Project No. 101069500—AfroSAFE

AfroSAFE: Safe System for radical improvement of road safety in low- and middle-income African countries

HORIZON EUROPE—European Union's funding programme for research and innovation

Deliverable 3.2

Safe Infrastructure: Proposal for national guidelines for the introduction of the tools comprising Road Infrastructure Safety Management

Deliverable due date: 31.08.2024

Project start: 01.09.2022
Duration: 48 months

Lead contractor for this deliverable:
Lund University, Sweden

Version 4, Final (2024.08.12)

Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Document information

Authors: András Várhelyi (Lund University, Sweden)
Enoch F. Sam (University of Education, Winneba, Ghana)
Ladislaus Bigamo (Ministry of Work and Transportation, Tanzania)
Siya Rimoy (University of Dar es Salaam, Tanzania)
Susan Mawele (Zambia Road Safety Trust)

Quality check: Haneen Farah (Technical University of Delft, the Netherlands)

Project Coordinator

Aliaksei Laureshyn
Department of Technology and Society
Faculty of Engineering, LTH
Lund University

Box 118
221 00 Lund, Sweden

Phone: +46 46 222 91 31
Email: aliaksei.laureshyn@tft.lth.se

www: https://www.ictct.net/afrosafe/project

Coordinator of WP3

András Várhelyi
Department of Technology and Society
Faculty of Engineering, LTH
Lund University

Box 118
221 00 Lund, Sweden

Phone: +46 46 2224824
Email: Andras.varhelyi@tft.lth.se

Project funding

Horizon Europe
Grant Agreement 101069500

Revision and History Chart

Version	Date	Comment
1	2024-05-25	First draft
2	2024-06-30	Updated with input from local partners
3	2024-07-14	Final version for internal review
4	2024-08-12	Final version

This project has received funding from the Horizon Europe, the European Union's funding programme for research and innovation under grant agreement No 101069500.

Definitions

Black Spot Management (BSM)

Identification and treatment of hazardous road locations (black spots) in the road infrastructure with higher number of accidents than other similar locations.

Network Safety Management (NSM)

Safety analysis of road networks comprising the identification and treatment of road sections with high concentration of injury/fatality accidents that have occurred in previous years per unit of road length in relation to the volume of traffic and, in case of intersections, the number of such accidents per site.

Road Infrastructure Safety Management (RISM)

A set of procedures that support a road authority in decision making related to the improvement of the safety of the road network.

Road Safety Audit (RSA)

A formal safety performance examination of planned roads by an independent audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.

Road Safety Impact Assessment (RSIA)

A strategic comparative analysis of the effects of building new roads or a substantial modification to the existing network on the safety performance of the road network. RSIA is carried out at the initial planning stage before the infrastructure project is approved to indicate the road safety considerations which contribute to the choice of the proposed solution.

Road Safety Inspection (RSI)

A systematic review of existing roads to identify any potential hazards, faults or deficiencies that may lead to severe accidents.

Executive Summary

As part of the AfroSAFE project, national guidelines for Black Spot Management (BSM) were developed for Tanzania and Zambia, and guidelines for Network Safety Management (NSM) and Road Safety Impact Assessment (RISA) were developed for Ghana, Tanzania and Zambia. These guidelines were developed as there were no existing guidelines for these RISM tools in the African partner countries. These Road Infrastructure Safety Management (RISM) guidelines are based on the best international practice.

These guidelines should be used by the national road authority, since the road authority has the best knowledge about the road network. The national road authority should have full access to accident databases to retrieve the necessary accident data in the form that best suits for carrying out the necessary analyses.

A fundamental prerequisite for carrying out these analyses is that road accidents are recorded, and the records contain adequate information about the locality of each accident, time of occurrence, accident type, and severity. In addition, the records have to have an acceptable level of reporting. If this is not the case, BSM and NSM cannot be carried out according to best practice.

It is recommended that the mandatory utilisation of these guidelines should be prescribed by legislation, e.g., included in the Highway Authority Act, or in any other relevant legislative act. Also, the legislation should point out the supervisory authority with responsibility to supervise the process of carrying out RISM activities. Legislation should also prescribe that the accident database owner regularly provides the Road Authority with accident data necessary for carrying out RISM activities. A national regulatory framework should be established regarding procedures and responsibilities for initiating, carrying out, supervising, administrating and documenting RISM activities.

A training centre with staff and curricula for training road safety professionals to be able to carry out RISM activities should be established. The trainers might be brought in from outside when needed, but the permanent secretary of the training centre should continuously monitor the need for training and advertise for training courses, as well as the need for trainers.

Societal costs, and statistical values of fatal accidents, accidents with severe injuries, and slight injuries should be established.

Table of Contents

1 Introduction

1.1 Background

As part of the HORIZON EUROPE project AfroSAFE: Safe System for radical improvement of road safety in low- and middle-income African countries, activities on improving road infrastructure safety are being carried out. The objectives of these activities are:

- Review national regulations, guidelines, and procedures for Road Infrastructure Safety Management (RISM).
- Develop guidelines for the non-existing RISM tools in the African partner countries.
- Build capacity by providing training to professionals in the African partner countries for applying RISM tools.
- Run pilot projects demonstrating the application of RISM tools.

The review activity stated in the first bullet point above was carried out in a previous task and was reported in deliverable D3.1 (Várhelyi, et al., 2003). The present deliverable addresses the second point above and the related work was performed based on the results presented in the deliverable D3.1.

1.2 Aim

The aim of the work is to develop national guidelines for the non-existing RISM tools in the African partner countries, which includes:

- Black Spot Management (identification and treatment of hazardous locations in the road network) in Tanzania and Zambia,
- Network Safety Management (identification, selection, and treatment of road sections with high accident concentration) in Ghana, Tanzania and Zambia, and
- Road Safety Impact Assessment (assessment of the safety effects of building new roads) in Ghana, Tanzania and Zambia.

1.3 Method

Existing literature on state-of-the-art approaches and best practice guidelines on Black Spot Management, Network Safety Analysis, and Road Infrastructure Safety Assessment (such as Elvik, 2007; Ragnøy, et al., 2002; RIPCORD-ISEREST, 2011; Sorensen, 2006; Sorensen, 2007; Sorensen & Elvik, 2007;), as well as handbooks (such as Elvik, et al., 2009; SafetyCube, 2023), manuals (such as FHWA, 2010; PIARC, 2003; Laureshyn & Várhelyi, 2018) were reviewed and existing national reports (Afukaar, et al., 2007) and guidelines (such as Transport Infrastructure Ireland - TII, 2016; TII, 2017; TII, 2017a; Ghana Highway Authority, 2002) were considered in the development of the best practice guidelines for Ghana, Tanzania and Zambia.

During the development of the guidelines, the relevant national authorities - who are expected to incorporate the guidelines into their daily activities - were consulted and a key person in the subject was involved as co-author of the guidelines.

2 Results

2.1 Guidelines for Black Spot Management

The guidelines for Black Spot Management were developed for Tanzania and Zambia (Ghana already has one). The guidelines are based on best practice in Black Spot identification and treatment. The stepwise description of the process, with examples at each step, allows a systematic and efficient practice to identify hazardous locations, analyse accident contributory factors at these sites, propose cost-effective countermeasures and design an evaluation study on the effectiveness of the proposed measures. A fundamental prerequisite for carrying out Black Spot Management is that road accidents are recorded, and the records contain adequate information about the locality of accidents, time of occurrences, accident types, and severity.

Since the developed guidelines for Black Spot Management for Tanzania and Zambia are basically identical, only one of them is presented in Appendix I.

It is recommended that the first Black Spot Management exercise is carried out in a city of a smaller size, allowing the safety analysts to gain experience in carrying out the whole process without being overwhelmed with heavy burden of large data to be managed.

It is also recommended that after the BSM tool has been implemented, the method and the data is maintained. Hence, an essential part of the implementation of the method is to establish a procedure for maintenance. A basic issue is to allocate resources for maintaining and updating the method, as well as the required data for its operation.

2.2 Guidelines for Network Safety Management

The guidelines for Network Safety Management were developed for all three African partner countries, i.e., Ghana, Tanzania and Zambia. The guidelines are based on the best international practice. The stepwise description of the process allows systematic and efficient practice to identify hazardous road sections, analyse accident contributory factors at these sections, propose cost-effective countermeasures and design an evaluation study on the effectiveness of the proposed measures.

Since the developed guidelines for Network Safety Management for the three countries are basically identical, only one of them is presented in Appendix II.

A fundamental prerequisite for carrying out Network Safety Management is that road accidents are recorded, and the records contain adequate information about the locality of accidents, the time of occurrences, the types of accidents, and their severity.

After the NSM tool has been implemented, the method and the data should be maintained. Hence, an essential part of the implementation of the method is to establish a procedure for maintenance. The Authority, responsible for initiating NSM should ensure that the process is repeated and that it is conducted annually. A basic issue is to allocate resources for maintaining and updating the method and the required data for its operation.

Besides continuously registering traffic accidents, it is important to maintain and update data on changes in road design. When changes are made at a certain location in the road infrastructure, it is important to record when the changes were made.

2.3 Guidelines for Road Safety Impact Assessment

The guidelines for Road Safety Impact Assessment were developed for all three African partner countries, i.e., Ghana, Tanzania and Zambia. The stepwise description of the process allows a systematic and efficient practice to select the proposed infrastructure alternative with the highest net benefit.

The guidelines are based on best practices, however, since monetary values for accidents, fatalities, and injuries are not developed yet in Tanzania and Zambia, a simplified qualitative assessment is proposed instead of cost-benefit analysis. To make the method more adapted to the conditions in Tanzania and Zambia, monetary values of accidents (with fatality, severe injury, and slight injury), as well as travel time costs per vehicle should be established.

Since the developed guidelines for Road Safety Impact Assessment for all three countries are basically identical, only one of them is presented in Appendix III.

3 Conclusions and Recommendations

The guidelines developed for the three countries, Ghana, Tanzania and Zambia allow a systematic and efficient practices with improving safety of the road infrastructure. These guidelines should be used by the national road authority, since the road authority has the best knowledge about the road network. The road authority should have full and regular access to the accident database to retrieve the necessary accident data best suited for carrying out the necessary analyses.

A fundamental prerequisite for carrying out these analyse is that road accidents are recorded, and the records contain adequate information about the locality of the accidents, time of occurrences, accident types, and severity. In addition, accident records must have an acceptable level of reporting. If this is not the case, BSM and NSM cannot be carried out according to best practice.

It is recommended that the mandatory utilisation of these guidelines should be prescribed by legislation, e.g., included in the Highway Authority Act, or in any other relevant legislative act. Also, the legislation should point out the supervisory authority with responsibility to supervise the process of carrying out RISM activities. Legislation should also prescribe that the accident database owner regularly provides the Road Authority with accident data necessary for carrying out RISM activities. A national regulatory framework should be established regarding procedures and responsibilities for initiating, carrying out, supervising, administrating and documenting RISM activities.

A training centre with staff and curricula for training road safety professionals, capable of carrying out RISM activities, should be established. The trainers might be brought in from outside when needed, but the permanent secretary of the training centre should continuously monitor the need for training and advertise for training courses, as well as monitoring of trainers capacity.

Societal costs, and statistical values of fatal accidents, accidents with severe, and slight injuries should be established to facilitate cost-benefit analysis of countermeasures implemented to improve road safety.

References

- Afukaar, F.K., Agyemang, W., Debra, E.K., Ackaah, W. (2007) The Socio-Economic Cost of Road Traffic Accidents in Ghana. Council for Scientific and Industrial Research, Building and Road Research Institute, Kumasi, Ghana.
- Elvik, R. (2007) State-of-the-art approaches to road accident black spot management and safety analysis of road networks. TØI report 883/2007. Institute of Transport Economics. Norway.
- Elvik, R. Höje, A., Vaa, T., Sörensen, M. (2009) The Handbook of Road Safety Measures. Second Edition. Elsevier.
- FHWA (2010) SafetyAnalystTM: Software Tools for Safety Management of Specific Highway Sites. Publication No. FHWA-HRT-10-063, Federal Highway Administration, USA.
- Ghana Highway Authority (2002) Identifying and Treating Accident Sites.
- Laureshyn, A., Várhelyi, A. (2018) The Swedish Traffic Conflict Technique - Observer's manual. Lund University, Sweden.
- PIARC (2003) Road Safety Manual. PIARC Technical Committee on Road Safety, Cedex, France.
- Ragnøy, A., Christensen, P., Elvik, R. (2002) Skadegradstetthet – SGT Et nytt mål på hvor farlig en vegstrekninger. In Norwegian (Injury Severity Density. A new approach to identifying hazardous road sections). TØI rapport 618/2002. Institute of Transport Economics. Norway.
- RIPCORD-ISEREST (2011) Road Infrastructure Safety Management - Brochure http://www.ripcord-iserest.com (2011-12-12)
- SafetyCube (2023) The European Road Safety Decision Support System https://www.roadsafety-dss.eu/#/. (Downloaded 11/11 2023).
- Sorensen, M. (2006) Grå straekninger i det åbne land – udvikling av, anvendelse og vurdering af alvorlighedsbaseret metode til udpegning, analyseog udbedring af grå straekninger. (In Danish) PhD thesis. Department of Development and Planning, Aalborg University, Denmark.
- Sorensen, M. (2007) Best Practice Guidelines on Black Spot Management and Safety Analysis of Road Networks. TØI report 898/2007. Institute of Transport Economics. Norway.
- Sorensen, M., Elvik, R. (2007) Black Spot Management and Safety Analysis of Road Networks. Best Practice Guidelines and Implementation Steps. TØI report 919/2007. Institute of Transport Economics. Norway.
- TII (2016) Road Safety Impact Assessment Guidelines. PE-PMG-02005. Transport Infrastructure Ireland.
- TII (2017) Network Safety Analysis Procedures. TII Publications GE-STY-01036. Transport Infrastructure Ireland.
- TII (2017a) Network Safety Analysis. TII Publications GE-STY-01022. Transport Infrastructure Ireland.
- Várhelyi, A., Farah, H. Sam, E.F., Rimoy, S. Mawele, S. (2023) Review of National Design Guidelines and Procedures. Deliverable 3.1 of the AfroSAFE project No. 101069500. Horizon Europe.

Appendix I. Black Spot Management Guidelines for Tanzania

See separate file: App I – BSM Guidelines for Tanzania

Project report 3.2.BSM.T

2024-08-12

Black Spot Management Guidelines for Tanzania

Document information

Authors: András Várhelyi (Lund University, Sweden)
Jaqueline Masaki (University of Dar es Salaam, Tanzania)
Siya Rimoy (University of Dar es Salaam, Tanzania)
Ladislaus Bigamo (Ministry of Work and Transportation, Tanzania)

AfroSAFE - Safe System for radical improvement of road safety in low- and middle-income African countries

www.afrosafe-eu.africa

Project funding

Horizon Europe
Grant Agreement 101069500

This project has received funding from Horizon Europe, the European Union’s funding programme for research and innovation under grant agreement No 101069500.

Preface

In early days of motorisation, the police identified accident locations in the road network by putting a pin on the map for localisation of each accident. Locations with accumulated pins became black spots - hazardous sites with frequent occurrences of accidents, in need of some kind of improvement. Since then, the method has been developed and became more scientifically strengthened. Today, Black Spot Management (BSM) is one of the highly effective and efficient Road Safety Infrastructure Management (RISM) tools to improve the safety of the road infrastructure.

These Guidelines are developed for Tanzania within the framework of the HORIZON EUROPE project AfroSAFE - Safe System for radical improvement of road safety in low- and middle-income African countries. The guidelines are based on the best international practices for Black Spot identification and treatment.

The state-of-the-art approach to identify black spots presumes that all relevant data about accidents, traffic volume, road design, traffic control and surrounding environment are available, have sufficient quality, unambiguously located on the road network and interoperable with each other. The state-of-the-art approach also requires that there are comprehensive resources with regard to money, time, personnel and professional expertise to implement it. However, this is rarely the case, hence the second-best approach is the best practice approach which is constrained to limited data regarding quantity and quality (Sorensen and Elvik, 2007).

A fundamental prerequisite for carrying out Black Spot Management is that road accidents are recorded, and the records contain adequate information about the locality of accident, time of occurrence, accident type, and severity. In addition, the records have to have an acceptable level of reporting. If it is not the case, BSM cannot be carried out according to best practice.

The present guidelines follow the best practice approach whenever it is assumed possible due to the prevailing conditions in Tanzania.

The Structure of the Guidelines

The document commences with a general introduction of the place of Black Spot Management in the toolbox of Road Infrastructure Safety Management and the definition of black spots – hazardous locations in the road network. Subsequently, each stage and step of the process of identification, evaluation and treatment is described and illustrated with a numerical example to simplify understanding.

Abbreviations and Definitions

Black spot -	Any site at which the site specific **expected number of accidents** is higher than for **other similar sites** due to **local risk factors** present at the site. As synonyms to black spots, other expressions, such as accident prone locations, hazardous road locations, problem locations, hot spots, or sites with promise have been used. Black spots in the road infrastructure can be intersections, crossings, curves or short road stretches, with unusually high accident frequency or accident rate.
BSM	Black Spot Management Identification and treatment of hazardous road locations (black spots) in the road infrastructure with higher number of accidents than other similar locations.
NSM	Network Safety Management Identification and treatment of road sections with high concentration of injury or fatality accidents that have occurred in previous years per unit of road length in relation to the volume of traffic and, in case of intersections, the number of such accidents per site.
RAP	Road Assessment Programme A proactive tool for assessing the safety level of a road. It involves the collection of data on road characteristics with the aim to determine the level of protection the road environment provides for the road user when a crash occurs.
RISM	Road Infrastructure Safety Management A set of procedures that support a road authority in decision making related to the improvement of safety of the road network.
RSA	Road Safety Audit A formal safety performance examination of planned roads by an independent audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.
RSI	Road Safety Inspection A systematic review of existing roads with the intention to identify any potential hazards, faults or deficiencies that may lead to serious accidents.
RSIA	Road Safety Impact Assessment A strategic comparative analysis of the effects of building new roads or a substantial modification to the existing network on the safety performance of the road network. RSIA is carried out at the initial planning stage before the infrastructure project is approved to indicate the road safety considerations which contribute to the choice of the proposed solution.

