediate relevance, road safety measures are to be implemented in the future,
Level 4 – high relevance, urgent implementation of road safety measures is necessary,
Level 5 – conflict road section, immediate implementation of road safety measures is necessary, traffic restrictions possible.

Each level refers to the so-called Index of Losses from Road Accidents, i.e. total losses, including material damage accidents, per road length unit and time unit.

The staging point for classification of individual levels is level 2, which refers to the current Index of Losses from Road Accidents per 250 m-long road sections for the last two years. Calculation of the Index of Losses from Road Accidents, as current quality levels, is shown in FIGURE 2-1

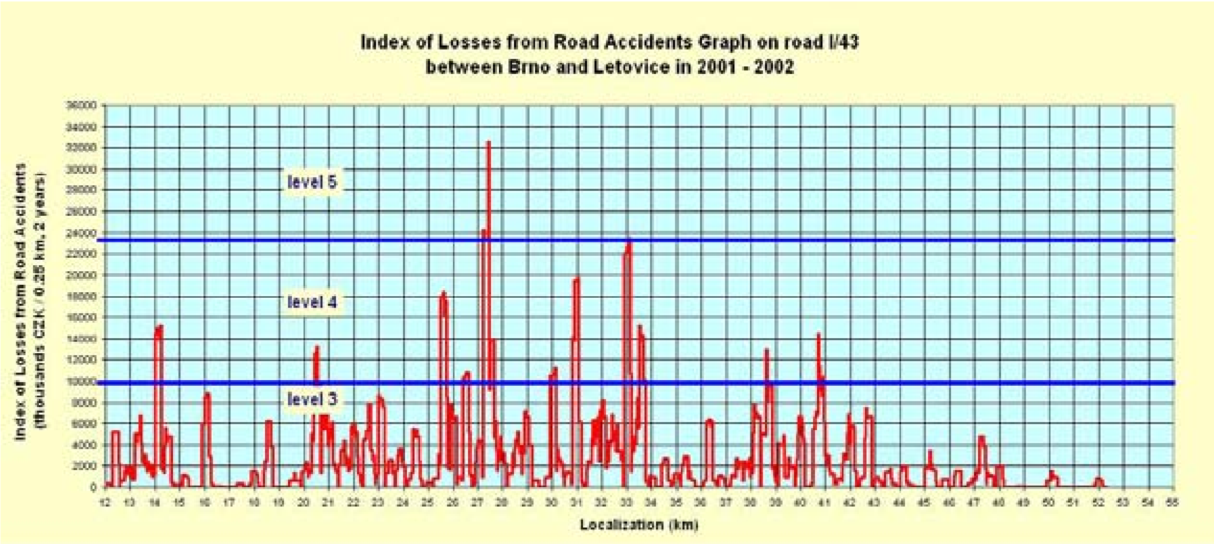
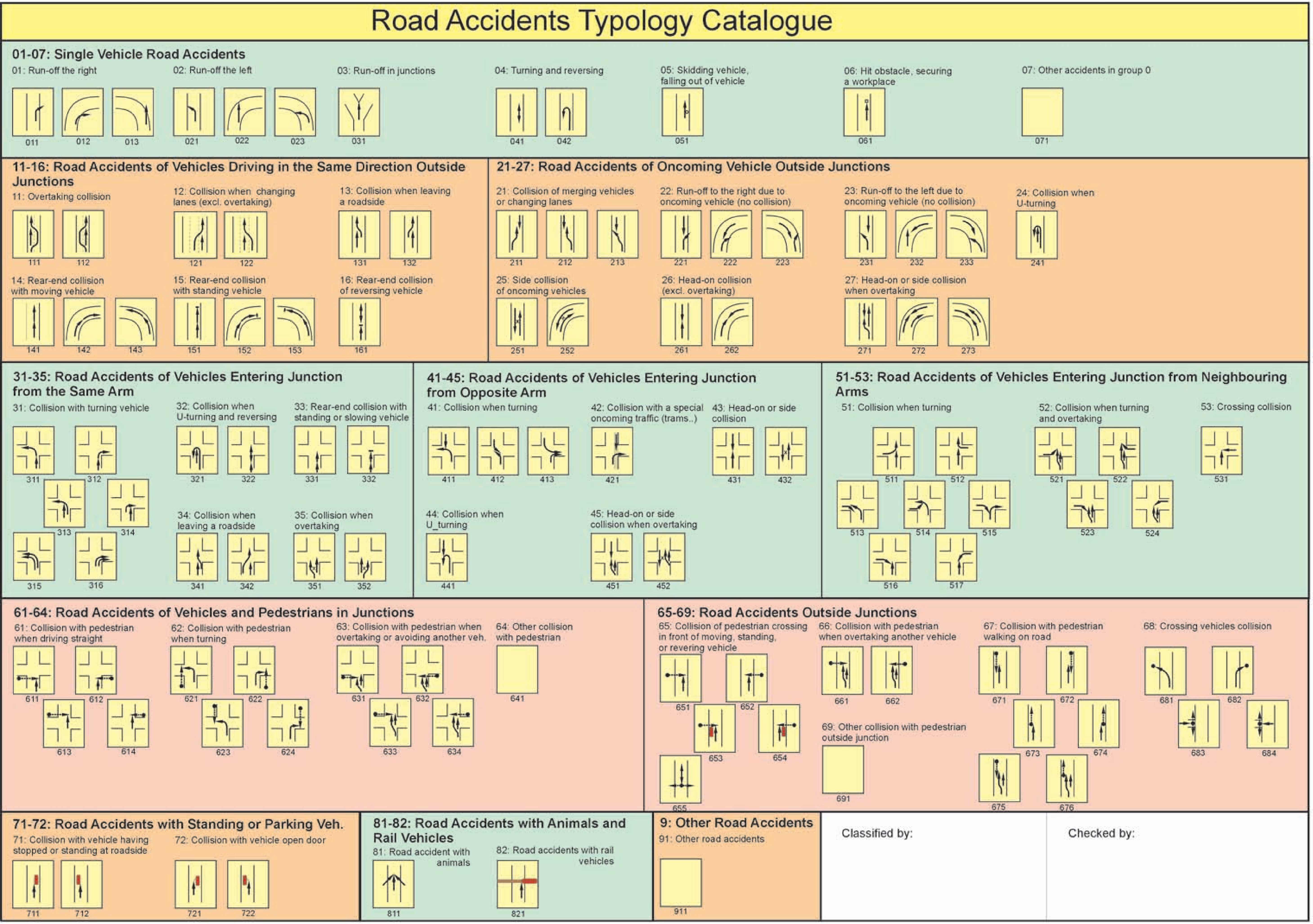


