THE NEW APPROACH OF ROAD INFRASTRUCTURE SAFETY MANAGEMENT – PRECONDITIONS, INSTRUMENTS AND EXAMPLES FROM EUROPE AND FROM DEVELOPING COUNTRIES

Dr.-Ing. Juergen Gerlach
University of Wuppertal, Germany
Department of Civil Engineering, Centre of Traffic and Transport
Institute for Road Traffic Planning and Engineering
jgerlach@uni-wuppertal.de

ABSTRACT

The infrastructure safety management focuses on the four procedures of a Road safety impact assessment, Road safety audits, Network safety management and Safety inspections. The Road safety impact assessment is a strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network, at the initial planning stage before the infrastructure project is approved. The Road safety audit is an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages from planning to early operation as to identify, in a detailed way, unsafe features of a road infrastructure project. The purpose of a Network safety management is to target investments to the road sections with the highest accident concentration and/or the highest accident reduction potential. Furthermore Road safety inspections are an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety as a preventive tool. This article describes the background of these instruments and gives examples and experiences of the implementation and application and of typical road deficiencies in emerging and developing countries, especially in Germany and Egypt.

1. INTRODUCTION

Road infrastructure is an important contributing factor in many severe accidents and managing its safety offers a wide scope for improvement. In that respect, the European Parliament published the Directive 2008/96/EC [1], which introduces a comprehensive system of road infrastructure safety management. Latest in the year 2010 the European member states implemented the system approach in their law and operate more or less with the specifications of the Directive. In other countries like the United States similar instruments still exist.

All over the world this new development is recognized and the whole system or parts of it influence the decisions for improving the road infrastructure with the aim of increasing road safety for all road users. However, the Directive is related to the trans-European road network only, Member States may and do also apply the provisions to the whole national, regional and local road infrastructure. Keeping in mind that severe accidents happen on interurban and rural roads and the most risks can be seen in urban roads, the development should be used by planning and maintaining the whole network.

The infrastructure safety management focuses on the following four procedures:

- Road safety impact assessment
- Road safety audit
- Network safety management (Ranking of high accident concentration sections and network safety ranking)
- Safety inspections

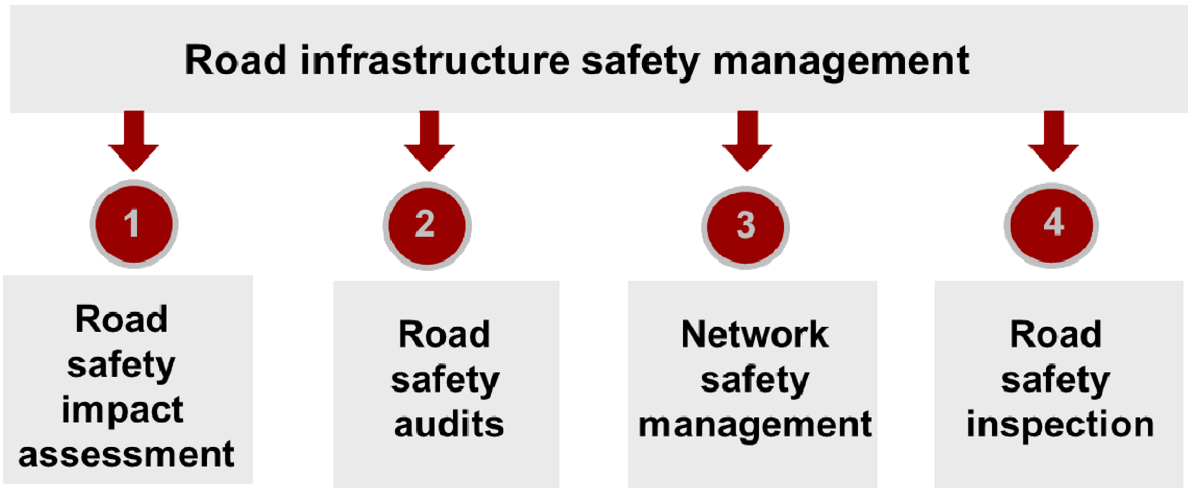


Figure 1: The four instruments of the Road infrastructure safety management

This article describes the background of these instruments and gives examples and experiences from the implementation and application in Europe and in developing countries or countries in transition, especially in Germany and Egypt.