Table of Contents

1 Introduction

1.1 Road Infrastructure Safety Management Tools

Road infrastructure is one of the three main components of the human-machine-infrastructure system in road transport. Even if most often the human actor is (unfairly) blamed for causing accidents, there are several contributory factors to each accident and adapting the road infrastructure to the conditions of humans constitutes the corner stone of the Safe System approach.

There are several well-established Road Infrastructure Safety Management Tools available to the road safety engineer, such as (see also Figure 1):

- **Black Spot Management (BSM)**
  Identification and treatment of hazardous road locations (black spots) in the road infrastructure with higher number of accidents than other similar locations.
- **Network Safety Management (NSM)**
  Identification and treatment of road sections with high concentration of injury/fatality accidents that have occurred in previous years per unit of road length in relation to the volume of traffic and, in case of intersections, the number of such accidents per site.
- **Road Assessment Programme (RAP)**
  A proactive tool for assessing the safety level of a road. It involves the collection of data on road characteristics with the aim to determine the level of protection the road environment provides for the road user when a crash occurs.
- **Road Safety Audit (RSA)**
  A formal safety performance examination of planned roads by an independent audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.
- **Road Safety Inspection (RSI)**
  A systematic review of existing roads with the intention to identify any potential hazards, faults or deficiencies that may lead to serious accidents.
- **Road Safety Impact Assessment (RSIA)**
  A strategic comparative analysis of the effects of building new roads or a substantial modification to the existing network on the safety performance of the road network. RSIA is carried out at the initial planning stage before the infrastructure project is approved to indicate the road safety considerations which contribute to the choice of the proposed solution.

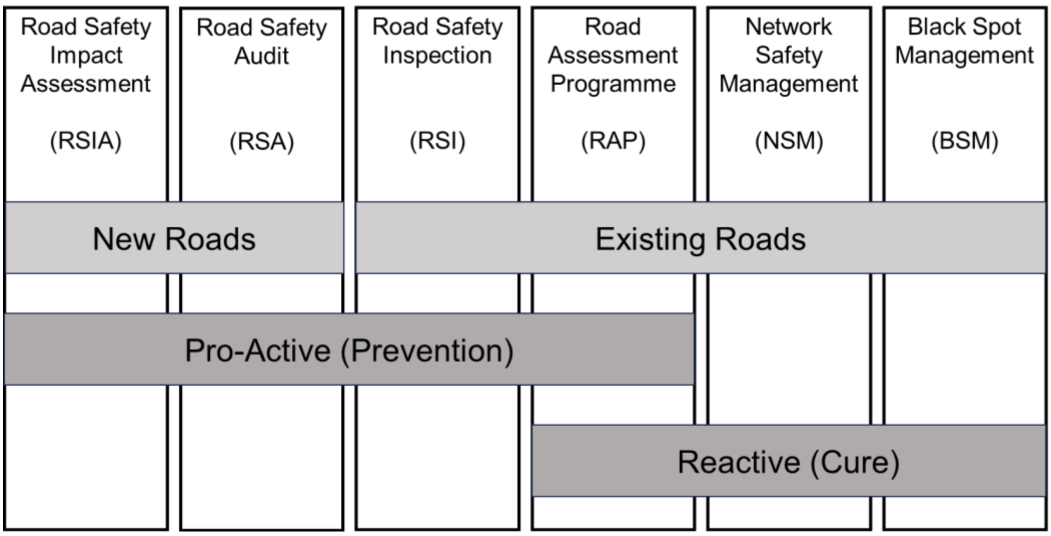


Figure 1. Road Infrastructure Safety Management Tools (Based on RIPCORD-ISEREST, 2011).

As seen in Figure 1, BSM is a re-active tool undertaken on existing roads. The output of BSM consists of proposed countermeasures for the identified hazardous sites, which are expected to decrease the risk of accidents/injuries at the treated locations. RAP can be considered as reactive and pro-active since it uses both accident data and observational data.

1.2 Implementing BSM and NSM

Both Black Spot Management and Network Safety Management should be carried out by the road authority since it has the best knowledge about the road network. They should have full access to the accident database to be able to retrieve the necessary accident data in the form that suits best for carrying out these analysis methods.

Several of the implementation steps are similar for BSM and NSM, however, if neither of these methods is practiced yet in the country, it is recommended to start with BSM, because (Sorensen and Elvik, 2007):

- BSM is immediately more understandable than NSM.
- There are numerous black spots when starting to implement BSM and also several years after having implemented BSM, which means that resources for site specific safety work can be used effectively on the identified black spots.
- Black spots have typically a lot of accidents with clear accident patterns which often can be treated with low-cost measures. This gives a cost-effective traffic safety work.

After having implemented and running BSM for a few years and its use has become a routine, it is recommended to supplement it with NSM and during a period, both methods ought to be used in parallel. BSM should be continued as long it has potential to efficiently contribute to safety improvements and all the black spots have been identified and treated. Then, it is recommended to focus primarily on NSM. (Sorensen and Elvik, 2007).

When implementing the Road Infrastructure Safety management tools, it is important that the method and the data is maintained and updated. An essential part of the implementation of the method is to establish a procedure for maintenance. A basic issue is to allocate resources for maintaining and updating the methods, as well as the required data for their operation.

2 The Process of Black Spot Management

The stages of the Black Spot Management process is shown in Figure 2.

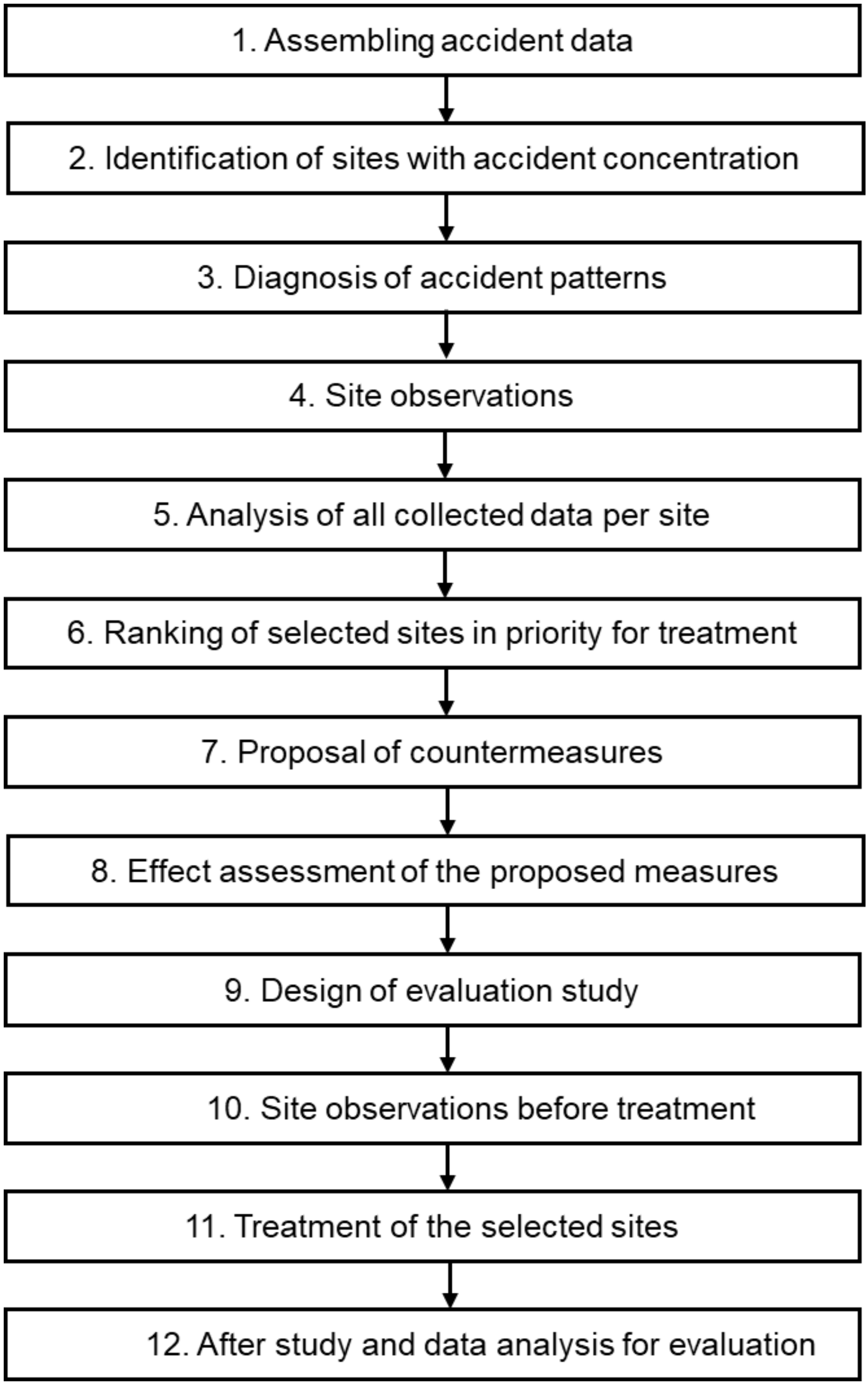


Figure 2. Stages of the Black Spot Management process.

2.1 Stage 1 – Assembling accident data

Work should start with defining suitable sets of study units of interest. These may be, e.g., intersections (with 3 legs or 4 legs), roundabouts, access ramps, bridges, tunnels, curves with radius within a certain range, or short sections (up to 500 m) of roads in urban or rural areas. The selected units of interest should be clearly defined and numbered. This allows theoretical probability distributions for accidents to be fitted to the empirical distribution of recorded accidents at these units and allows statistical criteria of deviancy to be formulated (Sorensen and Elvik, 2007).

The study units of interest should be subdivided into smaller groups based on their design details (e.g., type of regulation, and traffic volumes).

Geo-located accident data for the study units of interest during the latest 3-5 years should be obtained from the national accident database. Only accidents with fatality and injury should be considered since damage only accidents are unreliable due to heavy underreporting.

Example: Intersections of a middle sized city – Assembling accident data

All 55 intersections of the city are numbered from 1-55 and listed in an excel file, indicating their recorded number of injury accidents during the last three years, their type (signalised / non-signalised or roundabout), and traffic volume, see Table 1.

Table 1. Intersections by recorded number of injury accidents and traffic volume.

Inter-sec-tion Nr	Intersection type 1=Non-signalised 2=Signalised 3=Roundabout	Traffic volume AADT	SIte type	**R** Recorded Number of injury accidents
1	1	<10000	1	0
2	1	<10000	1	0
3	1	<10000	1	1
4	1	10000-20000	11	2
5	2	10000-20000	2	1
51	3	20000<	33	1
52	3	20000<	33	3
53	3	20000<	33	4
54	3	10000-20000	3	2
55	3	10000-20000	3	1
			Number	146
			Mean	2,65
			Variance	4,23

2.2 Stage 2 – Identification of sites with accident concentration

This stage, i.e., the identification of sites with unusually high number of accidents and/or accident rate consists of several steps. The description and equations below draw on Elvik (2003).

Hazardous road locations should be identified in terms of the **estimated expected number of accidents**, not the recorded number of accidents. That is because an abnormally high recorded number of accidents could be largely the result of random variation and does not necessarily mean that a site has a high expected number of accidents. Hence, the best way of identifying hazardous road locations is that for each location to estimate the "normal" number of accidents and then combine this with the accident record for each site, yielding an estimate of the site-specific expected number of accidents. A road location would be considered hazardous if the site-specific expected number of accidents was (substantially) higher than the "normal" number of accidents for similar sites. Examples of similar sites are intersections with the same type of regulation/signalisation, or roundabouts, same speed limit, comparable traffic volumes, comparable types of road users, etc.

2.2.1 Analysis of variation in the number of accidents

The distribution of accidents should be analysed with respect to the mean number of accidents and variance. The objective of the analysis is to determine the amount of systematic variation in the number of accidents. If there is little systematic variation, there is little hope to be able to point out hazardous locations. If, on the other hand, the number of accidents is found to contain significant systematic variation, it implies the existence of units with deviating hazard level.

The number of accidents at a given intersection is assumed to be Poisson distributed. In order to ascertain systematic variation in the number of accidents between intersections, the actual distribution of number of accidents over intersections can therefore be compared with a Poisson distribution with the same mean value of actual accidents per intersection. In the Poisson distribution, the variance is equal to the mean, hence, by definition the size of random variance in the count of accidents equals the expected number of accidents. The total variation in the count of accidents in a sample of study units can be decomposed into random variation and systematic variation:

$$\text{Total variance} = \text{Random variance} + \text{Systematic variance} \quad (1)$$

Thus, there is systematic variation in the number of accidents whenever the variance exceeds the overall mean of accidents (m). This is usually referred to as over-dispersion. One way to identify over-dispersion (and thereby systematic variation) is thus to look at the ratio:

$$\alpha = m \,/\, Var(x) \quad (2)$$

If α is less than 1, we have an indication that there is systematic variation in the data. The smaller α gets, the larger is the systematic variation. In those cases, we have reason to assume that high recorded numbers of accidents are (partly) an indication of true hazardousness, and not only the result of random variation of accidents.

The proportion of variance, attributable to systematic variation, can be estimated as

$$S = (Var(x) - m) \,/\, Var(x) \quad (3)$$

Example: Intersections of a middle-sized city - Analysis of variation in the number of accidents

Estimating the proportion of variance, attributable to systematic variation (see data in Table 2):
Mean of Recorded Number of injury accidents: 2.65
Variance of Recorded Number of injury accidents: 4.19

$$S = (4.19\text{-}2.65)/4.19 = 37\%$$

So, of the total variance, 37% is attributable to systematic variation and we have reason to assume that high recorded numbers of accidents are partly an indication of true hazardousness.

2.2.2 Assessing the “normal” number of accidents for each type of site

According to best practice, the “normal” number of accidents for a certain type of site is estimated by a safety performance function. A safety performance function is a function of traffic volume and a set of factors (e.g., type of regulation, speed limit, number of lanes, etc.) and shows how various risk factors affect accident occurrence. However, lacking validated safety performance functions for estimating the “normal” number of accidents, as a simplification, the mean value of the number of accidents of the intersection type in question can be used (e.g., the mean value for the recorded number of accidents for signalised intersections, non-signalised intersections, roundabouts, etc.).

If there was no systematic variation among sites, this mean value would also be the number of accidents that we would be predicted to occur at each site of the given type.

As an example for assessing the "normal" number of injury accidents for each type of site see column 6 in Table 2 below.

2.2.3 Estimating the expected number of accidents for each site

The best estimate of the expected number of accidents for a studied unit is obtained by combining two sources of information: a) the number of recorded accidents (*R*) for a given site, b) the "normal" number of accidents (*N*) (i.e. the mean value) for the same type of sites.

Therefore, the best estimate of the expected number of accidents for a given site, is then:

$$E(N,R) = w*N+(1-w)*R \qquad (4)$$

Where $$w = 1/(1+Var(N)/N) \qquad (5)$$

The parameter *w* thus determines the weight given to the "normal" number of accidents for the type of sites in question, when combining it with the recorded number of accidents of a particular site, in order to estimate the expected number of accidents for that particular site.

Intuitively, we understand that:

- If there is much systematic variation in the data, the mean value (N) is not very informative concerning the expected accident number at a specific site, whereas,
- If there is much random variation in the data, the specific recorded number at a site (*R*) is not very informative, compared to the larger data source of all sites (N).

The interpretation of the three different estimates of safety (Recorded number, Normal number, and Expected number of accidents) can be explained as follows: **R** accidents were recorded at the individual site during the observation period, the "normal" number of accidents **N** is the number of accidents one would normally expect to occur at a similar site with the same regulation and traffic volume, as the site in question. **E** is the number of accidents we expect to happen assessed by combining two sources of information: a) the number of recorded accidents (*R*) at the site in question, and b) the "normal" number of accidents (N) for the same type of site. Thus, **E** tells us which are the most hazardous sites overall.

See example for estimating the expected number of accidents for each site in column 9 in Table 2 below.

2.2.4 Identifying hazardous sites

The difference between the site-specific expected number of accidents (**E**) and the "normal" number of accidents (**N**) for similar sites, **E-N** can be interpreted as an effect of local risk factors for the site, causing it to have a higher expected number of accidents than similar sites, and tells us which locations that are most hazardous, given their type of site.

Example: Intersections of a middle-sized city – Identifying hazardous sites

Table 2. “Normal” number, expected number of accidents, and identified hazardous sites. Colouring along the rows is due to “Site type”, i.e. intersections belonging to the same site type has the same colour.