FIGURE 2-1 : INDEX OF LOSSES FROM ROAD ACCIDENTS

Effective since 14th January 2003



Designed by: Jitka Rokytová

ANNEX 4:
POSSIBLE LINKS AMONG ACCIDENT TYPES, CAUSE OF ACCIDENT AND LEAD DEFICIENCY

Type Group 0
Personal road accidents

Major Accident Causes
Speeding

Road Deficiency
Non-homogeneous roadways, sudden changes in road arrangement, sudden changes in road alignment, poor optical alignment, inappropriate road cross-section, sudden change of road surface, poor quality of road surface.

Potential Improvement Measures
Removal of non-homogeneous road sections, improved optical parameters of horizontal curves, corrected road cross-section, reconstruction of road surfaces, speed reduction measures, appropriate road signing and marking.

Type Group 1
Road accidents of vehicles driving in the same direction outside of junctions

Major Accident Causes
Speeding

Road Deficiency
Major difference in vehicle speeds, short following distances between vehicles, inappropriate horizontal and vertical road alignment, poor distance estimation, poor road surface.

Potential Improvement Measures
Construction measures to reduce speed, road reconstruction, reconstruction of road surface, appropriate road signing and marking.

Type Group 2
Road accidents of oncoming vehicles outside of intersections

Major Accident Causes
Speeding, illegal or inadvisable overtaking.

Road Deficiency
Non-homogeneous road, optical illusions, poor distance estimation, inappropriate road signing and marking.

Potential Improvement Measures
Construction measures to reduce speeds, road reconstruction (greater visual distance of oncoming vehicles in horizontal curves), reconstruction of road surface, appropriate road signing and marking.

Type Group 3
Road accidents of vehicles entering junction from the same corridor.

Major Accident Causes
High speed of vehicles entering junctions, insufficient lane width distance between vehicles, blind angles.

Road Deficiency
Inappropriate junction layouts, ambiguous channelization – inappropriate guidance in junctions, single-track vehicles (motorcycles, ect.) overtaking in junctions.

Potential Improvement Measures
Easily decipherable junction layouts, consistent road marking and signing with conspicuous design information, or construction measures (e.g. traffic islands) delineating vehicle paths.

Type Group 4
Road accidents of vehicles entering intersections from opposite corridors.

Major Accident Causes
Failure to give way to oncoming vehicles, psychological pressure on drivers, erroneous speed and distance estimations of oncoming vehicles.

Road Deficiency
Inappropriate intersection layout, ambiguous channelisation – inappropriate guidance information.

Potential Improvement Measures
More decipherable junction layout, consistent road marking delineating vehicle paths, installation of turning lanes (particularly for left turning), traffic signal installation.

Type Group 5
Road accidents of vehicles entering junction from neighbouring corridors.

Major Accident Causes
The high speed of vehicles entering intersections, insufficient sight distance, effects of psychological rights of way, failure to comply with traffic light signals in traffic-controlled intersections.

Road Deficiency
Inappropriate intersection layout, contradiction between actual and psychological right of way, obstacles in sight triangles, poor intersection lighting, ambiguous channelization – inappropriate guidance at intersections, obscured road signs, insufficient visibility of road signs.

Potential Improvement Measures
More conspicuous intersection layout, consistent road marking or construction measures (e.g. traffic islands) delineating vehicle paths, installation of clear road signing and marking.

Type Group 6

Accidents between vehicles and pedestrians.

Major Accident Causes
Failure of drivers or pedestrians to comply with traffic light signals, insufficient optical contact, disrespect for pedestrian rights of way, forcing the right of way inappropiately.

Road Deficiency
Insufficient layout of pedestrian pavements and crossings, insufficient separation of pedestrians from motorised traffic, missing pavement width, missing refuge islands.

Potential Improvement Measures
Sensible layout of pedestrian pavements and crossings at heavy pedestrian traffic sites, installation of refuge islands to protect pedestrians, construction measures to improve visibility, traffic calming at the perimeters of pedestrian zones.