2. ROAD SAFETY IMPACT ASSESSMENT

The Road safety impact assessment is a strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network, at the initial planning stage before the infrastructure project is approved. The instrument and the methods of a pro-active safety impact assessment are not established so far. The purpose is to demonstrate, on a strategic level, the implications on road safety of different planning alternatives of an infrastructure. The development of a methodology which allows a reliable forecast of accident rates for different solutions is not easy but more and more important especially in low and middle income countries, where the policies for land use and urban development are often leading to extremely unsafe road conditions with many victims especially of vulnerable road users. Their needs are regularly neglected by the transport and city planners.

For that reason Road Safety impact assessment has become a special focus of the Global Plan for the Decade of Action for Road Safety 2011-2020 [2] developed in order of the UN-General Assembly in several UN-Road Safety Collaboration meetings under the roof of the WHO. In the pillar 2 for safer roads and mobility, activity 2, the objective of “Promoting the needs of all road users as part of sustainable urban planning, transport demand management and land-use management by including safety impact assessment as part of all planning and development decisions” can be found..

The impact assessment is intended to be applied at the planning stage, often proceeding to a definite design for the scheme. A parallel to these two procedures can be seen in the Strategic Environmental Assessments (SEA) and Environmental Impact Assessments (EIA), which provide an estimate of the impact of possible schemes.

Scenario methods could be used to carry out a safety impact assessment. The elements of the assessment could be:

- Problem Definition,
- Description of the current situation and the „do nothing“ scenario,
- Formulation of road safety objectives,
- Analysis of impacts of the proposed alternatives,
- Comparison of the alternatives (including cost-benefit analysis) and
- Description of the best solution.

The starting point is the existing road network, the current pattern of traffic on that network, and the level of reported road accidents there. This information relates to a road network which is made up of roads of a number of types that have different road safety characteristics. Each road consists of junctions and stretches of road between the junctions, with associated traffic volumes, and numbers of accidents and casualties. Alternative scenarios to this current situation are the possible changes being studied in respect of the physical infrastructure and the associated traffic volumes in the road network in the future. If, for example, a new road is to be added to the existing network, the traffic and transport models can be used to estimate what this will mean for the traffic volumes throughout the network in the future.

The central step is to interpret these changes in terms of the impacts they will have on the numbers of accidents and casualties. To accomplish this, what are needed are quantitative indicators of risk (such as casualty rates per million vehicle-km) for each type of road, supplemented if possible by corresponding indicators for each type of junction. One way of obtaining such indicators is to estimate them at a national level and adjust them if necessary using data for the area in question. In addition, the design details like the cross section, the alignment, the road side features and all other elements which influence the performance of safety should be evaluated and taken into consideration. These kinds of information enable safety impacts to be estimated. In addition a Cost-Benefit Analysis could be used as a monetary valuation of safety (and other) impacts which are related to the costs of the measures.

At least the Impact Assessment should lead to an optimization where plans with road functions, road schemes or measures are changed in order to reach the optimal safety effect or the best cost/benefit ratio.

So far only a few road safety impact assessment tools and models have been developed and are still subject of study. These tools are not yet common. A comparison of different models and tools regarding applicability, quality and availability of data regarding possible indicators should be worked out in the future in order to support a better understanding of underlying traffic and transport patterns which influence road safety.

In Germany a new guideline for the Road infrastructure safety management, which will be published in 2012, gives a new method to calculate the estimated impact of new or reconstructed roads and junctions. The main idea is to define basic accident cost rates (BACR) for many different types of roads and intersections which are derived from the detailed assessment of existing accident cost rates. The BACR includes only that share of all accidents which couldn´t be avoided by a very good design an regulations conforming to standards. An example for different BACR corresponding to Standard cross sections of motorways can be seen in Figure 2. In the case of different possible deviations from standards like not conforming cross falls to the regular value or not sufficient sight distances surcharges have to be added to the BACR. Figure 3 shows examples of surcharges in the case of deviations from standards. At the end it is possible to estimate the accident cost rates for different alternatives and to define the level of safety (see Figure 4) which can be compared to the level of service.