Inter-sec-tion Nr	Intersection type 1=Non-signalised 2=Signalised 3=Roundabout	Traffic volume AADT	SIte type	**R** Recorded Number of injury accidents	**N** "Normal" number of injury accidents (Mean)	Variance *Var(N)*	w =1/(1+Var(N)/N)	**E** Expected number of injury accidents *E=w*N+(1-w)*R*	**E-N** Deviation from "normal" for site type
1	1	<10000	1	0	1,36	1,65	0,45	0,62	-0,75
2	1	<10000	1	0	1,36	1,65	0,45	0,62	-0,75
3	1	<10000	1	1	1,36	1,65	0,45	1,16	-0,20
4	1	10000-20000	11	2	3	3,2	0,48	2,48	-0,52
5	2	10000-20000	2	1	2,7	0,67	0,80	2,36	-0,34
6	3	10000-20000	3	1	0,71	0,57	0,56	0,84	0,13
7	2	20000<	22	5	6,25	1,07	0,85	6,07	-0,18
8	2	20000<	22	5	6,25	1,07	0,85	6,07	-0,18
9	2	20000<	22	6	6,25	1,07	0,85	6,21	-0,04
10	2	10000-20000	2	3	2,7	0,67	0,80	2,76	0,06
11	2	10000-20000	2	3	2,7	0,67	0,80	2,76	0,06
12	3	10000-20000	3	0	0,71	0,57	0,56	0,40	-0,32
13	3	20000<	33	1	2	1,14	0,64	1,64	-0,36
14	2	20000<	22	6	6,25	1,07	0,85	6,21	-0,04
15	2	20000<	22	6	6,25	1,07	0,85	6,21	-0,04
16	2	20000<	22	7	6,25	1,07	0,85	6,36	0,11
17	1	10000-20000	11	1	3	3,2	0,48	1,97	-1,03
18	1	<10000	1	0	1,36	1,65	0,45	0,62	-0,75
19	1	<10000	1	1	1,36	1,65	0,45	1,16	-0,20
20	2	10000-20000	2	2	2,7	0,67	0,80	2,56	-0,14
21	2	10000-20000	2	3	2,7	0,67	0,80	2,76	0,06
22	1	10000-20000	11	2	3	3,2	0,48	2,48	-0,52
23	2	20000<	22	7	6,25	1,07	0,85	6,36	0,11
24	2	20000<	22	8	6,25	1,07	0,85	6,51	0,26
25	3	10000-20000	3	0	0,71	0,57	0,56	0,40	-0,32
26	2	10000-20000	2	3	2,7	0,67	0,80	2,76	0,06
27	1	10000-20000	11	1	3	3,2	0,48	1,97	-1,03
28	1	10000-20000	11	2	3	3,2	0,48	2,48	-0,52
29	1	10000-20000	11	3	3	3,2	0,48	3,00	0,00
30	1	<10000	1	1	1,36	1,65	0,45	1,16	-0,20
31	1	<10000	1	2	1,36	1,65	0,45	1,71	0,35
32	1	<10000	1	4	1,36	1,65	0,45	**2,81**	**1,44**
33	1	10000-20000	11	3	3	3,2	0,48	3,00	0,00
34	1	10000-20000	11	3	3	3,2	0,48	3,00	0,00
35	1	10000-20000	11	4	3	3,2	0,48	3,52	0,52
36	1	<10000	1	1	1,36	1,65	0,45	1,16	-0,20
37	3	10000-20000	3	1	0,71	0,57	0,56	0,84	0,13
38	3	20000<	33	2	2	1,14	0,64	2,00	0,00
39	3	20000<	33	1	2	1,14	0,64	1,64	-0,36
40	3	10000-20000	3	0	0,71	0,57	0,56	0,40	-0,32
41	1	<10000	1	2	1,36	1,65	0,45	1,71	0,35
42	1	<10000	1	3	1,36	1,65	0,45	**2,26**	**0,90**
43	2	10000-20000	2	3	2,7	0,67	0,80	2,76	0,06
44	2	10000-20000	2	4	2,7	0,67	0,80	2,96	0,26
45	3	20000<	33	2	2	1,14	0,64	2,00	0,00
46	3	20000<	33	2	2	1,14	0,64	2,00	0,00
47	2	10000-20000	2	2	2,7	0,67	0,80	2,56	-0,14
48	1	10000-20000	11	5	3	3,2	0,48	**4,03**	**1,03**
49	1	10000-20000	11	7	3	3,2	0,48	**5,06**	**2,06**
50	2	10000-20000	2	3	2,7	0,67	0,80	2,76	0,06
51	3	20000<	33	1	2	1,14	0,64	1,64	-0,36
52	3	20000<	33	3	2	1,14	0,64	2,36	0,36
53	3	20000<	33	4	2	1,14	0,64	2,73	0,73
54	3	10000-20000	3	2	0,71	0,57	0,56	1,28	0,57
55	3	10000-20000	3	1	0,71	0,57	0,56	0,84	0,13

Four hazardous sites are identified (marked in red boxes): nr 32 and nr 42, both non-signalised intersections with a daily traffic volume of <10000; and nr 48 and 49, both non-signalised intersection with a daily traffic volume of 10000-20000. At these sites, the estimated expected number of accidents is substantially higher than the “normal” number of accidents for similar sites.

2.3 Stage 3 – Diagnosis of accident patterns

This stage has two objectives:

i. to identify the factors contributing to the hazardousness of the site;
ii. to ascertain whether the site is a true or a false black spot.

The first objective concerns identification of both accident contributory factors and factors contributing to injury severity, since the aim is to minimise/eliminate factors contributing to both accident and injury outcome.

Regarding the second objective, it is important to exclude the sites falsely identified in the previous stage as black spots from further action. If this is not done and false black spots are submitted to subsequent treatment, it results in an ineffective use of resources.

Work should start with in-office accident analysis subsequently complemented with site inspections and in-field traffic observations.

Accident tabulation

The recorded accidents for each identified black spot are analysed to find a pattern of accidents and factors contributing to the accidents and their severity. Accident analyses should include the following circumstances:

- Number of accidents by injury severity (fatal, with severe or slight injury);
- Distribution of accidents by type (situation (e.g., run-off the road, head-on, etc.), involved parties and vehicles);
- Distribution of accidents by time (e.g., during the day, week, year);
- Distribution of accidents by circumstances (e.g., road surface condition, light condition, weather);
- Characterisation of involved persons (e.g., use of safety device, blood alcohol content);
- Information of relevance (e.g., school zone, road work, proximity of a pub);

Information about the accidents at the studied site should be arranged in a way that makes it easy to identify accident patterns, see an example in Table 3.

Collision diagram

To get a good overview of the type of the accidents that occur at the studied location, a collision diagram – a graphic representation - displaying all the recorded accidents at the site should be made. See an example of a collision diagram in Figure 3.

Comparing to “typical” accident pattern

The identified accident pattern is not necessarily unique for the site in question – it can actually be consistent with the “typical” pattern for the given type of location. Hence, the information from the accident analysis and the collision diagram should be compared with the “typical” pattern of accidents of the sites of the same type. An overrepresentation of a given type of accident will indicate a specific safety problem at the site in question.

Example: Intersections of a middle-sized city - Accident tabulation and collision diagram

Table 3. Accident data arranged for site nr 49.

Nr	Severity	Type	Day of week	Time of day	Road condition	Light condition	Alcohol involved	Information of relevance
1	Fatal	Pedestrian - Car	Fri	18:10	Wet	Dawn/ dusk	Yes, pedestrian	Pub nearby
2	Slight injury	Car-car rear-end	Thu	07:30	Dry	Daylight	No	
3	Slight injury	Pedestrian - Car	We	11:52	Dry	Daylight	No	
4	Severe injury	Pedestrian - Car	Fri	17:50	Dry	Dawn/ dusk	Yes, pedestrian	Pub nearby
5	Slight injury	Car-car rear-end	We	21:10	Dry	Darkness	No	
6	Slight injury	Car-car rear-end	Mo	11:45	Dry	Daylight	No	
7	Severe injury	Pedestrian - Car	Sat	19:15	Wet	Darkness	Yes, pedestrian	Pub nearby
Key finding	***Fatal: 1 Severe: 2***	***Pedestrian: 4***	***Fri/Sat: 3***	***Evening: 3***	***Wet: 2***	***Darkness/dusk: 3***	***Alcohol: 3***	***Pub nearby***

The key finding from the accident tabulation is that the most severe accidents involve pedestrians hit by a car, on weekend evenings in dawn/dusk/darkness where the pedestrian was intoxicated by alcohol. The rest of the accidents were rear-end crashes between cars. Subsequent field observations should focus on checking friction of the road surface, illumination at the site, speed measurements, existence of pedestrian facilities and observation of pedestrian behaviour generally and during weekend evenings, as well as the location of the nearby pub.

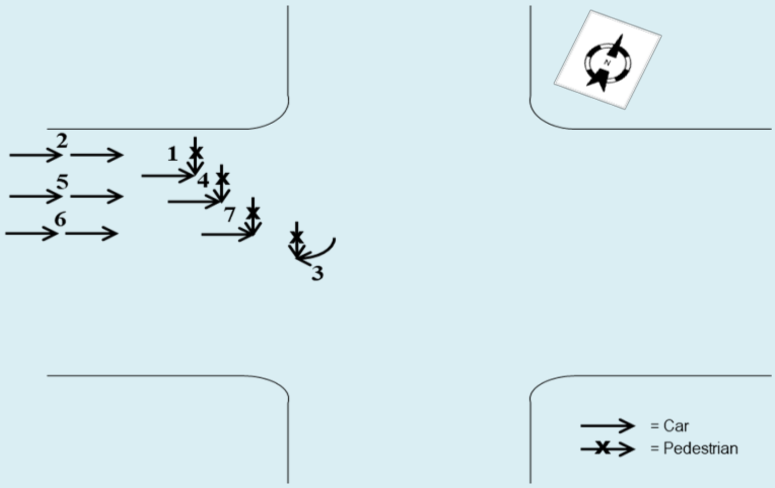


Figure 3. Collision diagram for site nr 49.

The key finding from the collision diagram is that all accidents occurred on one approach to the intersection, hence subsequent field observations should focus on this approach.

Based on the findings from the accident tabulation and the collision diagram the following hypotheses are formulated, to be checked through site visits and behavioural observations:

- Pedestrians behave aberrant when crossing the road.
- The repeated case of intoxicated pedestrians indicate an alcohol serving place nearby.
- Speeds of passing cars are too high for the conditions at the site.
- Rear-end crashes between cars indicate poor friction of the road surface.
- There might be visual obstructions hindering car drivers and pedestrians to detect each other.

- Illumination at the site during darkness might be poor.

2.4 Stage 4 – Site observations

To complement accident analyses, site inspection, traffic surveys, and possible interviews should be carried out. It should begin with a familiarising site visit. If the accident pattern is concentrated to certain period of time of day, site visits should be carried out at this same period of time too. The site inspector should walk, cycle, and drive through the site, carrying out the manoeuvres revealed by the collision diagram in both daylight and darkness. It is useful to make photographs of the site from all approaches to be able to visualize the site afterwards in the office. Talking to road users and local people may provide useful information.

It is useful to take to the site visit a drawing of the site, where notes can be made on details, and the collision diagram. To ensure personal safety during site visit reflective jackets should be worn and when in the carriage way someone else should watch for traffic. Traffic or visibility of road users should not be obstructed.

Site inspection

Since accident reporting is typically low and skew, site investigations may identify safety problems that did not appear from the accident analysis. Examples of site-related contributory factors to accidents are: obstructions to visibility by road furniture, trees, or parked vehicles, hard objects within the recovery zone, lack of pedestrian/cycle facilities, road surface with low friction, illumination deficiencies. Site investigations should be made relatively formalised to ensure objectivity, completeness, reproducibility, comparability and documentation, hence the use of checklists is recommended (Sorensen and Elvik, 2007). For Site Inspection Form see Appendix I.

Traffic conflict studies

A well-established formalised type of behaviour observation is the traffic conflicts technique. A few hours of observation of traffic conflicts on site reveals more information about safety problems than analysing recorded accidents at the site during several years. However, the method requires trained conflict observers. How to conduct a traffic conflict study is described in Appendix II. For more detailed description of the method refer to Laureshyn and Várhelyi (2018).

Traffic surveys

Speeds of randomly selected "free" vehicles in a traffic stream, i.e. vehicles that can "freely" choose their speed (not hindered by other vehicles or red/amber traffic light) can be measured with a hand-held radar gun - unobtrusively. The speed of approx. 100 vehicles per measurement section should be measured to get a representative measure. For protocol for speed measurements with radar gun see Appendix IV.

Driver behaviour at a pedestrian crossing can be observed by counting each encounter as one case and calculating percentages of various types of encounters. For recording sheet of driver behaviour at a pedestrian crossing see Appendix V.

Other types of behavioural observations can be carried out to quantify events of aberrant behaviour identified at the familiarising site visit. Such aberrant behaviour may be red light running/walking, jay-walking, crossing at inappropriate place or adverse route choice. As an example see the recording sheet of cyclists' adverse route choice in Appendix VI.

Example: Intersections of a middle-sized city – Results from site visit and behavioural observations for site nr 49

Site visits revealed the following risk factors at the site:

- The road surface on the approaches to the intersection along the main road is very smooth indicating poor friction.
- There is a bus stop before the pedestrian crossing (see drawing from the site inspection form in Figure 4 below) creating visual obstructions between approaching car drivers and pedestrians intending to cross the road.
- Illumination at the pedestrian crossing during darkness is unsatisfactory.
- There is a pub serving alcohol near the site.

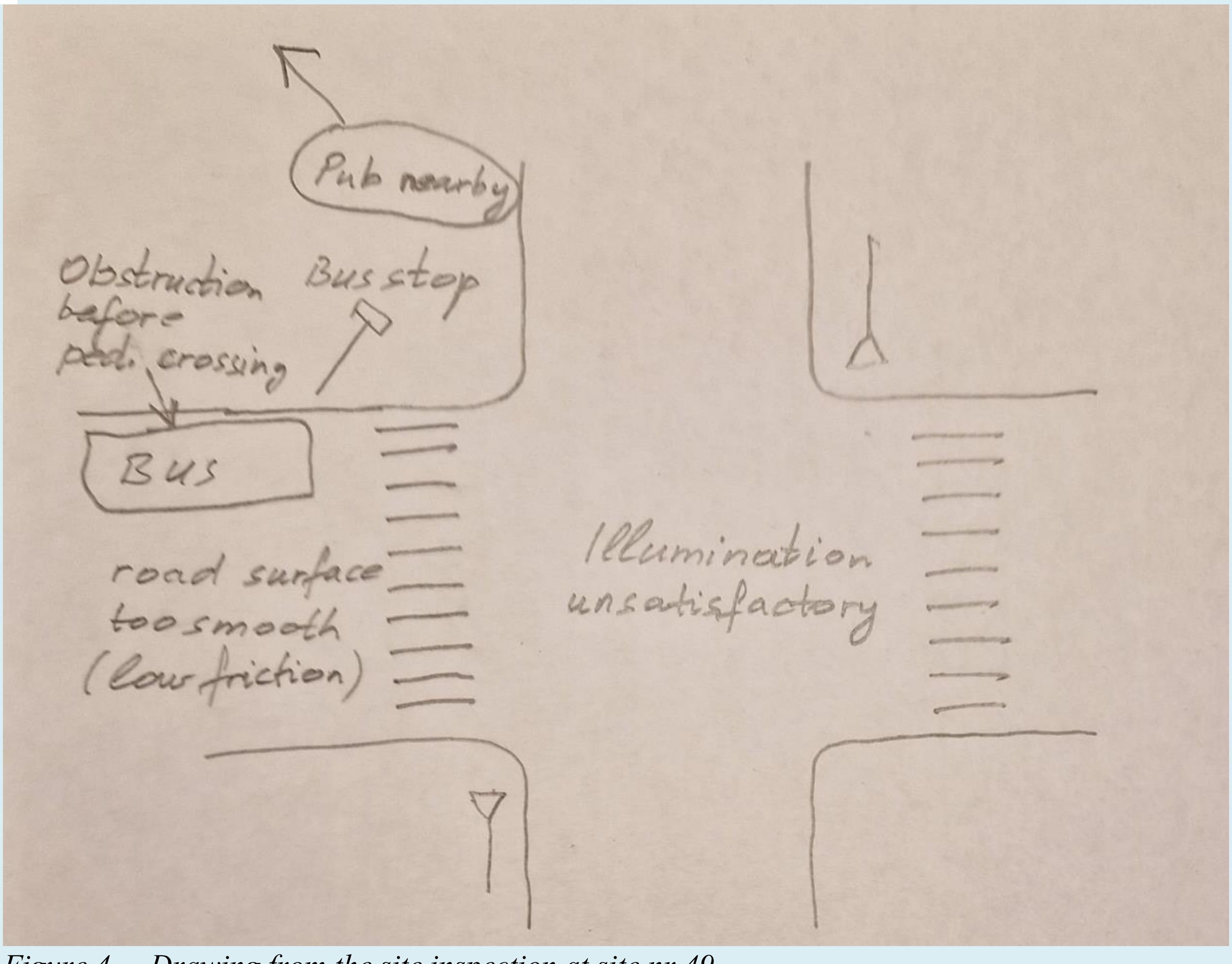


Figure 4. Drawing from the site inspection at site nr 49.

Behavioural observations and speed measurements revealed that:

- Pedestrians do not pay attention to both directions when crossing the road.
- The mean speed of passing cars is over 50 km/h, which is too high for the conditions at the site.

2.5 Stage 5 – Analysis of all collected data per site

It is important to determine whether the identified sites are true black spots or sites that erroneously have been identified due to a randomly high number of accidents. For this assessment the result of the accident analyses, site inspections and traffic surveys should be used. The accident analyses (tabulation and collision diagram) is used to generate hypotheses about risk factors contributing to accidents, while the site inspection and traffic surveys are used to test these hypotheses. Conformity between the results from these analyses will indicate that the given site is a true black spot. (Sorensen, 2007).

If the detailed analysis of accident data, data from site inspections and traffic surveys do not identify site related contributory factors to the recorded accidents, it can be concluded that the site in question is likely to be a false black spot and no treatment will be recommended.