Type Group 7

Road accidents with standing or parked vehicles.

Major Accident Causes
Driver inattention, inappropriate location of parking sites and their exits.

Road Deficiency
Inappropriate widths of road shoulders and parking lanes, inappropriate location of parking site exits, poor cycle lane geometry.

Potential Improvement Measures
Better separation of moving and standing vehicles, minimized numbers of parking site exits and their concentration on single collector roads.

Type Group 8

Road accidents with animals and rail vehicles.

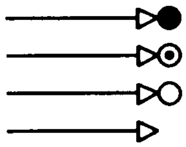
Major Accident Causes
Failure to comply with warning light signals announcing oncoming rail vehicles.

Road Deficiency
Existence of crossings at grade on roads with high traffic volumes, insufficient sight distances, faulty warning light signals, insufficient fenceing to prevent animals from roads.

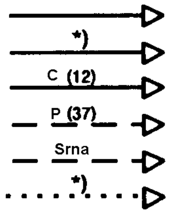
Potential Improvement Measures
Building of grade-separated crossings of roads and railways, upgrading technological equipment at railway crossings, improved sight distance, installation of fences along roads at sites of higher animal traffic, building bio-corridors.

ANNEX 5:

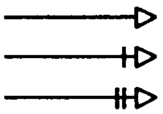
SIGNS AND SYMBOLS USED IN COLLISION DIAGRAMS (THE CZECH REPUBLIC):



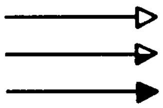
Accident consequences
Death of a person
Seriously injured person
Slightly injured person
Material damage accident



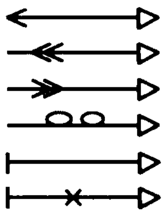
Types of vehicles or road users
Personal vehicle
Other motor vehicle
Cyclist (age)
Pedestrian (age)
Domestic or wild animal
Indirect accident participant *)



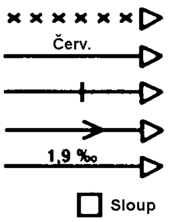
Road surface condition
Dry
Wet
Ice, frost, snow



Light conditions
Daylight
Dusk, dim light, dawn
Darkness



Specific movement
Reversing
Slowing
Accelerating
Skidding or aquaplaining
Stopped due to outside conditions
Stopped, parked



Other information
Traffic signals off
Red, red + amber, amber
Driver was aware of right of way
Driver was unaware of right of way
Drinking
Obstacle on road or at roadside

*) Type of vehicle or road user (excl. passenger cars) are shown on the arrow stick. The following abbreviations are used: N (heavy vehicle), NS (Truck-trailers or Semi-trailers), BUS (bus), MOTO (motorcycle), MOP (moped), C (cyclist), P (pedestrian), TRAM (tram), T (tractor). Other road users are shown with spelled words (towed vehicles, handcart, production machinery)

ANNEX 6:
EXAMPLES OF COLLISION DIAGRAMS FOR DETECTING ROAD DEFICIENCIES IN ROAD DESIGN AT HIGH RISK SITES

Example No. 1 (the Czech Republic):
Pedestrian crossing on a main urban route

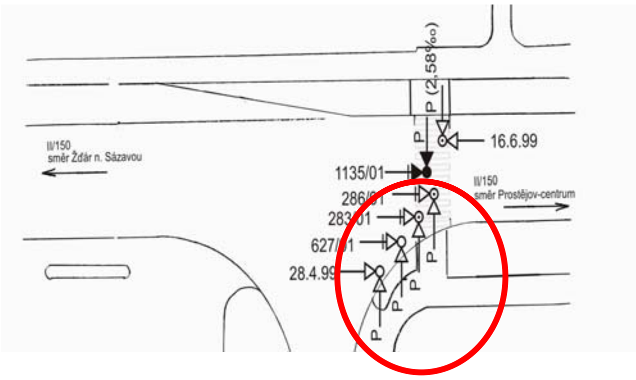
The unsuitable design of a pedestrian crossing led to the accumulation of accidents with pedestrians. Six accidents involving pedestrians were recorded in a period of 3 years with one serious injury, and 3 slight injuries. After rectification, which was based on collision diagrams analysis (see Figure 6-4), no accidents have been recorded in the last 3 years. The situation “before” is illustrated in Figures 6-1, 6-2 and 6-3.

Situation “Before”

Figure 6-1: „Invisible“ crossing

Figure 6-2: Absence of a pedastrian island

Figure 6-3: Crossing is too long



Main group of accidents

Figure 6-4: Accumulation of accidentss

The following safety problems were identified during an analysis and site visit:

- Unsuitable drainage, water staying on the road (pedestrians trying to deal with the water obstacle fail to observe approaching vehicles)

- The crossing is unsuitably placed, and is abrupt from the psychological point of view of motorists – see Figure 6-1 (road marking is insufficiently distinct for approaching drivers. The situation worsens in wet conditions)

- The crossing is too long (9 m), and not equipped with a traffic island– see Figure 6-3 and Figure 6-2

- The speed of passing cars is too great

Accident analysis conducted by using the collision diagrams showed a clear accumulation of accidents with similar contributory factors (see Figure 6-4). According to this analysis, the following solutions were suggested and implemented (see Figure 6-5 and 6-6).