Standard Cross Section	Criteria of differentiation	BACR [EUR/(1000 veh* km)]
SCS 43,5	8 lanes	18 (v_{perm} free) 15 (v_{perm} 120 km/h)
SCS 36	6 lanes	17(v_{perm} free) 14 (v_{perm} 120 km/h)
SCS 31,5	6 lanes	15 (v_{perm} 80 km/h) 17 (v_{perm} 100 km/h)
SCS 31	4 lanes	16 (v_{perm} free) 13 (v_{perm} 120 km/h)
SCS 28	4 lanes	13 (v_{perm} 100 km/h) 15 (v_{perm} 120 km/h)
SCS 26	4 lanes	14 (v_{perm} 80 km/h) 16 (v_{perm} 100 km/h)

Examples: Standard Cross Sections SCS 43,5 and SCS 26

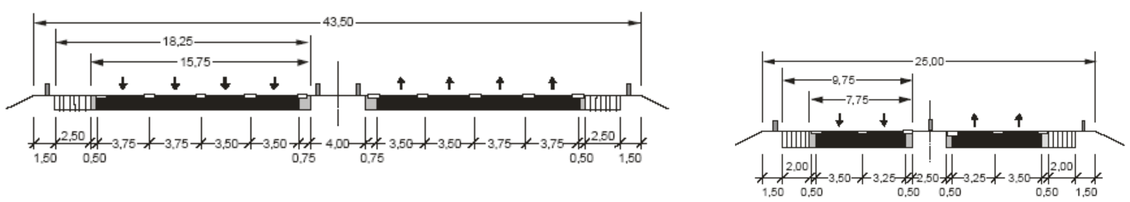
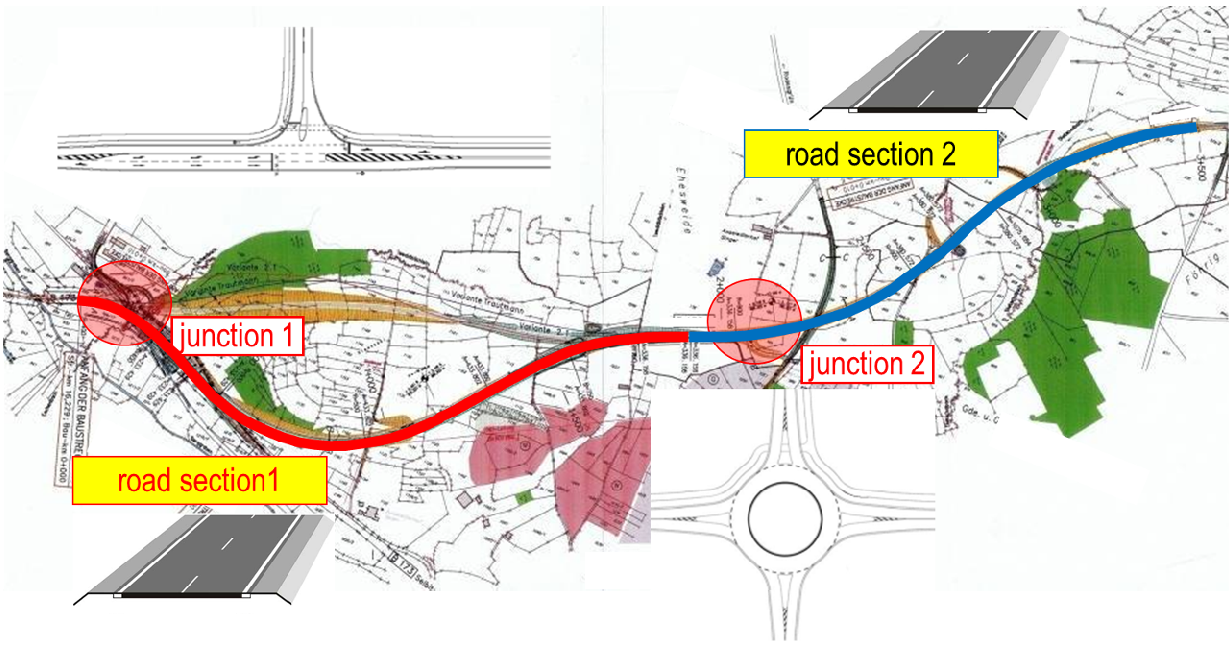


Figure 2: Basic Accident Cost Rates for Cross Sections of Motorways in Germany [3]

Criteria	Deviations from constructions conforming to directives	ACR [EUR /(1000 v)]	
		SCS 43,5	SCS 36
Sight	Existing sight distance < required stopping sight distance	6	6
Road space design	Cross slope of the line c < 2.5 %	1	1
	Cross slope of the circular line c (R) to small	2	2
	Diagonal slope d > 9.0 %	1	1
	Zone of low drainage	6	6
Road side	Punctual dangerous spot without protection measures	3	3
	Punctual dangerous spot with protection measures	1	1
	Vertical dangerous spot without protection measures	10*lenght [km]	10*lenght [km]
	Vertical dangerous spot with protection measures	2*length [km]	2*length [km]