Example: Intersections of a middle-sized city – Analysis of all collected data for site nr 49

Site visits and behavioural observations confirmed most of the hypotheses formulated based on the findings from the accident tabulation and the collision diagram:

- The road surface on the approaches to the intersection along the main road is very smooth indicating poor friction.
- There is a bus stop before the pedestrian crossing creating visual obstructions between approaching car drivers and pedestrians intending to cross the road.
- Illumination at the pedestrian crossing during darkness is unsatisfactory.
- There is a pub serving alcohol near the site.
- Pedestrians do not pay attention to both directions when crossing the road.
- The mean speed of passing cars is over 50 km/h, which is too high for the conditions at the site.

Subsequent proposal of countermeasures should be directed to the above identified safety deficiencies.

2.6 Stage 6 – Ranking of selected sites in priority for treatment

The identified hazardous sites should be ranked for treatment based on their estimated expected number of accidents.

Example: Intersections of a middle-sized city – Priority ranking of identified hazardous sites

The identified hazardous sites are priority ranked based on their estimated expected number of accidents in Table 2. The priority order of the identified hazardous sites for treatment is as follows:

- Intersection nr 49 with 5.06 estimated expected number of accidents,
- Intersection nr 48 with 4.03 estimated expected number of accidents,
- Intersection nr 32 with 2.81 estimated expected number of accidents,
- Intersection nr 42 with 2.26 estimated expected number of accidents.

2.7 Stage 7 – Proposal of countermeasures

This stage comprises the presentation of the priority list of sites with proposals for their treatment to minimize and eliminate the identified safety problems. If there is a clear accident pattern at the site in question, and evidence for identified risk factors contributing to this pattern, the most effective treatment will be identified easily. Cost-effective countermeasures have been composed by PIARC (2003); Elvik, et al. (2009); and SafetyCube (2023) https://www.roadsafety-dss.eu/#/. Also, the Tanzanian Road Geometric Design Manual (Ministry of Works, 2011) should be consulted.

The proposed countermeasures should be subjected to an assessment including a socio-economic assessment of the proposed countermeasures and a qualitative consideration of whether the measures will have any positive/negative or neutral effect on, safety, accessibility, and mobility.

When thinking about appropriate countermeasures, the following issues should be considered:

- Cost-effectiveness. Low-cost measures should be prioritised. Some measures may be effective, but may be unnecessarily expensive.
- Long lasting, i.e. the initial effect does not wear off as drivers get used to them.
- Will not increase unsafety (cause other types of accidents, or other unacceptable nuisances).
- If its implementation needs considerable publicity campaign or heavy police enforcement.
- If the necessity of its implementation can be explained to decision makers.

Example: Intersections of a middle-sized city – Proposal of countermeasures for site nr 49

The proposed countermeasures are directed to the identified safety deficiencies in the analysis stage:

- Resurface the road on the approaches to the intersection along the main road to improve friction.
- Install a speed hump of standardised type (see Figure 5), which ensures 30 km/h speed of passage without causing inconvenience at that speed level. The hump should begin appr. 10 metres before the pedestrian crossing to ensure effective interaction between drivers and pedestrians.
- Install middle refuge to prevent drivers from taking the opposite direction to avoid the hump.
- The bus stop before the pedestrian crossing should be moved to after the intersection.
- Prevent parking before the pedestrian crossing by installing bollards along the curb.
- Illumination at the pedestrian crossing during darkness is to be enhanced.

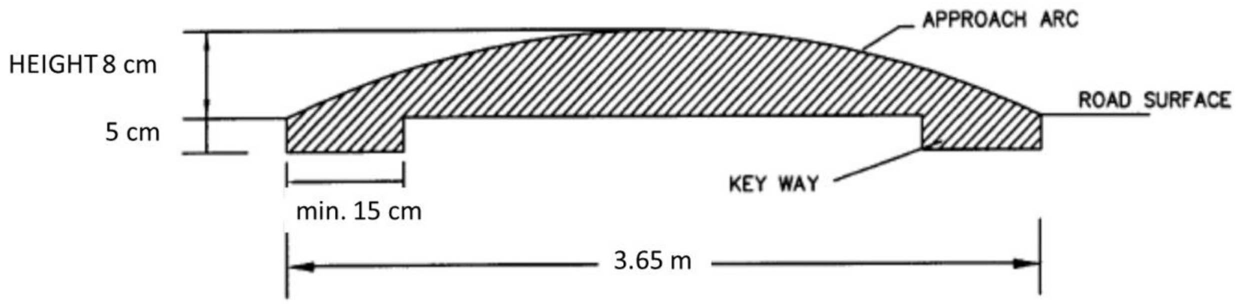


Figure 5. Speed hump of standardised type which ensures 30 km/h speed of passage without causing inconvenience at that speed level (Watts, 1973).

Design of countermeasures

It is advisable to produce a schematic drawing with all proposed countermeasures for each site. Doing it makes you to think through the proposal in its completeness, it enables you to see how everything will fit on the site and whether there will be any ambiguities, it enables tenderers to understand what is expected from them, and it provides the basis for controlling the construction work on the site.

For altering carriage ways, curbs, road markings, and installing refuges, islands, humps, roundabouts, etc., a drawing in scale will have to be prepared. It is good practice to submit the drawings for a Road Safety Audit carried out by an auditor who was not involved in the design of the measures.

Example: Intersections of a middle-sized city – Schematic drawing of countermeasures for site nr 49

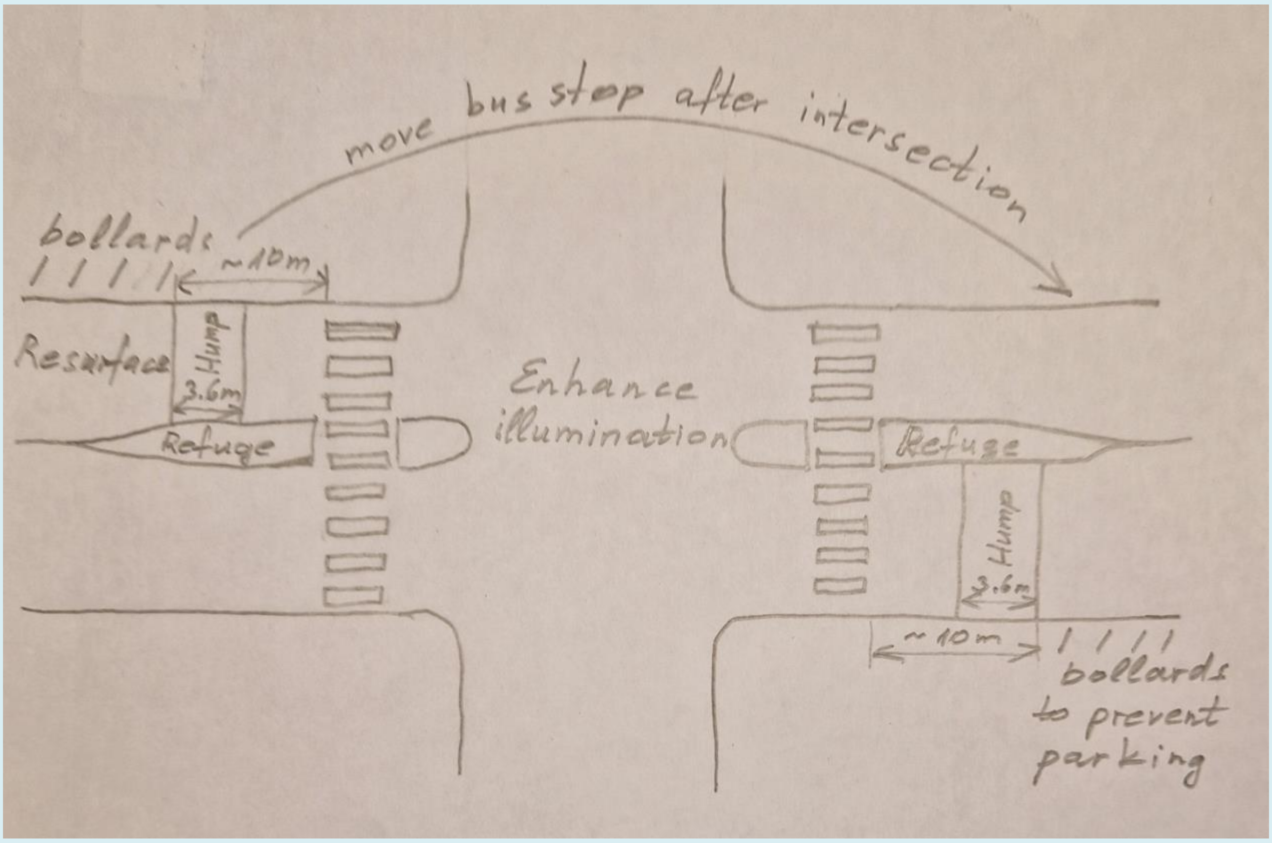


Figure 6. Schematic drawing of countermeasures for site nr 49.

2.8 Stage 8 – Effect assessment of the proposed measures

A cost/benefit analysis of implementing the proposed measures should be carried out. However, since values for preventing injuries and fatalities are not available in Tanzania a monetary based cost/benefit analysis cannot be made. Though, a simplified effect assessment, a prospective evaluation can be useful to present the advantages and disadvantages of the proposed measures. The effect assessment considers basic criteria of transport, such as accessibility, level of service, environmental effects and safety and yields an effect profile showing assessed values on a scale from minus 3 to plus 3. For effect assessment sheet see Appendix VIII.

Example: Intersections of a middle-sized city – Effect assessment of proposed measures for site nr 49

The effect profile of the proposed measures in Figure 7 below displays that the strongly positive effects for safety and level of service for pedestrians outweigh the negative effects of somewhat deteriorated level of service for cars and buses, and increasing emissions and noise.

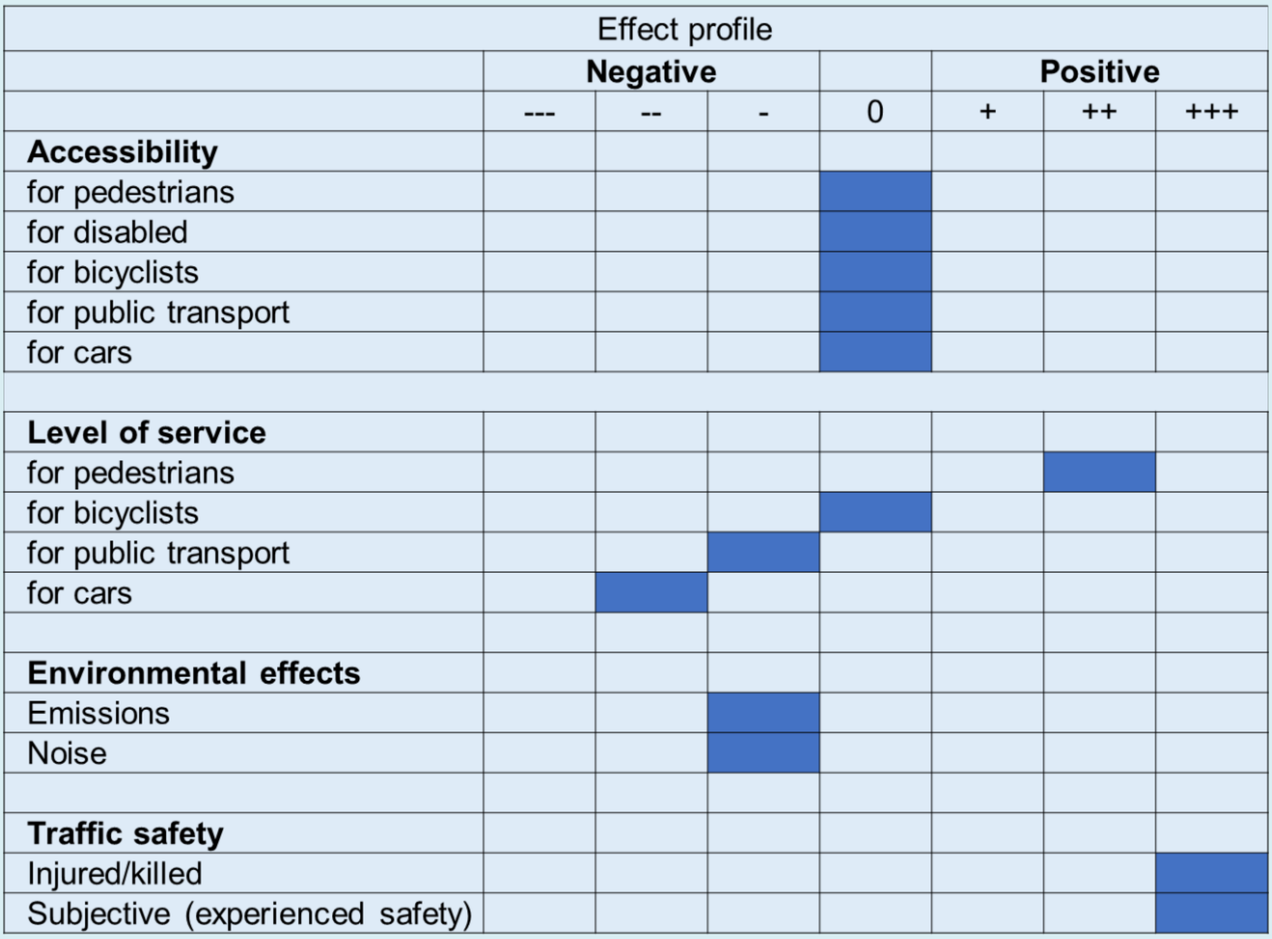


Figure 7. Effect assessment of the proposed measures for site nr 49.

2.9 Stage 9 – Design of evaluation study

The effects of the implemented measures should be subsequently evaluated. Evaluation should control for local changes in traffic volume, long term trends in accident development and regression-to-the-mean effects. The best way to do this is employing a before-after study. The before-after study should be designed before the treatment of the sites, so the data collection for the before situation can be carried out on site.

To make an accident-based evaluation of the safety effects, one should have access to accident data for at least three years after the implementation of the measures. Even if accident-based evaluation is planned for at a later stage, studies using non-accident based safety indicators, such as traffic conflicts, road user behaviour, speed, and interviews with road users should be made.

To control for effects of extraneous variables, such as changes in traffic pattern, vehicle mix, and long-term safety trends, the evaluation study - besides the site in question - should include similar sites for control with respect to area type, design factors and traffic volumes. At both the study site and the control sites the same type of surveys should be carried out both before and 4-6 months after (to let road users to get used to the new situation) the implementation of the countermeasures, see Table 4. However, at the study site a short survey should be made to check if no new safety or other problems were created by the countermeasures.

Table 4. Evaluation study design.

	Before	After 1 (immediate impacts)	After 2 (long term impacts)
Study site	√	√	√
Control site(s)	√	-	√

A first visit to the site should be made to identify occurrence of events and behavioural issues that may affect the safety situation of the site. Examples for occurrence of events affecting safety are presence of street vendors, parking cars or bus stop before a pedestrian crossing, etc. Examples for behavioural issues for which a systematic survey should be prepared to quantify the percentage of the behaviour type are drivers not giving way to pedestrians at pedestrian crossing, one driver stops before the pedestrian crossing and another one passes, not stopping at stop sign, red light running/walking, aberrant movements, etc.

Traffic surveys are time consuming and expensive. To get the most benefit for the least costs a careful planning is necessary. A careful planning saves unnecessary costs during data collection and analyses.

The steps of an evaluation study are as follows:

- Formulating hypotheses, selecting observational variables and observational methods,
- Planning of practicalities,
- Data collection in field,
- Analysis of collected data,
- Presentation of the results and conclusions.

Formulating hypotheses, selecting observational variables and observational methods

Based on the identified safety issues at the site, hypotheses for each issue to be formulated, the main hypothesis being that safety will improve on the site in question. Such hypotheses, formulated for relevant safety indicators related to site-specific problems may be: accident will decrease, traffic conflicts will decrease, speed violations will decrease, red light running will decrease, stopping behavior will improve, yielding behavior will improve, rule compliance will improve, etc. To be able to verify or reject the formulated hypotheses, observational variables have to be selected for each of them. Observational data for these variables before and after the implementation of the countermeasures will yield information whether the measures brought about any changes.

Example: Intersections of a middle-sized city – Hypotheses, observational variables and survey methods for site nr 49

A first visit to the site could identify the occurrence of the following behavioural issues: vehicle speeds seem to be too high when passing the pedestrian crossing, drivers do not yield to pedestrians intending to cross at the pedestrian crossing, some pedestrians do not cross at the pedestrian crossing and do not pay attention to both directions when crossing the road. Also, some road users expressed that they don't feel safe when crossing the carriage way. For each of these safety issues hypotheses, observational variables and survey methods to be identified, see Table 5.

Table 5. Hypotheses, observational variables and methods for site observations for site nr 49.

Hypotheses	Observational variables	Survey methods
Less accidents	N of accidents	Accident analysis
Less conflicts	N of conflicts	Observation of traffic conflicts
Lower speeds	Mean speed, 85^{th} percentile speed, Percent of vehicles not speeding	Speed measurements with radar
Less aberrant behaviour	Drivers yielding behaviour towards pedestrians Pedestrians' crossing behaviour	Observation of percentage of correct giving way behaviour Observation of percentage of correct crossing behaviour
Road users feel safer	Opinion of road users on the site	Interviews with road users on site

2.10 Stage 10 – Site observations before treatment

Some of the observations were already carried during the site observation stage and the results from there can be used. Those results to be complemented with one or more traffic surveys.

Traffic counting

Knowledge about traffic volumes at the site will be of importance when comparing the before-after situation. Traffic counting should be carried out on working days during one hour in morning peak traffic and one hour in afternoon peak traffic, since volumes in different turning directions may differ significantly at these time periods. For manual traffic counting protocol see Appendix III.