Solution :

- Repair water drainage

- Protect pedestrians by implementing the traffic island

- Improved street lighting, pedestrian crossing lighting, accessories for blind people

After

No accidents in the following 3 year period

Figure 6-5 and 6-6: New appearance of the pedestrian crossing

Example No. 2 (the Czech Republic):

Junction Treatment

An intersection of of inadequate design between two second class roads and one urban street, which was causing problems related to limited sight distances. Analysis of collision diagrams showed the clear accumulation of a particular accident type.

Figure 6-7 and 6-8: Insufficient sight distances

Safety problems identified:

- Insufficient sight distances (see Figure 6-7 and 6–8)
- Improper shape of traffic island
- Improper angle of crossing
- Too many potential collision points (points where a crash is very probable)
- Areas of missing pavement

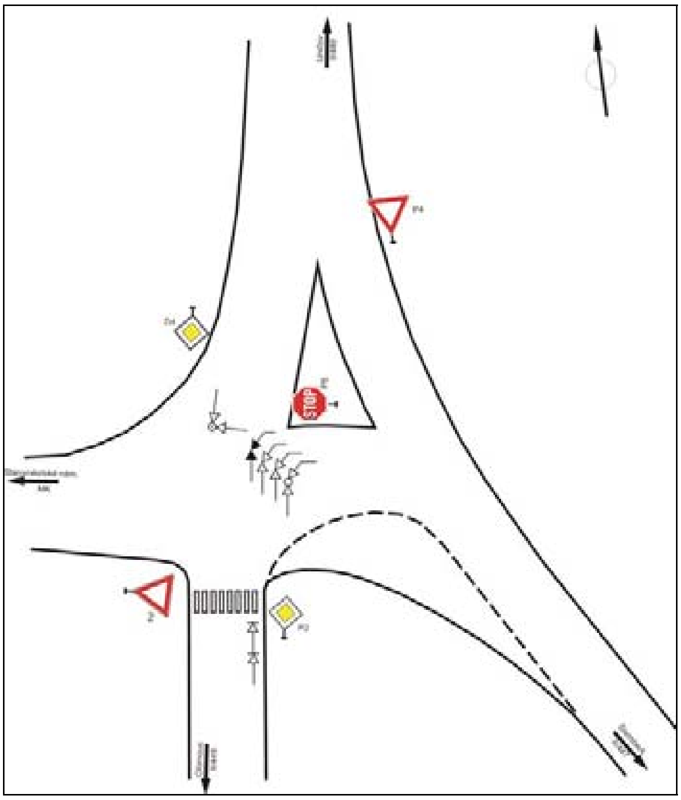


Figure 6- 9: Collision diagrams and cumulation of accidents

Implementation of the following measures were recommended:

- Improvement of sight distances (displacement of crossing borders)
- Improvement of the shape of traffic island and the angle of crossing
- Rebuilding the crossing into a roundabout would solve the majority of the above mentioned problems

Example No. 3 (the Czech Republic): Junction in a rural area

This intersection of second and third class roads shows typical road safety deficiencies. The whole area of the intersection is too large and unfragmentated. The traffic is not canalized and moves too quickly. The analysis of collision diagrams of accidents during the 1999 – 2001 period (see Figure 6-12) showed a clear accumulation of accidents on one approach (7 events, although the total number of accidents in the entire intersection is 13 for the period).

Figure 6-10 and Figure 6-11: Safety deficiencies

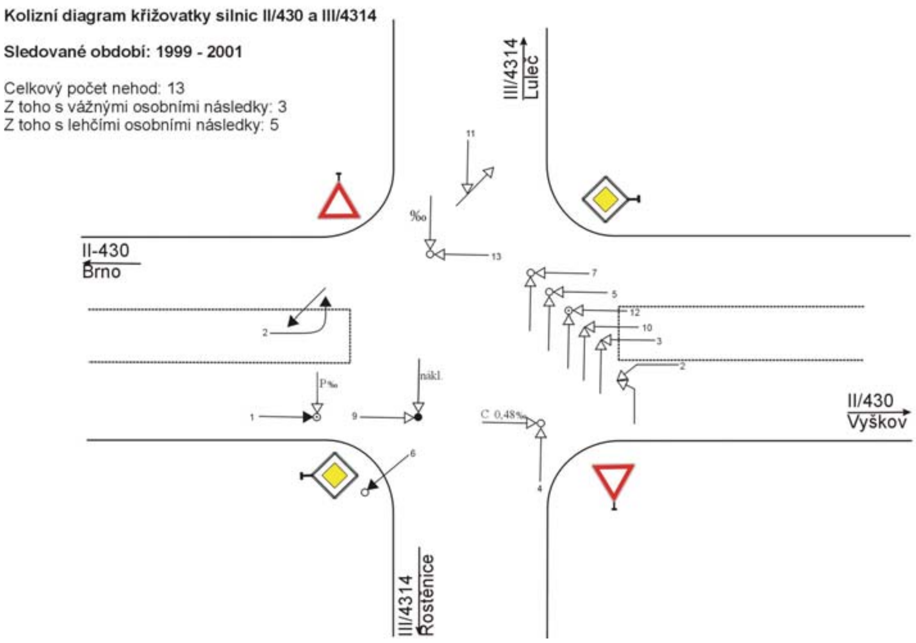


Figure 6-12: Collision diagrams

The following safety problems were identified:

- Accident occurance is spread throughout the entire large intersection area
- High speeds on the main road are supported by the intersection design, which increase the potential of accident occurrence
- Unsuitable sight distances. There is a danger of a hidden car behind an obstacle if the driver on the secondary road enters the junction without stopping.