Figure 3: Examples for surcharges to Basic accident cost rates [3]



		ACRsection [EUR / 1000 v * km]	ACRjunction [EUR / 1000 v * km]	LOS (safety)
Alternative 1	section 1	28 + Δ		B
	section 2	28 + Δ		C
	junction 1		12 + Δ	A
	junction 2		24 + Δ	B
Alternative 2	section 1	34+ Δ		D
	section 2	34+ Δ		D
	junction 1		10 + Δ	A
	junction 2		24 + Δ	B

Figure 4: Estimated Accident Cost Rates and LOS Safety for different alternatives of road sections and junctions [4]

In developing countries and in countries in transition it is mostly not possible to implement the instrument of the Road safety impact assessment currently. As it is shown in the examples a detailed knowledge about accidents, accident costs and accident rates related to different road and junction types is strictly needed. This knowledge doesn´t exist e.g. in many African and Asian countries. Accidents are mostly underreported or not reported in an appropriate way.

A review on the existing accident data base for example for the year 2008 in Egypt (Twinning Project EG08/AA/TP13, [5]) came to the result that three different accident data sources are available:

- Ministry of Health (4.500 fatalities per year)
- Ministry of Interior (6.800 fatalities per year)
- World Health Organisation (12.300 fatalities per year)

Given the discrepancies in statistics, it is difficult to come up with exact figures for fatalities and injuries from road accidents in Egypt. However, it is likely that actual numbers are considerably higher than the officially reported figures. In addition the accidents cannot be located in that detail as it would be necessary for the calculation of accident rates in different types of road sections and junctions. Therefore in several countries there is a need for reliable accident data and for the implementation of a statistical system as a first step towards a new instrument of a Road safety impact assessment.

3. ROAD SAFETY AUDITS

The Road safety audit (RSA) is an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages from planning to early operation as to identify, in a detailed way, unsafe features of a road infrastructure project. The RSA is still used in some countries for several years and PIARC published a well-known RSA guideline [6].

Audits are carried out by independent Auditors from private firms or road administrations or an Audit Centre, not involved in the project design team. Auditors have to be trained and fully qualified. The outcome of a RSA is a Report, which identifies any road safety deficiency and if appropriate, makes recommendations aimed at removing or reducing the deficiencies. The RSA process is divided into distinct stages, which are similar in most countries where it is undertaken. This allows the client to take corrective action in a timely manner and prevents the designer from abortive effort. The key stages which should be audited are the Feasibility Study, the Preliminary design, the Detailed design and the Pre-and Post-opening.

The plans to be checked have to be submitted of the customer to the auditor. Then the independent check of the documents follows on the part of the road safety auditor. After that a walk-through is necessary to judge the safety deficiencies which were found in the plan. The audit report contents project information, background information, all listed deficiencies and if necessary recommendations. The customer should comment every single deficit in writing and judge whether the recommendations of the road safety audit should be implemented or, where it is decided otherwise, to give reasons for the decision. After that the audit phase is completed.

In Germany Road safety audits have a nationwide application on all federal and most state roads and a more seldom application on urban roads, where audits are optional so far. Road safety auditors must attain an additional qualification besides a basic qualification. The additional qualifications are specialised and standardized training courses for auditors, which are divided into interurban and urban aspects and courses. Since 2002 more than 270 road safety auditors were trained for motorways and rural roads at the Bauhaus University of Weimar and for urban roads at the University of Wuppertal in Germany. The training includes seven days at the university and minimum 10 days of homework. At the beginning of the training actual road design plans are called in from the participants. Audit reports of these plans and of additional planning in all design stages have to be done during the trainings and in house exercises. Certificates are awarded with 3 years validity. Requirements for extensions are the verification of three audits and the participation on two courses like the annually offered two-days „Symposia for road safety with auditor forums“ at the two Universities.

The training of 30 engineers from the Egyptian road administration was one of the key elements of the Twinning project “Enhancing Road Safety in Egypt” [5] in totally 25 working days in the years 2010 and 2011. The aim is to implement Road Safety Audits as a regular instrument for all design projects in Egypt.