Traffic conflict studies

A well-established formalised type of behaviour observation is the traffic conflicts technique. A few hours of observation of traffic conflicts on site reveals more information about safety problems than analysing recorded accidents at the site during several years. However, the method requires trained conflict observers. For instructions to carry out traffic conflict observations and conflict recording sheet see Appendix II.

Speed measurements

Vehicle speeds can be measured with help of pneumatic tubes on the road surface or a hand held speed gun. Speeds of randomly selected "free" vehicles in a traffic stream, i.e. vehicles that can "freely" choose their speed (not hindered by other vehicles or red/amber traffic light) should be measured. The speed of approx. 100 vehicles per measurement section should be measured to get a representative measure. From the measurements, mean speed, 85th percentile speed and speed distribution should be calculated for each measurement site. For protocol for speed measurements with radar gun see Appendix IV.

Behavioural observations

Behavioural observations are carried out to quantify different safety relevant behaviour types identified at the familiarising site visit. Each behavioural type is subdivided into several possible courses of events. Behaviour types may be stopping/yielding behaviour, red light running/walking, jaywalking, crossing at inappropriate place or adverse route choice.

An example is behaviour of drivers of vehicles approaching to a pedestrian crossing, where a pedestrian intends to cross. In this case, the possible courses of events are as follows: the driver 1) increases speed; 2) maintains speed; 3) reduces speed; 4) gives priority to the pedestrian. Each encounter is one case and represented by one of the types of the course of events. Approx. 100 cases should be observed to obtain a statistically robust base for conclusions. The analysis consists of calculating percentages of the various types of course of events.

To quantify each behavioural type, an observational protocol (mostly on a paper sheet) should be developed. For examples of such observational protocols see Appendix III-VI.

Interviews with road users

If the familiarising site visit revealed safety relevant issues experienced by road users those issues should be quantified by formalised interviews. An interview sheet should be prepared with a few safety relevant questions and approx. 100 people should be interviewed on site.

Planning of practicalities

In connection with carrying out the data collection, there are almost always some practical difficulties. In order to avoid such difficulties, it is wise to make a sample survey – a pilot study. It can give valuable information if the observation method works, the protocols are useful and so on. A sample survey testing the intended method can provide valuable opportunities for adjustments in advance, thereby eliminating sources of error. It is essential that the pilot study is as similar to the final study as possible.

An important part of the planning is the training of the survey staff. They must be motivated, informed about the purpose of the study and about the methodology.

Data collection in field

The work in the field must be followed from the start so that the staff will have the opportunity to ask questions and so that any misunderstandings can be corrected at an early stage. Reasonability checks of raw data should take place on an ongoing basis in order to detect registration errors in good time. The work schedule of the field staff must not include long work shifts. The ability to concentrate in the field decreases sharply after about an hour and a half without a break.

Example: Intersections of a middle-sized city – Observations before treatment for site nr 49

The variables to be studied for the site are:

- Traffic volumes – data about traffic volumes at the site will be of importance when comparing the before and after situations, hence manual traffic counting should be carried out on working days during one hour in morning peak and one hour in afternoon peak traffic, since volumes in different turning directions may differ significantly at these time periods. For traffic counting protocol see Appendix III.
- Vehicle speeds - speed of approx. 100 “free” vehicles approaching the pedestrian crossing should be measured at approx. 10 m before the pedestrian crossing. For the protocol for speed measurements with radar gun see Appendix IV. Since speed measurements already were carried out during the site observation stage those data can be used.
- Drivers´ behaviour towards pedestrians at the pedestrian crossing - Approx. 100 encounters, when a car approaches the pedestrian crossing where a pedestrian intends to cross to be observed. Each event should be registered as one of the following course of events: the driver 1) increases speed; 2) maintains speed; 3) reduces speed; 4) gives priority to the pedestrian. For the recording sheet of driver behaviour at a pedestrian crossing see Appendix V.
- Pedestrians’ crossing behaviour – Approx. 100 pedestrians crossing the carriage way at the intersection to be observed. For each event the following variables should be recorded: 1) pedestrian looks to left/right/both/not at all; 2) the trajectory of crossing (one of the numbered alternatives, see recording sheet in Appendix VI.
- Road users’ experienced safety - Approx. 100 road users to be interviewed at the site about their experienced safety and any specific details they think contributes to experience safety at the site. See interview form in Appendix VII.

2.11 Stage 11 – Treatment of the selected sites

It is a good idea to make a trial of the proposed scheme on the site to see how well it works. If new features are introduced (e.g. a roundabout, splitter islands, refuges), the borders of these features could be marked with traffic cones and temporary traffic signs could be installed. Then, it can be observed how well road users cope with the new layout, or if any adjustments are needed.

It may also be beneficial to arrange a publicity campaign in connection with the implementing of the measures, especially if the measure is unfamiliar for the road users and could be hazardous for those who do not understand it or might misuse it. A publicity campaign may inform the public why the measure is needed and how to use if safely. Putting notices in daily newspapers shows that the road authority has a caring attitude to road users' safety and may help prevent criticism.

For certain schemes police enforcement on site may be necessary during the first few weeks of the measure being in force.

2.12 Stage 12 – After study and data analysis for evaluation

Directly after the implementation of the countermeasures, a short observation on the site should be made to check if the countermeasures work as intended and they haven´t created any new safety or other problems. One should be ready to review the treatment and alter it if there is evidence of severe safety problems.

The after studies should be carried out at both the study site and the control site 4-6 months after the implementation when road users had enough time to get used to the new situation. The same types of observations and during the same conditions (type of day, weather) as during the before study should be carried out.

Analysis of observational data collected during the before and after periods

A comparative analysis of observational data collected during the before and after periods to be made. Comparing traffic volumes before and after may reveal if the traffic pattern remained unchanged at the study site or some traffic moved to alternative routes (thereby contributing to safety improvement on the study site, but possibly increasing safety problems at sites with increased traffic volumes).

If traffic conflict studies were carried out, their results give a "direct" indication if the safety situation changed. Output from speed measurements in the form of mean speed, 85^{th} percentile speed and speed distribution also are good "direct" indicators of changes in safety, since speeds play a basic roll in accident and injury occurrence. Observational data from safety related behaviour gives an indication whether behaviour has improved/deteriorated and interview data reveals whether road users feel safer at the site after the implementation of the treatment or there are any remaining overlooked issues.

Accident data analysis

An accident based evaluation of the safety effects of the implemented measures can be carried out when having access to three year's accident data during the after period. According to best practice the registered number of accidents at the study site is to be compared with control sites where no measures were implemented. This approach assumes that the annual average number of accidents (during the after period of 3-5 years) recorded at the study site provides an estimate of the expected number of accidents at that site. The annual average number of accidents (during the same 3-5 years period) recorded at the control sites provides an estimate of the expected number of accidents at the study site during the after period given that no measures were implemented. This approach controls for long term trends in accident development and local changes in traffic volume.

Example: Intersections of a middle-sized city – Before-after data analysis for site nr 49

Before-after analysis of observational data

The following variables were studied at the study site before and after the treatment: 1) traffic volumes; 2) vehicle speeds; 3) drivers´ behaviour towards pedestrians at the pedestrian crossing; 4) pedestrians' crossing behaviour; 5) road users' experienced safety.

Analysis of **traffic volumes** shows no changed traffic pattern regarding share of volumes in various directions at the study site. However, the total volume entering the intersection decreased by around 10 %, indicating that some traffic moved to alternative routes, which may contribute to increased safety at the study site, but it should be investigated if increasing traffic volumes may have caused safety problems at sites of the alternative routes.

The results from **speed data** analysis are presented in Table 6 and Figure 8. Even if the change in mean speed is small, the variance of speed decreased considerably. Also, the highest speeds decreased most: the 85th percentile speed decreased form 53 km/h to 44 km/h, and max speed from 65 km/h to 50 km/h. This change is positive for safety.

Table 6. Results from speed data analysis before and after the treatment for site nr 49.

Speed	Before	After
N of observations	100	100
Mean	42,4 km/h	41,4 km/h
Stdav	9,7 km/h	4,3 km/h
Median (50th percentile)	41 km/h	41 km/h
85th percentile	53 km/h	44 km/h
Max speed	65 km/	50 km/h

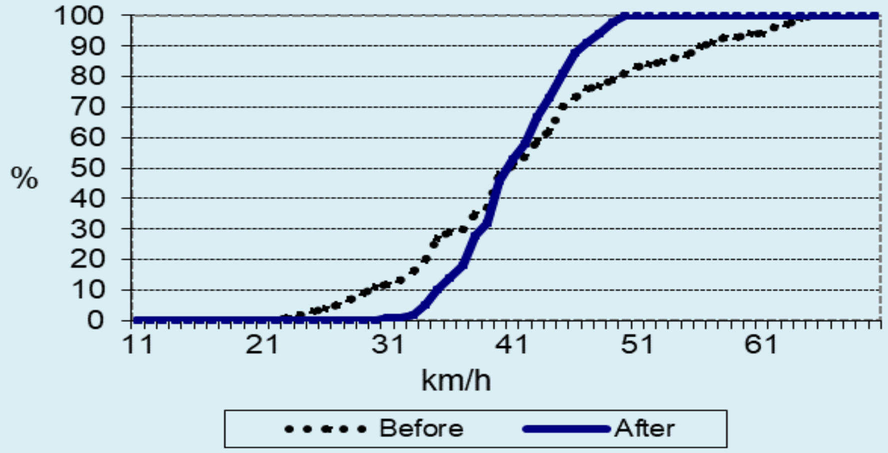


Figure 8. Speed distribution before and after the treatment for site nr 49.

Comparing **drivers´ behaviour towards pedestrians at the pedestrian crossing** reveals that the share of events when the driver reduces speed and gave priority to the pedestrian at the pedestrian crossing increased from 15 % to 45 %, which should be positive for the safety and mobility of pedestrians.

Comparing **pedestrians' crossing behaviour** reveals that a somewhat larger share (75 %) of pedestrians cross the carriage way at the pedestrian crossing than in the before situation (68 %), which is an improvement.

The interview results reveal that **road users' experienced safety** has improved after the implementation of the measures. The share of respondents stating that the site was very unsafe decreased from 35 % to 20 % and 55% of the respondents stated that the site was safer after the treatment.

Generally, it can be concluded that based on the observational before-after study, the implemented measures improved the safety situation at the site.

Before-after analysis of accident data

Site nr 49 is a non-signalised intersections with daily traffic volume 10000-20000. As control sites within this intersection type three sites are chosen, i.e. nr 29, 33, and 34), because their expected number of injury accidents equals the "normal" number of injury accidents for their type of site. During the 3 year after period, 2 injury accidents were recorded at site nr 29 and 33, and 3 accidents at site nr 34, giving an average of 2.33 per control site. During the same period, 2 injury accidents were recorded at the study site nr 49.

	Before	After
	Expected number of injury accidents	Recorded number of injury accidents
Study site (Nr 49)	5,13	2
Control sites (Nr 29, 33, 34)	3	2,33

	Number of injury accidents at study site	Mean number of injury accidents at control sites
Before	5,13	3
After	2	2,22
Change %	-61,0	-26,0
Effect of measure %	**-35,0**	

The number of injury accidents at the study site decreased by 61 % and at the control sites by 26 %. The difference between these percentages gives a 34.5 % safety improvement at site nr 49, brought about by the treatment.

In summary, both the observational before-after study, and the accident analysis show that the implemented measures improved the safety situation at the site.

3 Conclusions and Recommendations

Black Spot Management is one of the efficient Road Safety Infrastructure Management tools to improve safety of the road infrastructure. Several of the implementation steps for Black Spot Management are similar to those of Network Safety Management, however, if neither of these methods is practiced yet in the country, it is recommended to start with Black Spot Management, since black spots have typically a lot of accidents with clear accident patterns which often can be treated with low-cost measures.

The guidelines described above are based on best practice in Black Spot identification and treatment. The stepwise description of the process, with examples at each step, allows a systematic and efficient work to identify hazardous locations, analyse accident contributory factors at these sites, propose cost-effective countermeasures and design an evaluation study on the effectiveness of the proposed measures.

A fundamental prerequisite for carrying out Black Spot Management is that road accidents are recorded, and the records contain adequate information about the locality of accident, time of occurrence, accident type, and severity.

It is recommended that the first Black Spot Management exercise is carried out in a city of a smaller size, allowing the safety analysts to gain experience in carrying out the whole process without being overwhelmed with heavy burden of voluminous data to be managed.

After the BSM tool has been implemented by it is important that the method and the data is maintained and updated. Hence, an essential part of the implementation of the method is to establish a procedure for maintenance. A basic issue is to allocate resources for maintaining and updating the method, as well as the required data for its operation.

Besides registering traffic accidents continuously, it is important that data on traffic volumes, changes in road design and surrounding environment are maintained and updated. When changes are made at a certain location in the road infrastructure, it is important to record when it took place.

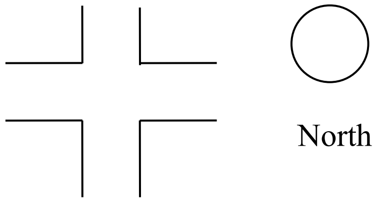
References

- Elvik, R. (2003) Traffic safety. Chapter 16 in Myer Kutz (editor): Transportation Engineers' Handbook. McGrawHill, 2003.
- Elvik, R. (2007) State-of-the-art approaches to road accident black spot management and safety analysis of road networks. TØI report 883/2007. Institute of Transport Economics. Norway.
- Elvik, R. Höje, A., Vaa, T., Sörensen, M. (2009) The Handbook of Road Safety Measures. Second Edition. Elsevier.
- Laureshyn, A., Várhelyi, A. (2018) The Swedish Traffic Conflict Technique - Observer's manual. Lund University, Sweden.
- Ministry of Works (2011) Road Geometric Design Manual - 2011 Edition, Tanzania.
- PIARC (2003) Road Safety Manual. PIARC Technical Committee on Road Safety, Cedex, France.
- RIPCORD-ISEREST (2011) *http://ripcord.bast.de/* http://www.ripcord-iserest.com *Brochure "Road Infrastructure Safety Management"* (2011-12-12)
- SafetyCube (2023) The European Road Safety Decision Support System https://www.roadsafety-dss.eu/#/. (Downloaded 11/11 2023).
- Sorensen, M. (2007) Best Practice Guidelines on Black Spot Management and Safety Analysis of Road Networks. TØI report 898/2007. Institute of Transport Economics. Norway.
- Sorensen, M., Elvik, R. (2007) Black Spot Management and Safety Analysis of Road Networks. Best Practice Guidelines and Implementation Steps. TØI report 919/2007. Institute of Transport Economics. Norway.
- Watts, G.R. (1973) Road Humps for the Control of Vehicle Speeds. TRRL Report LR 597.

Appendix I. Site Inspection Form

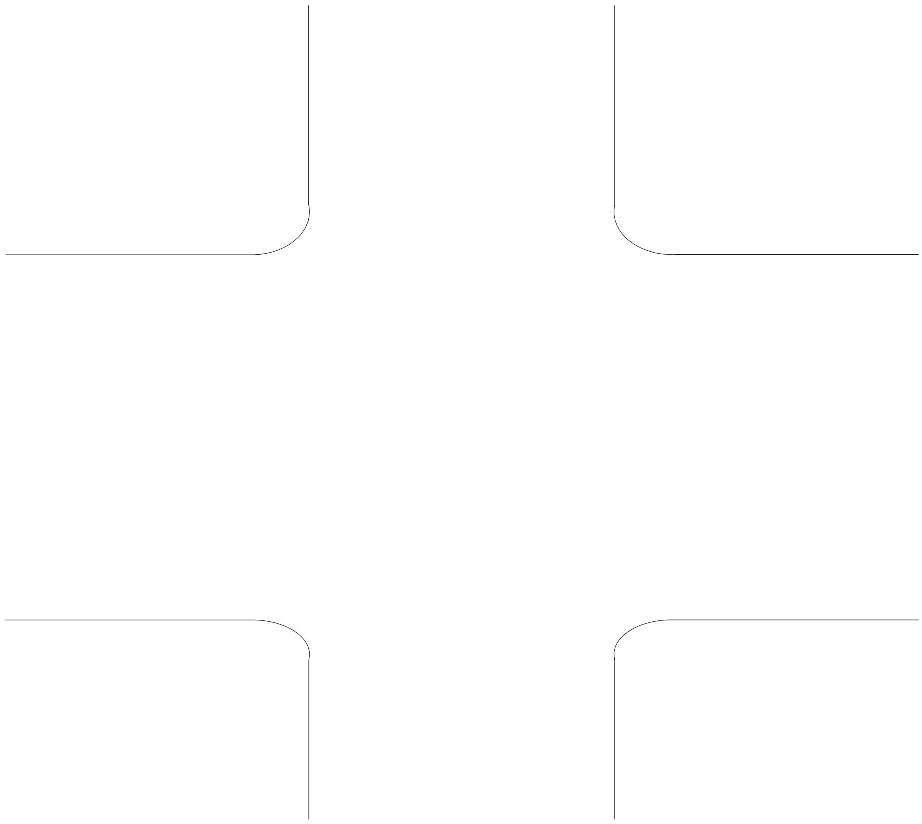
Observer:_________________ Date:__________ Time:________________ Site ID:_______

Name of Site:______________________________________



Weather: Sunny ☐ Cloudy ☐ Rainy ☐

Road surface: Dry ☐ Wet ☐



Mark: - North
- Road/street names
- Schools
- Markets/ vendors
- Bus stops
- Parking
- Hazardous objects

Appendix II. To Conduct a Traffic Conflict Study

The description below draws on the Swedish manual of the Traffic Conflict Technique (Laureshyn and Várhelyi, 2018).