Implementation of the following safety measures were recommended:

- Reduction of speed on the main road by using traffic signs to reduce the risk of serious accident occurrence
- Replace the signs 'Give Way' with 'Stop' signs to prevent hidden car affects
- The most suitable solution (also the most expensive) would be to redesign the crossing into a roundabout.

Example No. 5 (the Czech Republic): Junction in semi-urban area

The analysed intersection is located at the entrance to a town. The original design is shown in Figure 6-13. It has the typical shortcomings:

- The angle of crossing is not suitable
- The area of whole junction is too large and is not fragmented by traffic islands

The collision diagram for the 2000 – 2002 period was analysed. 22 accidents occurred on the site during this period, mainly only resulting in material property damage.

Before

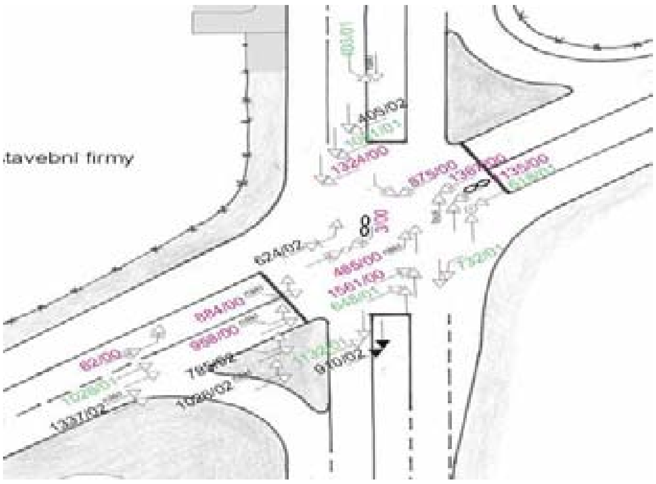


Figure 6-13 and Figure 6-14: Original shape of the junction and collision diagrams

A reconstruction into a roundabout was suggested and implemented. The final design is shown in Figure 6-15 and 6-16.

After

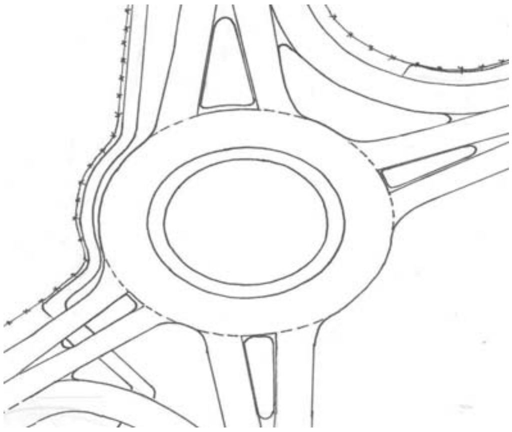


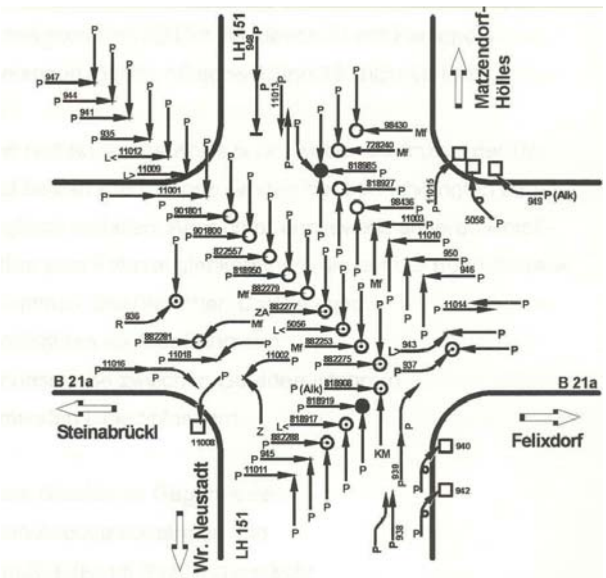
Figure 6-15 and Figure 6-16: New design of the junction

ILLUSTRATIVE EXAMPLES

The following examples are from the book "Handbuch der verkehrssicheren Straßengestaltung" by Konrad Pfundt. The collision digrams of typical intersection lay-out "before" and "after" treatments are showed here in order to demonstrate the clarity of collision diagrams and the effectiveness of the treatment in addition.