The courses were divided in different elements:

- Seminars (lectures) on Road Design, Road Side Features, Signing, Marking and Safety Aspects,
- Field studies and design document studies including documentation and proposals,

- Own field and document studies as homework including documentation and proposals in small groups and in their own districts,
- Presentations of results to the entire group and
- Discussions and review with experts.

This methodology of the training combines theoretical aspects and presentations with practical case studies. The acquired knowledge was developed further through self-study in small groups. The results of the self-study were presented by groups to the plenary and discussed with the experts during the courses. The official starting point for obligatory audit reports is still to be set – however hopefully soon.

4. NETWORK SAFETY MANAGEMENT

The Ranking of high accident concentration sections is a method to identify, analyse and rank sections of the existing road network upon which a large number of accidents in proportion to the traffic flow have occurred. In addition the network safety ranking is a method for identifying, analysing and classifying parts of the existing road network according to their potential for safety development and accident cost savings. The purpose is to target investments to the road sections with the highest accident concentration and/or the highest accident reduction potential.

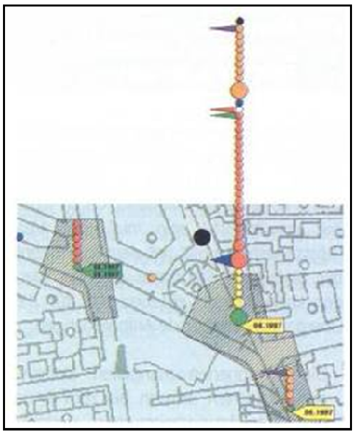
The purpose of the network safety management by evaluating road-traffic accidents as an accident investigation is to detect sections with high accident risks and accident black spots which have to be examined in detail. The primary aim of such research is to determine where black spots occur (example see Figure 5), why they occur at those precise locations and what measures would appear appropriate to eliminate identified accident sources. This requires accident-type maps to be created. In addition, accident-form archives should be kept. Collision diagrams should be produced for road sections where there is a particularly large number of accidents or concentrations of comparable accidents. These documents must be carefully evaluated. Comparable accidents (i.e. accidents similar in nature to each other) often indicate that the characteristics of the road are defective or the traffic-management system is inadequate.

Type of black spot	Authoritative maps	Identification of pecularities
Black spot patch BSP	1-YM; 3-YM(P); 3-YM(SP)	Limiting values
Black spot line BSL	3-YM(SP)	Visual density AD(SP); limiting values
Black spot area BSA	3-YM(P)	Accident density AD(SP)

Types of black spots, authoratative maps and criterias to identify pecularities

Accident type plug in map	Limiting values Number of accidents	Period under observation [months]
1-year map	5 (similar)	12
3-Years map (P)	5	36
3-Years map (SP)	3	36

Limiting values for black spots BS („similar": same typ of accident or circumstances)



Accident type plug in map

1-YM

Figure 5: Values and Examples of a Black Spot Management in Germany

While the black spot management is ruled in many countries there are still lacks in identifying road sections with high risks. The network safety ranking is a relatively new practice, which is based on the analysis of the existing road network in order to identify the parts with the higher accident density and those road safety measures that have the highest accident reduction potential, i.e. it will consider parts of the network where, respectively, accidents occurred most frequently during previous years and accident cost reduction potential is the highest, by targeting remedial treatment. The identification of high-risk road sections is necessary to target action on stretches of road where high numbers of fatal and severe accidents occur. In Germany, improvements in the road network safety are obligatory for the whole national network and are additional carried out in areas which are considered to have a high frequency of serious accidents. The basis for this work is the German guideline for safety analysis of road networks. The accidents per kilometer of road are converted into annual economic loss to get an indication of cost savings had the road been built according to national design standards. The data base with basis accident cost rates is the same as mentioned in the explanations for the Road safety impact assessment. The accident cost reduction potential is defined as the difference between the real accident costs of a section or a junction and the basic accident costs. Figure 6 shows an example of the accident cost reduction potential on national motorways in Germany. Normally it can be stated that 50-80% of the reduction potential can be found in 5-10% of the network – therefore an investigation in that sections and junctions could be very sufficient.