What is needed to carry out conflict observations at a site are register forms, a watch and a pencil. It is the observer who has to detect conflicts, judge them and make notes, all in real time. It is becoming more and more common to use video recording parallel to the observations so that the observer can go back and see the situations once again when summarising the results.

Observation period

The number of observation days and number of observation periods per day is determined based on the expected frequency of conflicts. The expected frequency of conflicts is usually derived from previous experiences. Thirty hours of observations at one site should produce sufficient amount of serious conflicts to allow for a safety analysis of the site.

Observations are usually done in periods of 1-2 hours with breaks in between for the observer to recover. If it is important to cover a longer continuous period, observers can alternate at the site.

The observation period should be of the prescribed length and start exactly on time. When the period starts, the observer should be 100% ready – the camera installed (if used), the clocks synchronised, observation sheets at hands, etc. Therefore, it is recommended to arrive at the site at least 10 minutes before the start of the actual observations.

In before/after studies, the observation periods should be the same. It is also of importance that the before and the after observations are carried out during periods of similar traffic conditions (considering school or climate periods). The after observations should not be carried out directly after the implementation of a measure; experience shows, that it may take up to 6 months for the road users to adapt to the changed traffic conditions.

Observations are carried out in most cases in daylight and under dry weather conditions (this is due to considerations of hardship for human observers). If the accident pattern at the site is time-related, observations should take place during the periods when safety problems are most likely can be observed. Observations should not be carried out under unusual conditions, for example when large events in the vicinity interferes with “normal” traffic patterns.

Observers

The tasks of the observer are:

- to detect the conflict;
- to note who and when took the evasive action;
- to estimate the road users’ speeds and the distances to the projected collision point;
- to make a sketch of the conflict;
- to fill in other relevant information together with a verbal description of the course of events.

Observers are the most important “tool” in manual traffic conflict studies, therefore their proper training is highly important and should not be rushed or saved on. The training course for observers in Swedish Traffic Conflict Technique takes one full week and includes theoretical lectures, practical instructions, training on video-recorded conflicts, real-life field observation sessions and calibration of the observers.

The reliability of the observers is of fundamental importance for the valid results: the same observer should record conflicts consistently over time and the different observers should record the same conflicts in a similar manner. The trained observers need to stay in practice and should be “calibrated” against each other from time to time.

The number of necessary observers at one site depends on the complexity of the site. Experience shows that one observer can deal with a simple four-leg intersection with no more than two lanes per approach (up to an AADT of 22000 vehicles). Larger sites require an additional observer. When only one specific type of conflict is collected, one observer might be able to manage the task even at a complex site.

In case of an evaluation study, the observer should not have been involved in any way in the proposed countermeasure under evaluation.

In before/after studies, it is essential that it is the same observer who makes the observations in the before and the after situation.

Recommended equipment

The equipment of the observer usually includes:

- conflict register forms (see below);
- a conversion table to convert speed and distance to TA (see below);
- a watch;
- a pencil (pencils perform better in rainy weather as they still can be used on slightly wet paper);
- a personal identification (from the organisation running the study);
- a video camera (if available) together with the equipment for mounting. The observer's watch should be harmonised with the camera clock before the start of the observations.

The conflict registering form

The conflict registering form contains some general information about the location, observer's name, observations date and time, weather and surface conditions (see below). For each conflict situation, the following information should be recorded:

- time of the event;
- road users involved;
- possible secondary road user(s);
- the speeds of the involved road users, their distances to the collision point;
- the calculated TA-value (from speed and the distance using the table in Appendix 2);
- type of evasive action(s);
- a sketch of the conflict (including any possible secondary road users);
- a short verbal description of the course of events;
- notes of any violations of traffic rules, hazardous behaviour or any other issues of interest.

Before the observations

Before conducting the actual observations, the following preparations are recommended:

- Collect relevant information about the actual site (a map and drawing of the site, accident history if available, type of regulation, signal settings, traffic volumes, etc.).
- Investigate possibilities for the camera installation (if available). Balconies, lamp posts or other pieces of road infrastructure can be used.
- Prepare a sufficient number of conflict registering sheets. A practical solution is to have a folder with pasted conversion tables on the left hand side and the conflict sheets on the right hand side.
- Check the weather forecast and take appropriate clothes.
- Have a phone number to the supervisor of the study in case of any inquires.

Carrying out the observations

After arriving at the site the observer should select an observational point offering a clear view over the observational area. The location of the observation point should be marked on the conflict register form together with an arrow, indicating the north direction. Alternatively, easy-to-find landmarks should be marked on the intersection sketch. This is extremely important for assigning correctly the directions of the involved road users and location of the conflict.

In before/after studies, the observational point should be the same.

The observer should be unobtrusive, i.e. his/her presence should not influence road users passing the site. For example, wearing a reflecting "yellow vest" is not recommended. However, it is important that the observer is not inside a vehicle or building, which could lead to loss of important information when "not breathing the same air" with the observed road users.

To facilitate estimation of distance and speed the observer should make some initial measurements at the first arrival at the scene (distance between salient objects or marks can be measured). Also, speed estimations with the help of a radar gun could be made to get a perception of the prevailing speeds at the site.

If more than one observer are working at the same site, they should clearly discuss and agree on which area each observer is in charge for. If a conflict occurs in a place where both observers might record it, a note should be done in a register sheet so that it can be checked afterwards to avoid double-counting.

Every detected conflict situation should be recorded on an individual register form. The form should be filled in as complete as possible immediately. To save time, some of the fields can be pre-filled in advance (e.g. location, observer's name and position, observation period, etc.). The conflict forms should be number to make sure that none of them been unintentionally lost.

All conflicts should be recorded, even if only the serious conflicts are used in the later analysis. When a conflict is first detected, it might not be obvious whether it is a serious conflict or not until the necessary indicators have been calculated.

Presentation and interpretation of the results

Presentation of the results of a conflict study includes usually:

- A sketch with location of the conflicts (see Figure II.1);
- A summary table presenting the conflicts by type of manoeuvre and road users involved (see Table II.1);
- A diagram displaying the conflict severity distribution (see Figure II.2);
- Short video clips containing the recorded conflicts (if available).

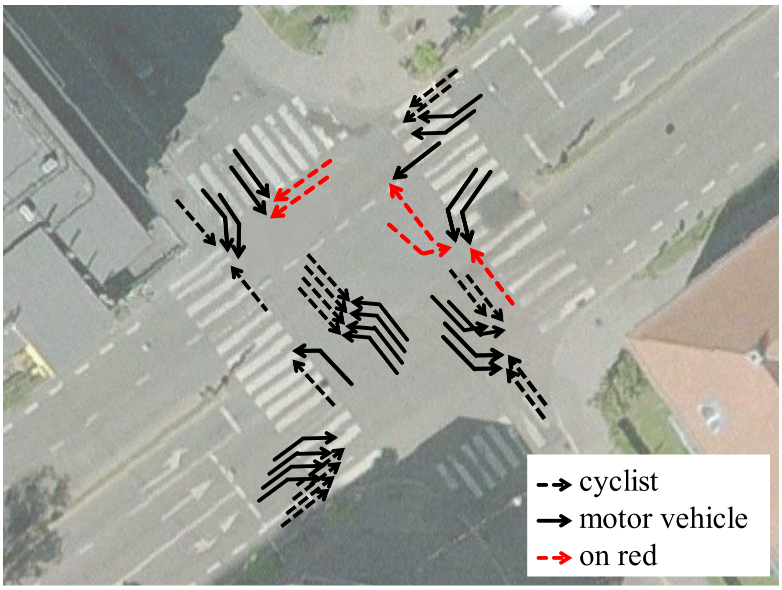


Figure II.1. An example of a sketch presenting the locations and types of the conflicts.

Table II.1. An example of a summary table of observed conflicts.

Conflict ID	Date	Conflict type	Road user 1	Road user 2	Time-to-Accident, sec.	Conflicting speed, km/h	Severity
28	2013-09-03, 07:09	Cyclist on red	cyclist	car	1,7	15	24
40	2013-09-03, 07:21	Cyclist on red	cyclist	moped	1,3	9	24
216	2013-09-04, 09:47	Cyclist on red	cyclist	car	1,1	32	26
254	2013-09-05, 07:28	Cyclist on red	cyclist	mc	1,9	14	24
22	2013-09-03, 07:01	Cyclist straight, Motor vehicle right	cyclist	car	1	12	25
32	2013-09-03, 07:12	Cyclist straight, Motor vehicle right	cyclist	car	1,1	10	25
207	2013-09-04, 09:11	Cyclist straight, Motor vehicle right	cyclist	car	1,2	8	25
292	2013-09-05, 08:57	Cyclist straight, Motor vehicle right	cyclist	car	1,6	12	24
396	2013-09-06, 09:50	Cyclist straight, Motor vehicle right	cyclist	car	0,8	11	25
934	2013-09-13, 07:40	Cyclist straight, Motor vehicle right	cyclist	car	1,4	17	25
62	2013-09-03, 07:59	Cyclist straight, Motor vehicle left	cyclist	car	1,5	10	24
496	2013-09-09, 09:28	Cyclist straight, Motor vehicle left	cyclist	car	0,9	12	25
594	2013-09-10, 08:33	Cyclist straight, Motor vehicle left	cyclist	car	1,4	13	24
710	2013-09-11, 08:10	Cyclist straight, Motor vehicle left	cyclist	car	1,7	19	24

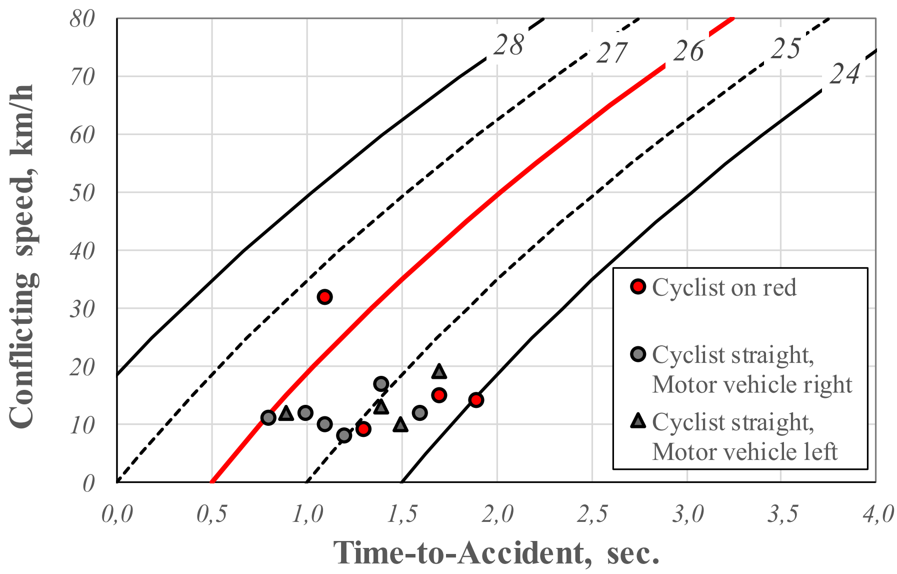


Figure II.2. An example of a conflict severity diagram.

Interpretation of the conflict study results includes:

- Identification of the common conflict types (by type of manoeuvre, types of road users involved, etc.);
- Identification of the positions where the conflicts take places;
- Identification of the particular circumstances for conflict occurrence (e.g. in darkness, peak or off-peak traffic, presence of parked vehicles hiding the view, etc.);
- Calculation of the mean Conflicting Speed and Time-to-Accident values.

In case of comparison between two sites or before/after studies, the following issues should be considered:

- Has accumulation of certain conflict types been eliminated?
- Has the severity of the conflicts decreased in general? For specific conflicts types?
- Have the mean Conflicting Speed and Time-to-Accident values changed?
- Have any new types of conflicts emerged not present before?

The Swedish conflict recording form

Observer:___________________________ Date:___________ Time:___________ Number:_____

City:____

Intersection:____

Weather: ☐ Sunny ☐ Cloudy ☐ Rainy

Surface: ☐ Dry ☐ Wet

Time period ☐ ☐ ☐ ☐ ☐ ☐ ☐ ....

	Road-user I	Road-user II	Secondary involved III
Private car	☐	☐	☐
Bicycle	☐	☐	☐
Pedestrian	☐	☐	☐
Other	______	______	______
Sex (ped.)	☐M ☐F	☐M ☐F	☐M ☐F
Age (ped.)	______	______	______
Speed	_____ kmph	_____ kmph	_____ kmph
Distance to coll. point	_____ mtrs	_____ mtrs	
TA value	_____ sec	_____ sec	
Avoiding action			
Braking	☐	☐	
Swerving	☐	☐	
Acceleration	☐	☐	
Possibility to swerve	yes ☐ no ☐	yes ☐ no ☐	

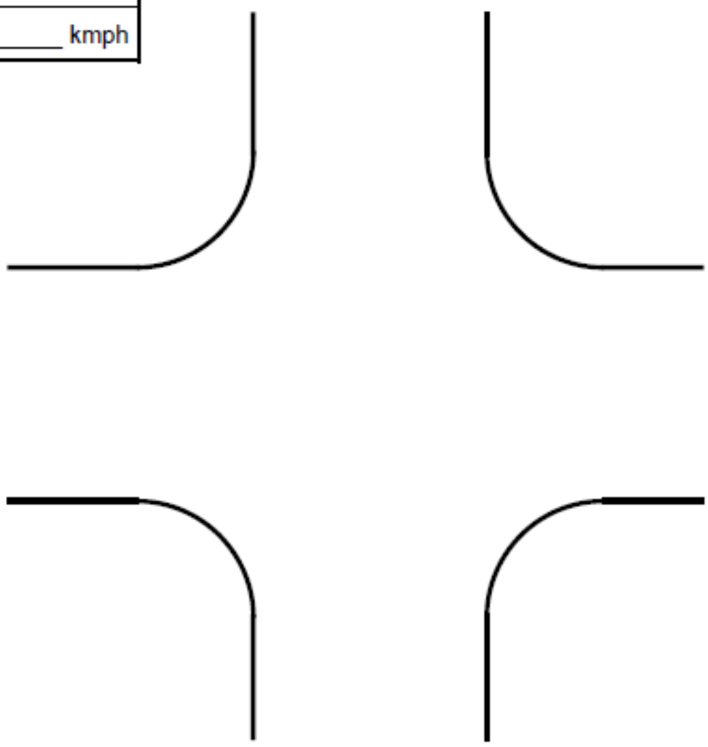
Description of the event:

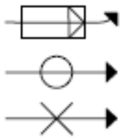
Continued on the other side: ☐ ⇒

Sketch including the positions of the road-users involved.