Example No. 6 (Austria)
Rural intersection with high accident rates

Before



After

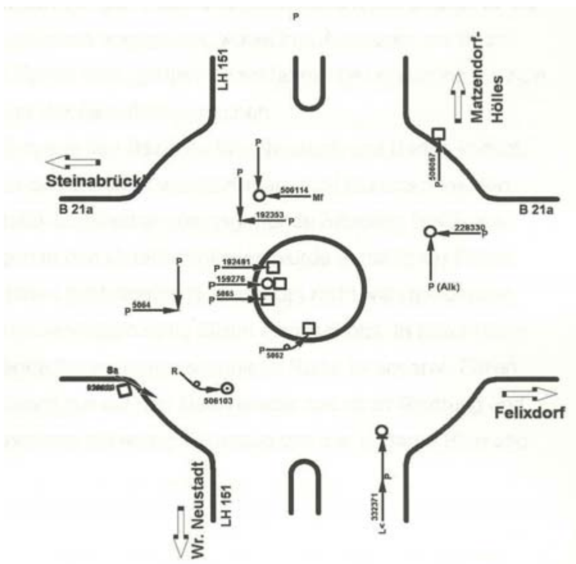


Figure 6-17 and Figure 6-18: Collision diagrams „before" and „after" reconstruction

Safety problems:

- High speeds on the main road imvokes serious accidents
- High traffic volumes on both roads
- Large collision area for potential events

Solution:

- Redesign crossing as a roundabout
- Standard improvements are not sufficient enough in this case

Example No. 7 (Germany):
Intersection with signs indicating 'yield', or 'give way'

Before

Majority of traffic accidents caused by an erroneous interpretation of the "give way" sign.
It is not distinctively clear who should give a way – phenomena of "psychological give way".

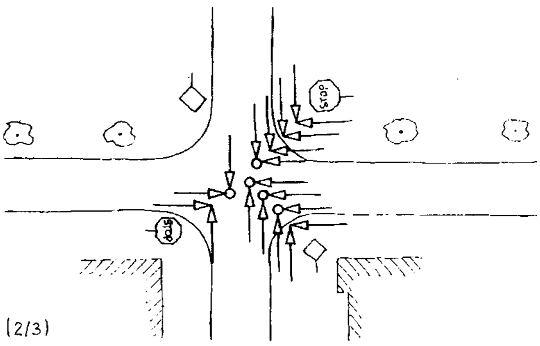


Figure 6-19: Collision diagrams „before" reconstruction

After

The problem was solved by the replacement of the intersection borders and by implementing the traffic islands.

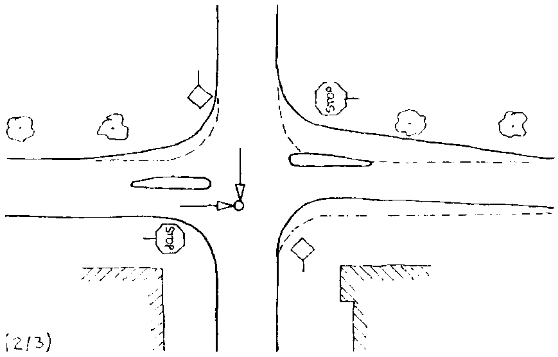


Figure 6-20: Collision diagrams „after“ reconstruction

Example No. 8 (Germany): Intersection equipped with ‘yield’ or ‘give way’ signs

Before

Majority of traffic accidents caused by unsuitable “give way” signing. It is not distinctively clear who should give way – a phenomena of “psychological give way”

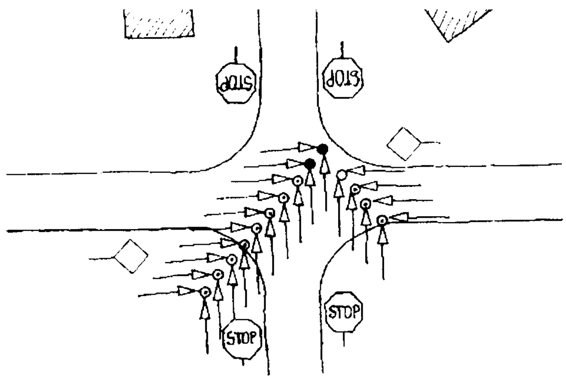


Figure 6-21: Collision diagrams „before“ reconstruction

After

This problem was solved by the placement of additional traffic signs above pavement. The obligation to “give way” was emphasized and is more clear now.

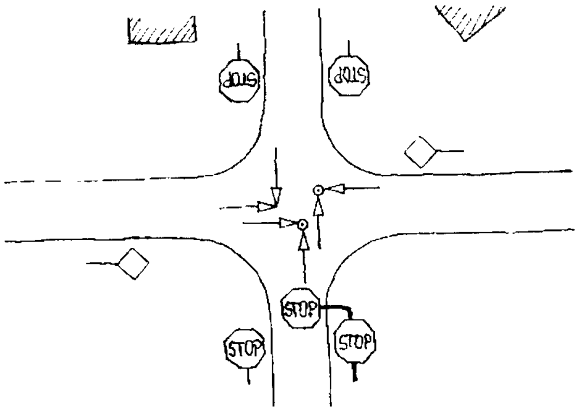


Figure 6-22: Collision diagrams „after“ reconstruction

Example No. 9 (Germany): Intersection equipped with "give way" signs, main road is turning to right

Before

The direction of the main road is turning. No additional measure to increase driver's attention is used.

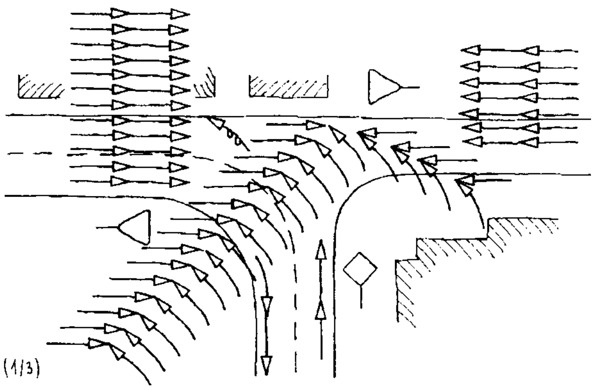


Figure 6-23: Collision diagrams „before" reconstruction

After

This problem was solved by the implementing the traffic islands and modification of the crossing borders. The obligation to "give way" was emphasized and is more clear now.