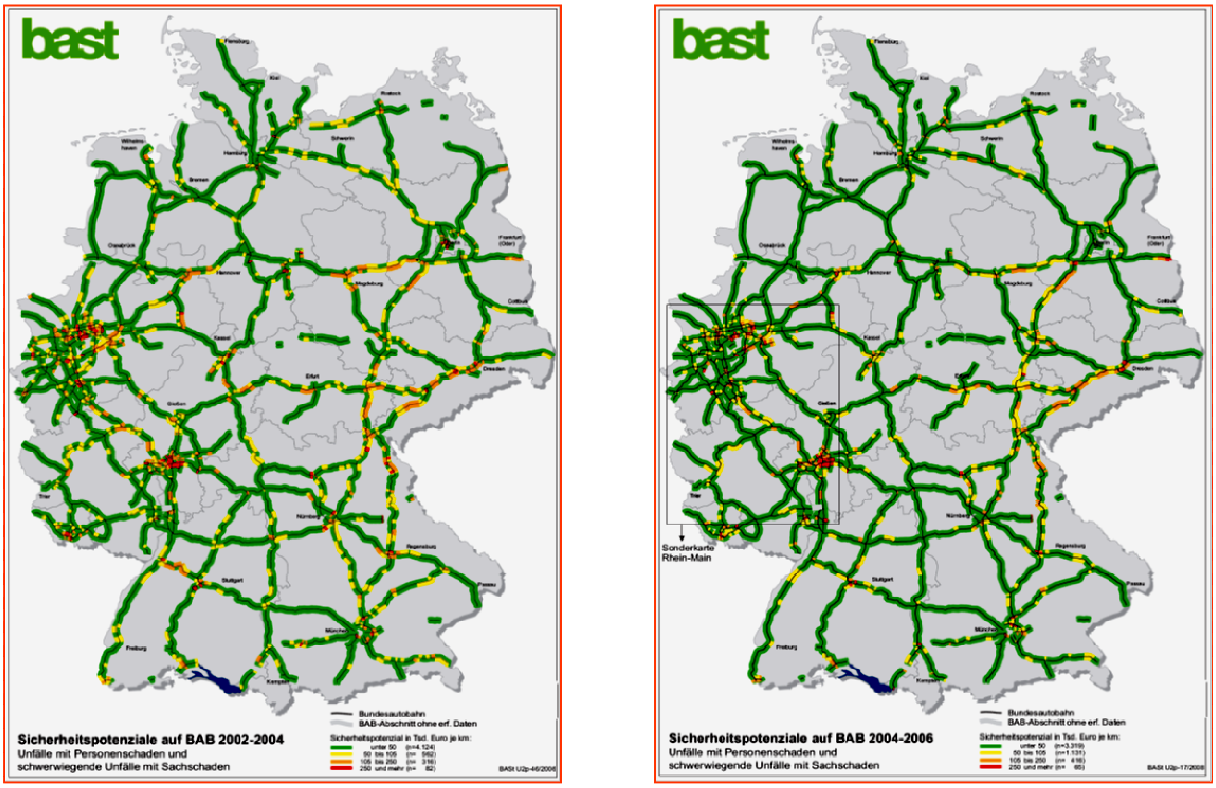


Figure 6: Examples of the accident cost reduction potential on national motorways in Germany [7]

The Network safety management should be carried out by an Accident Committee with permanent members of the police to evaluate the accidents, the traffic authority to find measures in signing and regulations and the planning authority to realise reconstructions and infrastructure orientated measures.

In developing countries and in countries in transition it is mostly not possible to implement the instrument of the Network safety management currently. As it is shown in the explanations of the Road safety impact assessment a detailed knowledge about accidents, accident costs and accident rates is not available in many countries. Once more the need for reliable accident data and for the implementation of a statistical system should be satisfied.

5. ROAD SAFETY INSPECTIONS

Road safety inspections (RSI) are an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety as a preventive tool. RSI's aim is to identify potential problems so countermeasures can be applied to remove or minimise the chance of an accident occurring. The PIARC RSI guideline [8] includes very detailed recommendations and checklists for all kind of roads.

The RSI process is systematic and can but need not to be focused on black spots or sections and junctions with a high accident cost reduction potential identified by accident data. Therefore an inspection should on the one hand at latest be carried out when the network safety management identified those network elements with high accident rates or high risks – on the other hand it can be a regularly assessment on the whole network system.

An RSI is comprehensive, with extensive preliminary work, on site appraisal including detailed check lists, analysis of the problems and suggested countermeasures. Inspections can identify safety deficiencies that are a result of poor maintenance, for example poor signing and line marking or visibility issues caused by vegetation. In addition the deficiencies could have other reasons like insufficient sight distances or design elements which surprise the road users. All inspections should take into account a range of human factors which relate to driver errors that are induced by the road.