Mark your own position with ⊗

If video is used mark the position of the camera with

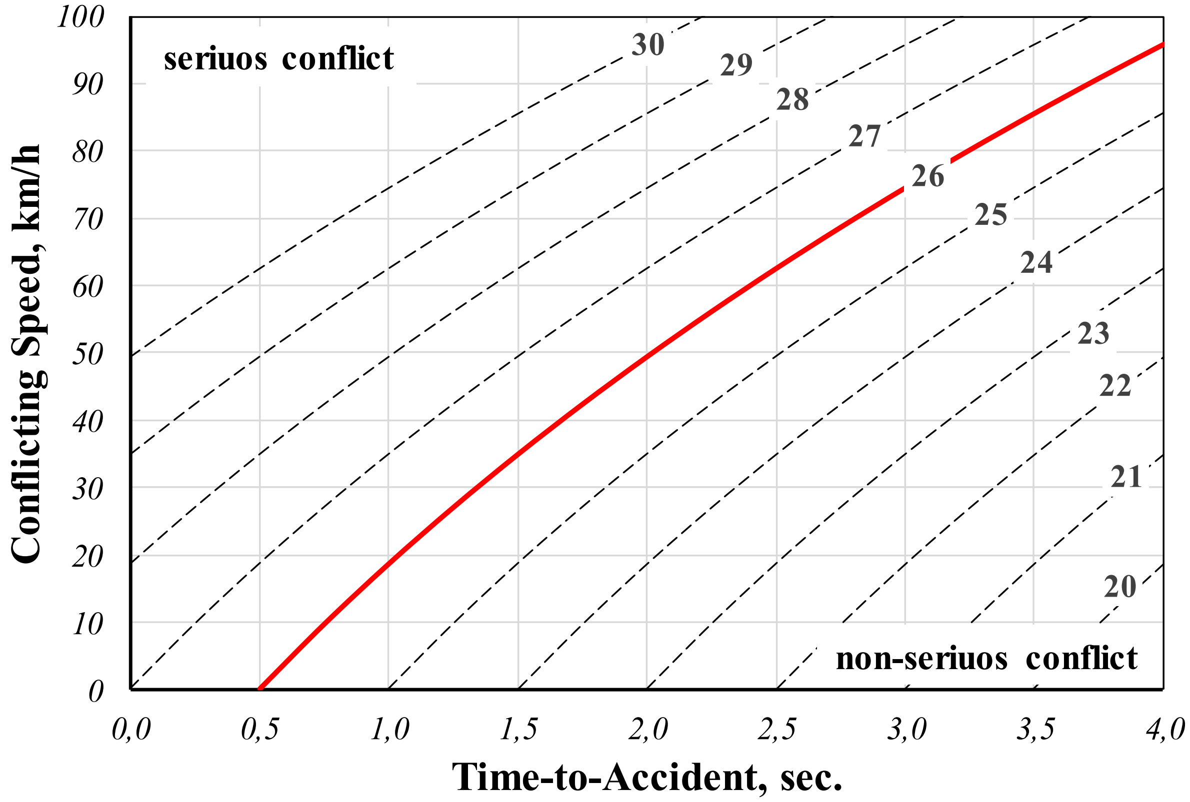




Conversion table to convert speed and distance to TA

Speed		Distance, m																			
km/h	*m/s*	0,5	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40	45	50	55
5	*1,4*	0,4	0,7	1,4	2,2	2,9	3,6	4,3	5,0	5,8	6,5	7,2									
10	*2,8*	0,2	0,4	0,7	1,1	1,4	1,8	2,2	2,5	2,9	3,2	3,6	5,4	7,2	9,0						
15	*4,2*	0,1	0,2	0,5	0,7	1,0	1,2	1,4	1,7	1,9	2,2	2,4	3,6	4,8	6,0	7,2	8,4	9,6			
20	*5,6*	0,1	0,2	0,4	0,5	0,7	0,9	1,1	1,3	1,4	1,6	1,8	2,7	3,6	4,5	5,4	6,3	7,2	8,1	9,0	9,9
25	*6,9*	0,1	0,1	0,3	0,4	0,6	0,7	0,9	1,0	1,2	1,3	1,4	2,2	2,9	3,6	4,3	5,0	5,8	6,5	7,2	7,9
30	*8,3*	0,1	0,1	0,2	0,4	0,5	0,6	0,7	0,8	1,0	1,1	1,2	1,8	2,4	3,0	3,6	4,2	4,8	5,4	6,0	6,6
35	*9,7*	0,1	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,5	2,1	2,6	3,1	3,6	4,1	4,6	5,1	5,7
40	*11,1*	0,0	0,1	0,2	0,3	0,4	0,5	0,5	0,6	0,7	0,8	0,9	1,4	1,8	2,3	2,7	3,2	3,6	4,1	4,5	5,0
45	*12,5*		0,1	0,2	0,2	0,3	0,4	0,5	0,6	0,6	0,7	0,8	1,2	1,6	2,0	2,4	2,8	3,2	3,6	4,0	4,4
50	*13,9*		0,1	0,1	0,2	0,3	0,4	0,4	0,5	0,6	0,6	0,7	1,1	1,4	1,8	2,2	2,5	2,9	3,2	3,6	4,0
55	*15,3*		0,1	0,1	0,2	0,3	0,3	0,4	0,5	0,5	0,6	0,7	1,0	1,3	1,6	2,0	2,3	2,6	2,9	3,3	3,6
60	*16,7*		0,1	0,1	0,2	0,2	0,3	0,4	0,4	0,5	0,5	0,6	0,9	1,2	1,5	1,8	2,1	2,4	2,7	3,0	3,3
65	*18,1*		0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,6	0,8	1,1	1,4	1,7	1,9	2,2	2,5	2,8	3,0
70	*19,4*		0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,8	1,0	1,3	1,5	1,8	2,1	2,3	2,6	2,8
75	*20,8*		0,0	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,7	1,0	1,2	1,4	1,7	1,9	2,2	2,4	2,6
80	*22,2*		0,0	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,7	0,9	1,1	1,4	1,6	1,8	2,0	2,3	2,5
85	*23,6*		0,0	0,1	0,1	0,2	0,2	0,3	0,3	0,3	0,4	0,4	0,6	0,8	1,1	1,3	1,5	1,7	1,9	2,1	2,3
90	*25,0*		0,0	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,4	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2
95	*26,4*		0,0	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,3	0,4	0,6	0,8	0,9	1,1	1,3	1,5	1,7	1,9	2,1
100	*27,8*		0,0	0,1	0,1	0,1	0,2	0,2	0,3	0,3	0,3	0,4	0,5	0,7	0,9	1,1	1,3	1,4	1,6	1,8	2,0

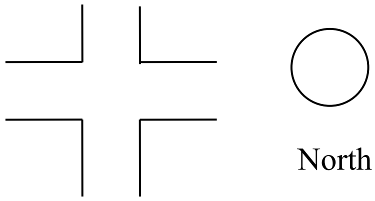
Conflict severity diagram



Appendix III. Protocol for manual traffic counting

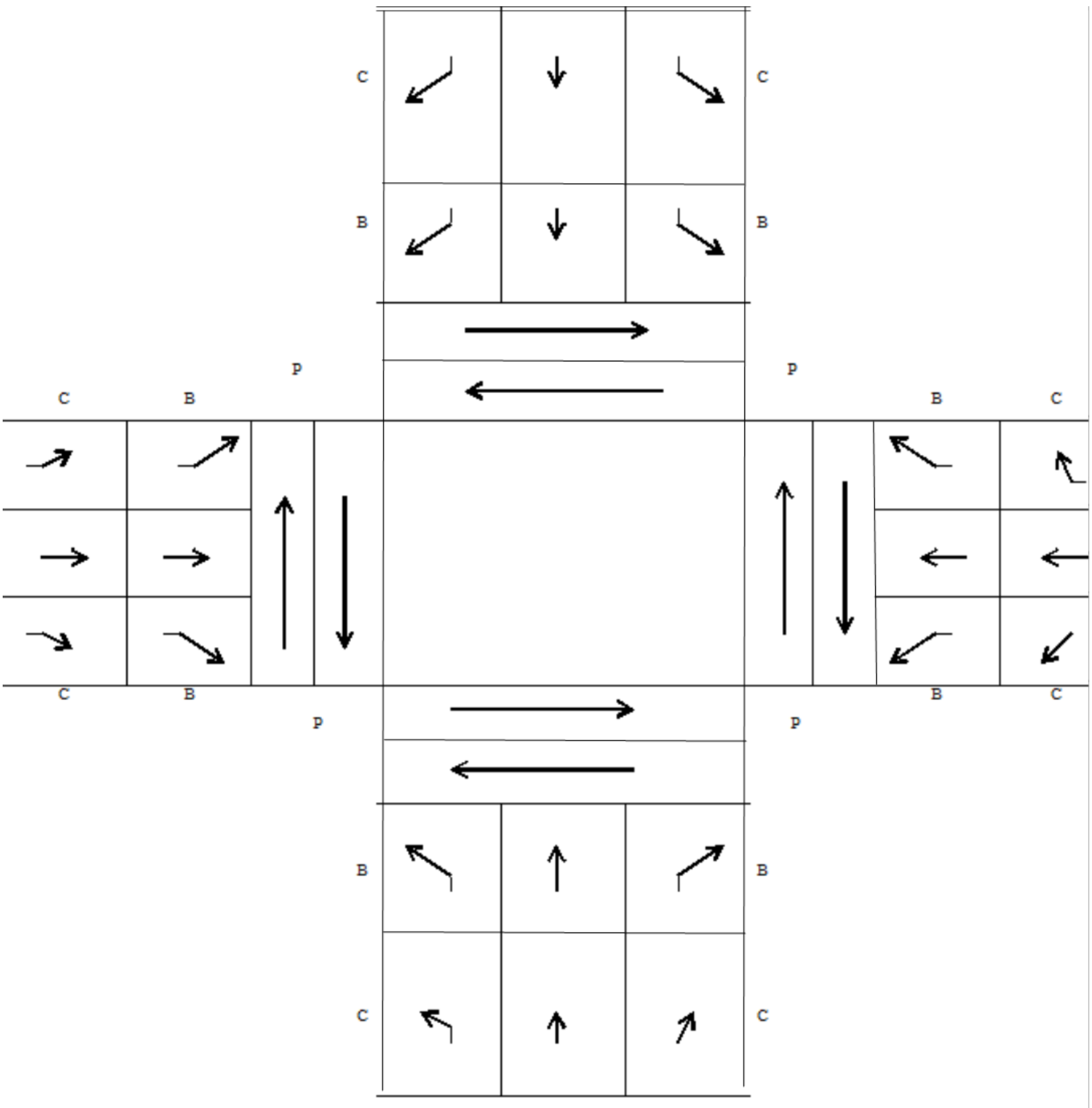
Observer:_________________ Date:__________ Time:________________ Site ID:_______

Name of Site:______________________________________



Weather: Sunny ☐ Cloudy ☐ Rainy ☐

Road surface: Dry ☐ Wet ☐

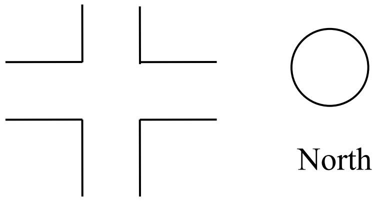


B = Bicyclist C = Car P = Pedestrian

Appendix IV. Protocol for speed measurements

Observer:__________________ Date:___________ Time:_________________ Site ID:_______

Name of Site:____



Weather: Sunny ☐ Cloudy ☐ Rainy ☐

Road surface: Dry ☐ Wet ☐

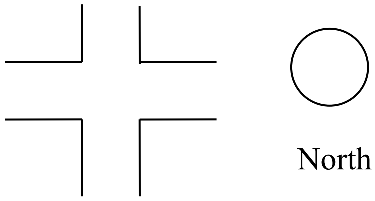
↑											N=
											m=
											Standdev.=

↓											N=
											m=
											Standdev.=

Appendix V. Recording sheet of driver behaviour at a pedestrian crossing

Observer:_________________ Date:__________ Time:________________ Site ID:_______

Name of Site:______________________________________



Weather: Sunny ☐ Cloudy ☐ Rainy ☐

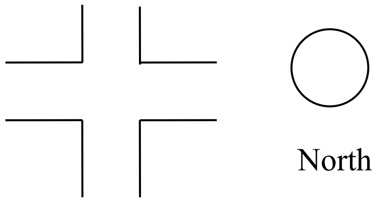
Road surface: Dry ☐ Wet ☐

Pedestrian from left				Pedestrian from right			
Car driver approaches and				Car driver approaches and			
Increases Speed on Sighting Pedestrian	Maintains Speed on Sighting Pedestrian	Reduces Speed on Sighting Pedestrian	Gives priority to Pedestrian	Increases Speed on Sighting Pedestrian	Maintains Speed on Sighting Pedestrian	Reduces Speed on Sighting Pedestrian	Gives priority to Pedestrian

Appendix VI. Recording sheet of pedestrians' crossing behaviour

Observer:_________________ Date:__________ Time:________________ Site ID:_______

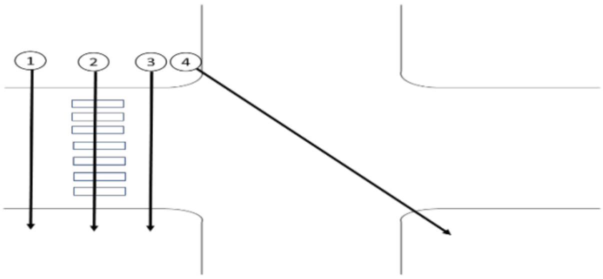
Name of Site:_______________________________________



North

Weather: Sunny ☐ Cloudy ☐ Rainy ☐

Road surface: Dry ☐ Wet ☐



Looking to direction			Trajectory					Comment
Left	Right	None	1	2	3	4	Other	

Appendix VII. Interview form

Name of Site:____ Site ID:_______

Interviewer:________________________ Date:__________ Time:_______________ Nr: ______

Gender ☐ Male ☐ Female

Age ☐ <18 ☐ 18-24 ☐ 25-64 ☐ 65+

---

1. How often do you pass this site?

   ☐ Daily ☐ Twice per week ☐ More seldom

2. Do you pass here most often as

   ☐ Pedestrian ☐ Cyclist ☐ Motorcyclist ☐ Driver ☐ Other
………………………

3. How do you experience road safety at this site?

   ☐ Very safe ☐ Safe ☐ Unsafe ☐ Very unsafe

4. Do you experience this site as more or less safe as a similar site? This site is

   ☐ Safer ☐ The same ☐ Less safe

5. What do you think makes this site unsafe?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

Appendix VIII. Effect assessment sheet

Effect profile							
	Negative				**Positive**		
	---	--	-	0	+	++	+++
Accessiblity							
for pedestrians							
for disabled							
for bicyclists							
for public transport							
for cars							

Level of service							
for pedestrians							
for bicyclists							
for public transport							
for cars							
Environmental effects							
Emissions							
Noise							
Traffic safety							
Injured/killed							
Subjective (experienced safety)							

Appendix II. Network Safety Management Guidelines for Ghana

See separate file: App II – NSM Guidelines for Ghana

Project report 3.2.NSM.G

2024-08-15

Network Safety Management Guidelines for Ghana

Document information

Authors: András Várhelyi (Lund University, Sweden)
Enoch F. Sam (University of Education, Winneba, Ghana)

AfroSAFE - Safe System for radical improvement of road safety in low- and middle-income African countries

www.afrosafe-eu.africa

Project funding

Horizon Europe
Grant Agreement 101069500

This project has received funding from Horizon Europe, the European Union's funding programme for research and innovation under grant agreement No 101069500.

Preface

Network Safety Management (NSM) is one of the highly effective and efficient Road Safety Infrastructure Management (RISM) tools for improving road infrastructure safety.

These Guidelines are developed within the HORIZON EUROPE project AfroSAFE - Safe System for radical improvement of road safety in low- and middle-income African countries. The guidelines are based on the best international practice.

The state-of-the-art approach for Network Safety Management presumes that all relevant data about accidents, traffic volume, road design, traffic control and surrounding environment are available, have sufficient quality, are unambiguously situated on the road network and are interoperable with each other. The state-of-the-art approach also requires comprehensive resources regarding money, time, personnel and professional expertise to implement it. However, this is rarely the case. Hence the second-best approach is the best practice approach which is constrained to limited resources and is based on limited data regarding quantity, quality and interoperability. (Sorensen and Elvik, 2007).

Network Safety Management should be carried out by the road authority, since the road authority has the best knowledge about the road network. They should have full access to the accident database to retrieve the necessary accident data in the form that best suits for carrying out the necessary analyses.

A fundamental prerequisite for carrying out Network Safety Management is that road accidents are recorded, and the records contain adequate information about the locality of the accident, time of occurrence, accident type, and severity. In addition, the records must have an acceptable level of reporting. If this is not the case, NSM cannot be carried out according to best practice.

The present guidelines follow the best practice approach whenever possible due to the prevailing conditions in Ghana.

Abbreviations and Definitions

BSM	Black Spot Management Identification and treatment of hazardous road locations (black spots) in the road infrastructure with higher number of accidents than other similar locations.
ISD	Injury Severity Density A construct of the number of injury accidents at a road section, weighted by their societal costs due to their severity degree.
NSM	Network Safety Management Safety analysis of road networks comprising the identification and treatment of road sections with high concentration of injury/fatality accidents that have occurred in previous years per unit of road length in relation to the volume of traffic and, in case of intersections, the number of such accidents per site.
RAP	Road Assessment Programme A proactive tool for assessing the safety level of a road. It involves the collection of data on road characteristics with the aim to determine the level of protection the road environment provides for the road user when a crash occurs.
RISM	Road Infrastructure Safety Management A set of procedures that support a road authority in decision making related to the improvement of the safety of the road network.
RSA	Road Safety Audit A formal safety performance examination of planned roads by an independent audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.
RSI	Road Safety Inspection A systematic review of existing roads to identify any potential hazards, faults or deficiencies that may lead to severe accidents.
RSIA	Road Safety Impact Assessment A strategic comparative analysis of the effects of building new roads or a substantial modification to the existing network on the safety performance of the road network. RSIA is carried out at the initial planning stage before the infrastructure project is approved to indicate the road safety considerations which contribute to the choice of the proposed solution.
	Hazardous Road Section Any road section with a significantly higher expected number and severity of accidents, than the average number for all sections of the same type as a result of local accident and injury contributing factors.

Table of Contents

1 Introduction

1.1 Road Infrastructure Safety Management Tools

Road infrastructure is one of the three main components of the human-machine-infrastructure system in road transport. Even if the human actor is most often (unfairly) blamed for causing accidents, there are several contributory factors to each accident, and adapting the road infrastructure to the conditions of humans constitutes the cornerstone of the Safe System approach.

There are several well-established Road Infrastructure Safety Management Tools available to the road safety engineer, such as (see also Figure 1):

- **Black Spot Management (BSM)**
  Identification and treatment of hazardous road locations (black spots) in the road infrastructure with higher number of accidents than other similar locations.
- **Network Safety Management (NSM)**
  Safety analysis of road networks comprising the identification and treatment of road sections with high concentration of injury/fatality accidents that have occurred in previous years per unit of road length in relation to the volume of traffic and, in case of intersections, the number of such accidents per site.
- **Road Assessment Programme (RAP)**
  A proactive too for assessing the safety level of a road. It involves the collection of data on road characteristics with the aim to determine the level of protection the road environment provides for the road user when a crash occurs.
- **Road Safety Audit (RSA)**
  A formal safety performance examination of planned roads by an independent audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.
- **Road Safety Inspection (RSI)**
  A systematic review of existing roads to identify any potential hazards, faults or deficiencies that may lead to severe accidents.
- **Road Safety Impact Assessment (RSIA)**
  A strategic comparative analysis of the effects of building new roads or a substantial modification to the existing network on the safety performance of the road network. RSIA is carried out at the initial planning stage before the infrastructure project is approved to indicate the road safety considerations which contribute to the choice of the proposed solution.