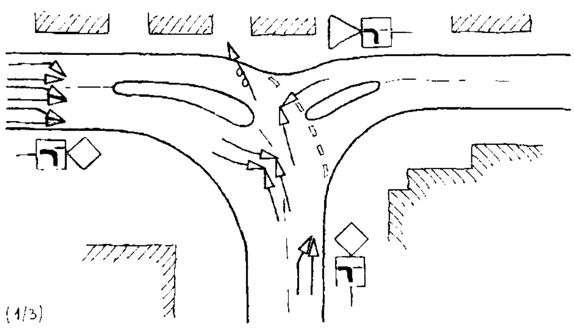


Figure 6-24: Collision diagrams „after" reconstruction

Example No. 10 (Germany): Intersection with wrong angle

Before

The awkward angle of the intersection arms caused an insufficient sight condition, especially for the driver who should give way from right side.

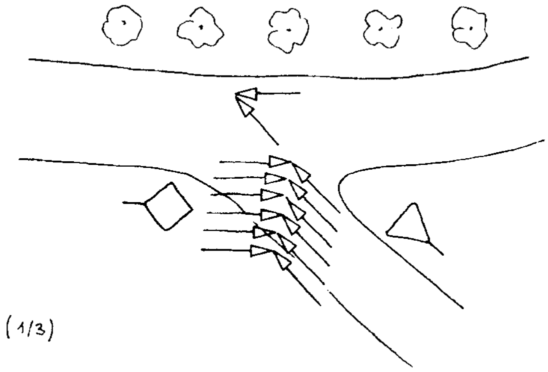


Figure 6-25: Collision diagrams „before“ reconstruction

After

The problem was solved after modification of the crossing borders and placement of a traffic island. Sight conditions and obligation to “give way” are clearer now.

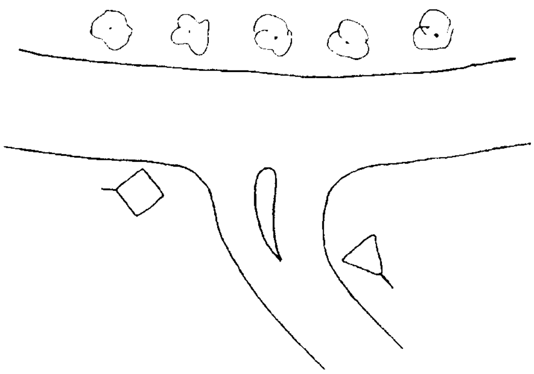


Figure 6-26: Collision diagrams „after“ reconstruction

Example No. 11 (Germany):
Intersection with improper parking on the middle traffic island

Before

Parking on the barrier traffic island shortens the sight distance for drivers giving way from the right side (contradiction between sight distance and speed).

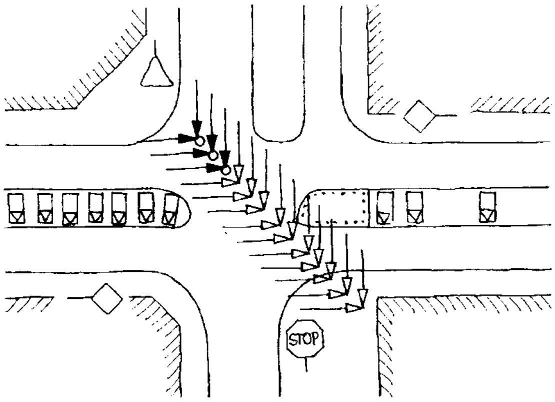


Figure 6-27: Collision diagrams „before“ reconstruction

After

Prohibiting parking on the middle track (prohibition of parking with the help of traffic signs and installation of concrete posts) helps to make the sight distance longer, and an avoidance of the majority of accidents

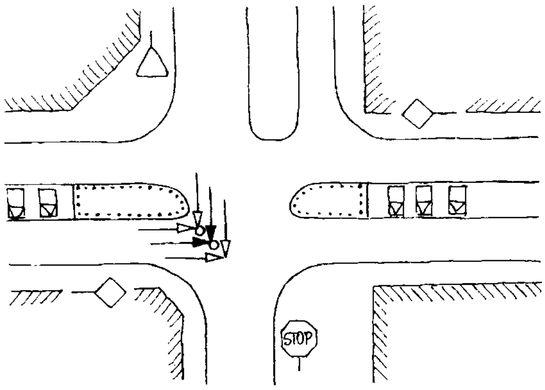


Figure 6-28: Collision diagrams „after“ reconstruction

Example No. 12 (Germany)
Accident curve

The following example demonstrates the effectiveness of stationary speed monitoring used in Germany as a treatment in the case of a particular accident prone curve (19 accidents in 36 months, 6 people were killed and 2 were seriously injured). After the treatment there were 5 accidents with no injuries in the following 24 month period.