Comparable to Road safety audits the main output of inspections is an RSI Report. A typical inspection report should be structured into [8]

- an Introduction describing the road being inspected,
- a part A with Project data (road function, traffic situation, road standards, surroundings),
- a part B with Investigation form listing all deficiencies,
- a part C with proposals and options for counter measures – short term (e.g. signage, enforcement), medium term (e.g. speed reductions using traffic calming measures, refuge islands for pedestrians etc.) and long term (larger investment may be required) and
- an appendix with maps and illustrations (in order to clarify the results, different kinds of illustrations may be used including photos and sketches of countermeasures, locations need to be specified).

Depending on the complexity of the work, an inspection should be done by a group of inspectors. The qualifications should be the same as for auditors and the police should be involved.

In Germany regularly and obligatory inspections are up to now restricted to maintenance issues. New rules for obligatory and systematically inspections which are related to all possible infrastructural deficiencies leading potentially to accidents are discussed at the moment. In many developing countries and countries in transition like Vietnam, Romania, Korea or Egypt the process was trained and regularly inspections are still to be implemented.

6. TYPICAL HAZARDS AND DEFICIENCIES

Analysing the safety deficiencies in German design plans it appears that the most deficits are based upon a breach of standards and rules. Some more are referred to the failing realisation of new findings resulting of research or they are the result of the inadequate use of the area of discretion in aid of road safety.

In general it has to been mentioned, that the education and training of german planners is of course quite good – the reasons for safety deficits are more to be found in missing coordination between various parts of authorities and in particular when the requirements from several person and institutions concerned reduce the safety. For example there could be the requirement for parking facilities which are expressed by tradespeople and politicians although it hinders the visibility of an intersection. Another reason is that the sensibility of planners concerning safety is not as high as the interest for capacity.

One typical deficiency especially in urban roads is the line-of-sight obstruction between vulnerable road users and car drivers caused by parking cars (example see Figure 7). For road safety at main roads it is very important to consider the sight distance (intervisibility) between motorized and non-motorized traffic. Especially when choosing the number and character of the parking areas, the intervisibility between vehicles and pedestrians/bicyclists is to guarantee at crossroads, T junctions, access roads and pedestrians crossings. Obstructions of sight prevent the cognition of conflict situations in sufficient time.

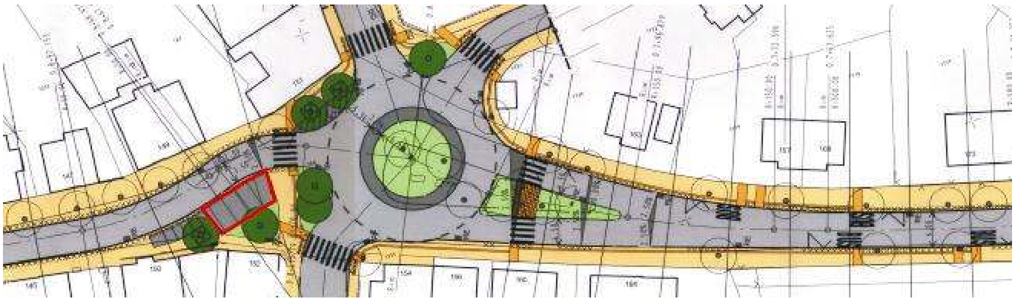


Figure 7: Sight obstructions between waiting pedestrian at a zebra-crossing and car drivers caused by parking lots

A further circumstance that is to be mentioned is the frequent use of segregated right turning lanes at urban intersections, although they often are black spots of urban main roads. Segregated right turning lanes are characterised by accumulations of rear-end collision accidents, to some extent with involved bicyclists and pedestrians. This circumstance is shown in the collision diagram in Figure 8. Nevertheless segregated right turning lanes are popular to reduce time of waiting at highly frequented junctions by the account of road safety.