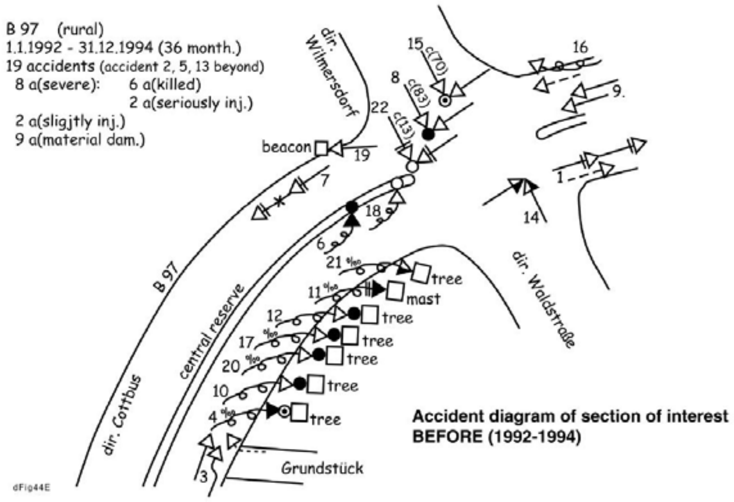


Figure 6-29: Collision diagrams „before“ reconstruction

Figure 6-30: Section of interest with stationary speed monitoring systém implemented

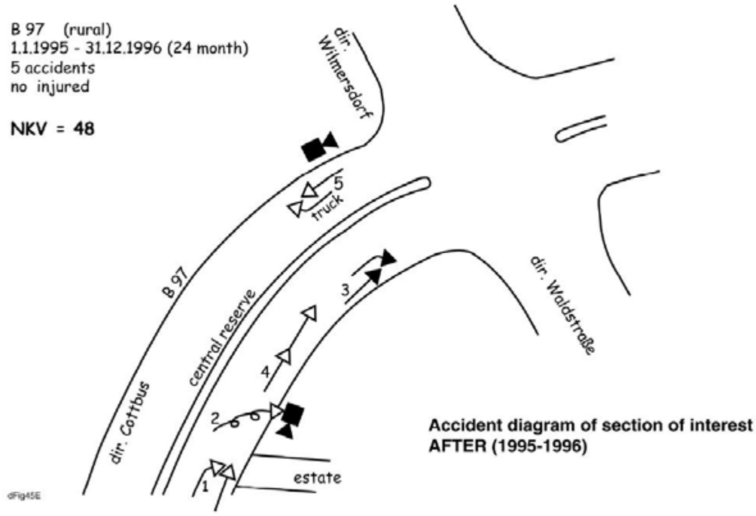


Figure 6-31: Collision diagrams „after“ reconstruction

Example No. 13 (South Australia)
T-junction

The following example shows the T-junction, which was rebuilt into a roundabout due to the high accident record from the eastern approach.

Figure 6-32 and Figure 6-33: Befor reconstruction - Looking west

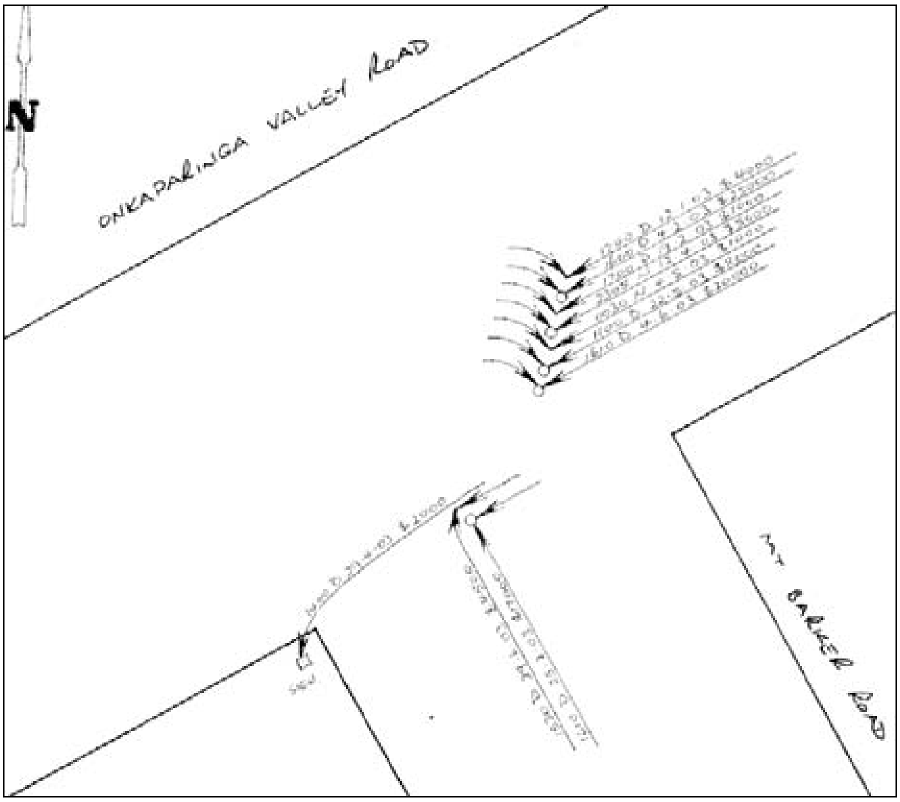


Figure 6-34: Collision diagrams „before“ reconstruction, year 2003

Figure 6-35: After reconstruction - Looking east , Figure 6 - 36: Looking west