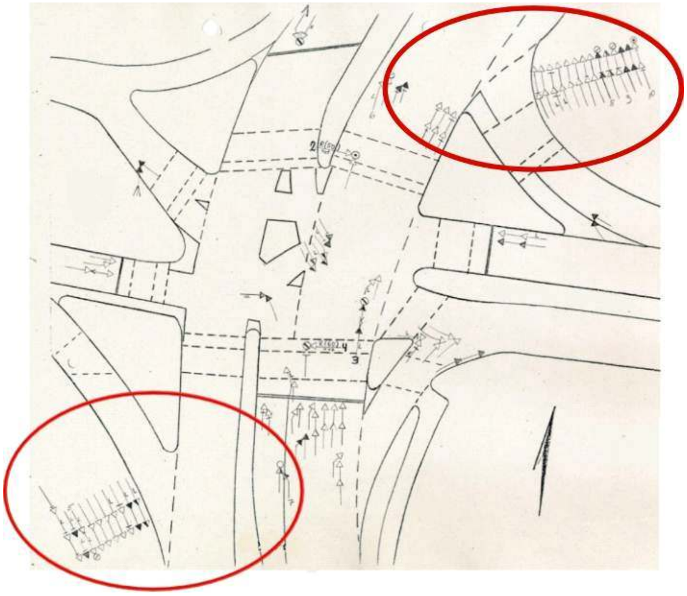


Figure 8: Collision diagram – accidents in one year at segregated right turning lanes

In many developing countries and countries in transition the different functions are not properly separated in so that there is along most of the public roads a dangerous mixture of Connectors and Access Roads. One of such dangerous examples is the Cairo - Alexandria Agriculture Road in Egypt, which is designed as a motorway with high speed, but going through many villages and towns (Figure 9).

Figure 9: Motorway with access to settlements in Egypt [5]

Mixed functions can be found on motorways and especially on express roads without special paths for pedestrians and agricultural vehicles and accesses to private and public roads. A speciality of mixed functions are so called linear settlement along interurban roads, where for the lack of access control especially poor people are settling very narrow to the carriageway of high speed roads. A structure of a clear hierarchy of the road network, following the objectives of land use is missed very often.

As in most emerging or developing countries the needs of vulnerable road users are totally neglected all over Egypt by the exception of a few tourist locations. In their latest report the World Health Organisation estimates the losses of lives and the injuries among this group with more than 50 % of all traffic victims in these countries. But most of them don't appear in their official statistics. The special deficiencies for example in Egypt are:

- No separation of vulnerable road users from the fast traffic along highways,
- The structure of linear settlement,
- High speed of traffic along the public roads in villages and small cities,
- The lack of usable sidewalks,
- The lack of safe crossing facilities and
- Bus stops especially of minibuses at unsafe locations.

The latter is a special safety problem along all roads in Egypt especially at Motorways, express roads, rural roads and urban main roads (Figure 10). A special focus on that issue should be the most important factor in a new approach of a safety management system with new recommendations and standards in those countries.

Figure 10: Pedestrians and Cyclists on Egyptian motorways [5]

CONCLUSIONS

Summing up the road infrastructure safety management should be integrated in all phases of planning, design and operation of road infrastructure. It can help to avoid several accidents all over the world. With implementing the safety management, an improvement and a significant reduction of accidents can be expected. The economic profit can be very high - economic profits rise highly above the additional costs.

A significant basis is the documentation, analysis and publication of accidents and further on of experiences with the safety management. A consequent safety management on that basis with the application of the whole method mix can help to improve road safety and to avoid accidents and their consequences.

REFERENCES

1. European Parliament and the Council of The European Union: Directive 2008/96/EC on road infrastructure safety management, Official Journal of the European Union, L 319/59, 2008
2. UN Road Safety Collaboration: Global Plan for the Decade of Action for Road Safety 2011-2020, Switzerland 2010
3. Bark, Andreas; Baier, Reinhold: Handbook for the assessment of road safety (proposal), orig.: Handbuch für die Bewertung der Verkehrssicherheit von Straßenverkehrsanlagen (Entwurf), Forschungsbericht FE 03.389/2005/FGB, Gießen-Friedberg/Aachen 2009
4. Weber, Roland, Bundesanstalt für Straßenwesen: Road Safety Management (Presentation on the German Road Research Congress 2008), orig.: Sicherheitsmanagement für die Straßeninfrastruktur, Bergisch Gladbach 2008
5. Twinning Project EG08/AA/TP13: The Twinning Expertise for Enhancing Road Safety in Egypt, Cairo 2011
6. PIARC Technical Committee C3.1 Road Safety: Road Safety Audit Guideline for safety checks of new road projects, ISBN 2-84060-199-0, Paris 2007
7. Bundesanstalt für Straßenwesen: Analyse of Accidents on motorway sections, orig.: Streckenbezogene Analysen von Unfällen auf Autobahnen, Bergisch Gladbach, 2008
8. PIARC Technical Committee C3.1 Road Safety: Road Safety Inspection Guideline for safety checks of existing roads, Paris 2007