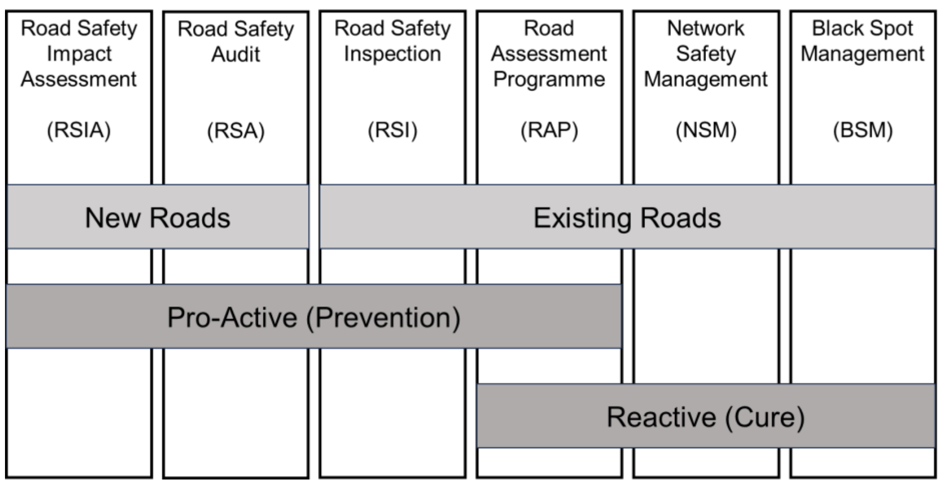


Figure 1. Road Infrastructure Safety Management Tools (Based on RIPCORD-ISEREST, 2011).

1.2 Implementing BSM and NSM

Both Black Spot Management and Network Safety Management should be carried out by the road authority since it has the best knowledge about the road network. They should have full access to the accident database to retrieve the necessary accident data in the form that best suits them for carrying out these analysis methods.

Several of the implementation steps are similar for BSM and NSM, however, if neither of these methods is practiced yet in the country, it is recommended to start with BSM, because (Sorensen and Elvik, 2007):

- BSM is immediately more understandable than NSM.
- There are numerous black spots when starting to implement BSM and also several years after having implemented BSM, which means that resources for site specific safety work can be effectively used on the identified black spots.
- Black spots typically have many accidents with clear accident patterns, which can often be treated with low-cost measures. This results in cost-effective traffic safety work.

NSM differ from BSM with regard to (Sorensen and Elvik, 2007):

- Philosophy: While BSM is retroactive, NSM has both a retrospective and a preventive nature, since the analysis stage of NSM should not only include an analysis of registered accidents but also a general examination of the road section in question to propose standard improvements.
- Attention to accident severity: It is not part of black spot identification, but it is an integrated part of the identification of hazardous road sections.
- Length of road elements under consideration. Black spots (if sections and not intersections) normally should be no longer than 0.5 kilometres, while hazardous road sections (in NSM) have a length of 2-10 kilometres, with an average length of 5-6 kilometres.
- Implementation frequency: BSM is normally performed every year, or every other year, while NSM should be carried out at regular intervals, every third or fourth year.

After implementing and running BSM for a few years and its use has become a routine, it is recommended to supplement it with NSM and during a period, both methods should be used in parallel. BSM should be continued as long it has potential to efficiently contribute to safety improvements and all the black spots have been identified and treated. Then, it is recommended to focus primarily on NSM. (Sorensen and Elvik, 2007).

The NSM process should be repeated at appropriate time intervals and conducted on an annual basis. It is important that the method and the data is maintained and updated. An essential part of implementing the method is establishing a maintenance procedure. A basic issue is allocating resources for maintaining and updating the methods and the required data for their operation.

2 The Process of Network Safety Management

The scope of the safety analysis of road networks is commonly the entire road network of a jurisdiction (state or region). However, it also may be done by route. NSM comprises several hundreds or even thousands of kilometres of road. Due to design parameters and traffic volumes, there will be a great variation among the roads submitted for analysis.

In most countries, roads are classified and numbered with numbered sections. Each of these sections is, ideally, homogeneous concerning design and traffic volume. However, they might differ among themselves concerning length and factors influencing the accident outcome. For NSM, the functional classification of the roads is important. National highways, Inter-regional highways and Regional highways are treated as separate categories.

The stages of the Network Safety Management process are shown in Figure 2.

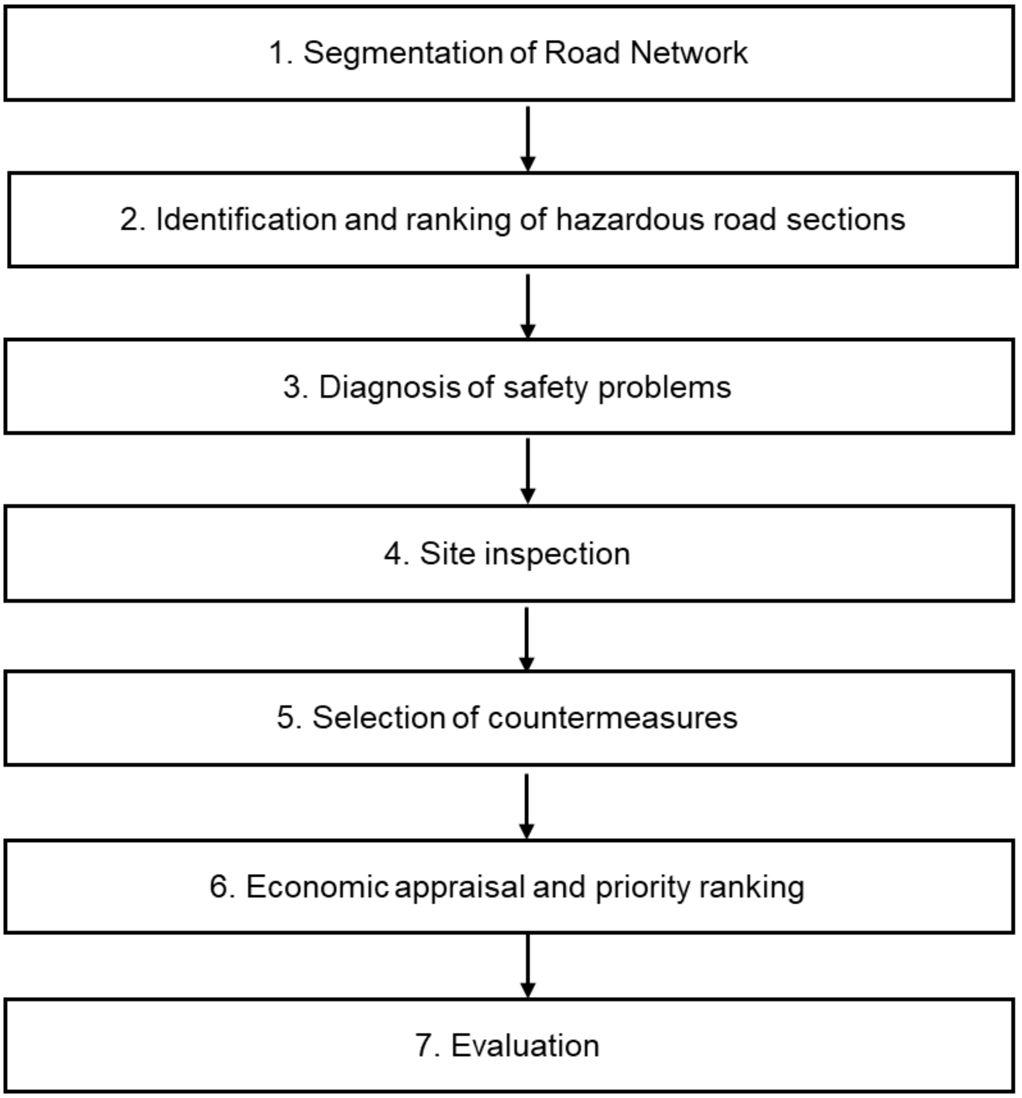


Figure 2. Stages of the Network Safety Management process.

2.1 Stage 1 – Segmentation of the road network

The road network can be divided into urban and rural network. Each network can then be split/classified into different subset, such as single-carriageway sections, dual-carriageway sections and motorway sections (TII, 2017). Then, suitable sets of study units of the network in question should be defined. A choice must be made in respect to homogeneity of each unit, i.e., traffic and road design parameters should be the same throughout the individual section. Relevant traffic and road design parameters are (Sorensen, 2006):

- Road category, type and function,
- Cross section – number of lanes, lane width, shoulder, presence of side strips or bicycle lane,
- Road alignment horizontally and vertically,
- Speed limit,
- Presence of oncoming traffic,
- Presence and type of intersections,
- Traffic volumes, i.e., AADT (Annual Average Daily traffic),
- Roadside buildings.

The selection of parameters depends on data availability. Collecting new data may be necessary, which can be resource demanding. Since speed limit information is the most available parameter, the sections (study units) are typically defined based on the speed limit in the first place, but also, it might be appropriate to use cross-section and road surface type in Ghana.

The criterion of homogeneity of each unit would sometimes request the use of relatively short sections as elementary units. Using very short units (below 50 m) has the disadvantage that it reduces the variation in accidents, meaning that almost all units will have 0 accidents and a few will have 1 accident. The shortest length of an elementary unit should be not less than the breaking distance at the prevailing speed level of the section since breaking distance is often present in accident contributory factors. On the other hand, using too long sections as elementary units would necessitate smoothing the data pertaining to shorter subsections, which would imply a loss of information. Consequently, the length of the elementary unit for the analysis must be a compromise. Sorensen (2007), in his best practice review of NSM of several countries, recommends that the road system be divided into homogenous road sections with varying lengths between 2 and 10 kilometres. It might be impossible to divide the road network into homogenous sections that all have a length between 2 and 10 kilometres, hence a small percentage of the sections will be shorter than 2 kilometres.

Motorways, typically are homogenous on longer sections than non-motorways, hence the study units of motorways can beneficially be longer.

To rationalize the division of the road network, work can start by dividing based on braking points, such as intersections, villages, or other salient "points". Thereafter, it is controlled if the defined road sections are homogenous. The selected units of interest should be clearly defined and numbered.

The output of the segmentation of the road network is a list of all numbered homogenous road sections including their length and attributes.

2.2 Stage 2 – Identification and ranking of hazardous road sections

2.2.1 Linking accidents to the individual road sections

Geo-located accident data for the road network during the last 3-5 years should be obtained from the national accident database, maintained by the Building and Road Research Institute (BRRI). Only accidents with fatality and injury should be considered since damage only accidents are unreliable due to heavy underreporting.

Accidents should be allocated to each section. Accident location is critical for linking an accident to a specific road section. Various ways can be used to locate accidents on the road network, such as GPS location, road code, road section numbering, and road name and address.

If the information regarding the location of an accident is not adequate to allocate it to the correct part of the road, it is recommended that the available information in the accident record be analysed to try to allocate it.

Accident severity should be integrated into the analysis by weighing accidents with different severity. The objective of weighting the accidents is to identify those accidents that make the most significant contribution to Injury Severity Density (ISD). ISD is a construct of the number of accidents at a road section, weighted by the societal costs of the injury accidents by severity degree. Accidents with fatalities and severe injuries are weighted more than accidents with slight injuries. The weight should be based on the socioeconomic cost per accident by severity type.

Afukaar, et a. (2007) calculated the national socio-economic costs of road traffic accidents in Ghana for the year 2004 as follows:

- Fatal accidents: ₵ billion 739.35
- Accidents with severe injury as highest severity outcome: ₵ billion 275.84
- Accidents with only slight injuries: ₵ billion 105.55

Hence, the following Injury Severity Density (ISD) is proposed:

$$ISD = 7*FA+2.6*SER+SLI \qquad (1)$$

where:

FA = Fatal accident
SER = Accident with severe injury as highest severity outcome
SLI = Accident with only slight injury

The output of linking accidents to the individual road sections is a list of all road sections (including their length and attributes) completed with numbers of fatal, severe injury and slight injury accidents, as well as ISD and ISD/km.

2.2.2 Assessing the “normal” value of ISD/km for each type of section

To estimate the “normal” value of ISD/km for a specific type of section, the mean value of ISD/km of the section type in question can be used. If there was no systematic variation among sections, this mean value would also be the ISD/km value that we would predict to occur at each section of the given type.

2.2.3 Analysis of variation of ISD/km

The distribution of ISD/km should be analysed with respect to variance. The objective of the analysis is to determine the amount of systematic variation in the ISD/km. If there is little systematic variation, there is little hope to be able to point out hazardous locations. On the other hand, if there is substantial systematic variation, it implies the existence of units with deviating level of hazard.

Since the ISD value is a construct of accident numbers at a given section, it is assumed to be Poisson distributed. In order to ascertain systematic variation in the ISD value between sections, the actual distribution of ISD over all sections can be compared with a Poisson distribution with the same mean value of the ISD value per section. In the Poisson distribution, the variance is equal to the mean, hence, the size of random variance in the ISD equals the expected value of ISD. The total variation in the ISD values in a sample of study units can be decomposed into random variation and systematic variation:

$$\text{Total variance} = \text{Random variance} + \text{Systematic variance} \qquad (1)$$

Thus, there is systematic variation in the ISD/km value whenever the variance exceeds the overall mean of ISD/km values (*m*). This is usually referred to as over-dispersion. One way to identify over-dispersion (and thereby systematic variation) is to look at the ratio:

$$\alpha = m \,/\, Var(x) \qquad (2)$$

If α is less than 1, we have an indication that there is systematic variation in the data. The smaller α gets, the more significant is the systematic variation. In those cases, we have reason to assume that a high ISD/km value is (partly) an indication of true hazardousness not only the result of random variation of ISD/km.

The proportion of variance, attributable to systematic variation, can be estimated as

$$S = (Var(x) - m) \,/\, Var(x) \qquad (3)$$

2.2.4 Estimating the expected value of ISD/km for each section

The best estimate of the expected value of ISD/km for a studied unit is obtained by combining two sources of information: a) the ISD/km value based on recorded accidents (*R*) for a given section, b) the "normal" value of ISD/km (*N*) (i.e. the mean value) for the same type of sections.

The best estimate of the expected value of ISD/km for a given section is then:

$$E(N,R) = w*N+(1-w)*R \qquad (4)$$

Where $w = 1/(1+Var(N)/N)$ (5)

The parameter *w* thus determines the weight given to the "normal" value of ISD/km for the type of sections in question, when combining it with the ISD/km value of a particular section based on recorded accidents, to estimate the expected value of ISD/km for that particular section.

Intuitively, we understand that:

- If there is much systematic variation in the data, the mean value (N) is not very informative concerning the expected value of ISD/km for a specific section, whereas,
- If there is much random variation in the data, the specific ISD/km value based on recorded accidents at a section (*R*) is not very informative compared to the larger data source of all sections (N).

The output of this activity is an added column to the list of all road sections with the expected values of ISD/km for each section.

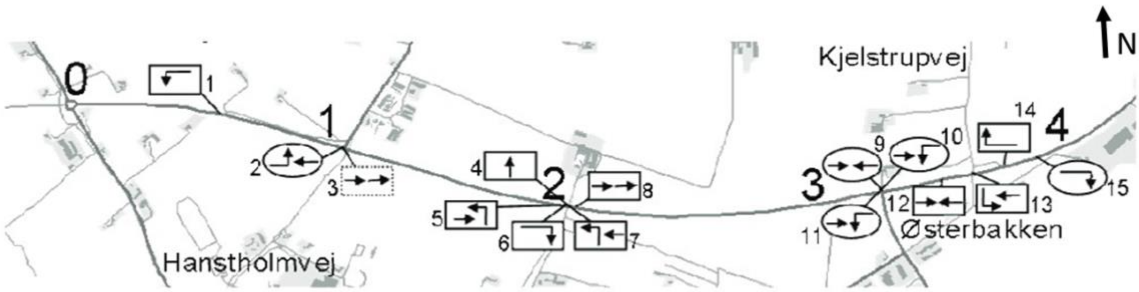
2.2.5 Identifying hazardous sections

The difference between the section-specific expected value of ISD/km (**E**) and the "normal" value of ISD/km (**N**) for similar sites **E-N** can be interpreted as an effect of local risk factors for the section, causing it to have a higher expected number of accidents than similar sections. This tells us which sections are most hazardous within their type.

The output from this step is a list of sections that are the strongest candidates for further investigation. An identified section does not necessarily imply that it has an existing safety concern. Identified sections are candidates for detailed analyses to identify appropriate countermeasures and assess whether those countermeasures are economically justified. Rather, the identification of a section indicates that it experiences a sufficiently high value of ISD/km that there may be an opportunity for a cost-effective safety improvement at that section. Identified sections are candidates for detailed analyses to identify appropriate countermeasures, and assessment whether those countermeasures are economically justified. Conducting detailed engineering studies of candidate sections for intervention is an expensive process, hence, only a limited set of sections can be investigated during a given year.

2.3 Stage 3 – Diagnosis of safety problems

For each specific section, an extended collision diagram should be created. An extended collision diagram combines a traditional collision diagram and information from general accident data, such as accident severity, time (of day, week day, month and year), and circumstances (weather, light, road condition). For an example see Figure 3.



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
Weather	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	-	-	-	-	-	-	-	-	-

Figure 3. An example of an extended collision diagram for a 4 km long section with 15 accidents. The large numbers indicate km. Rectangles accidents with severe injuries, ellipses indicate fatality accidents. L = Light, D = Darkness. (Sorensen, 2007).

The extended collision diagram in Figure 3 shows that driving intoxicated may have contributed to most of the accidents on the western part of the section. Most accidents in the middle section occurred in September and October, when darkness may have contributed to these accidents. Wet road conditions might have contributed to five accidents in the eastern part of the section.

Each specific section should be reviewed by a suitably qualified review team to ensure that all data used in identifying the section during the initial desktop review is correct. The review includes an examination of the collisions on the section to help establish if any particular collision pattern is present. Collision patterns may help establish any deficiencies within the road environment that may be counteracted by engineering measures. The review should provide a preliminary diagnosis for the specific section, identifying safety issues related to road deign and traffic engineering, considering human factors. When the review has been undertaken, the review team may decide if a site visit is required. (TII, 2017a).

The output from this activity is a list of the most hazardous sections under examination, their extended collision diagrams and preliminary initial diagnoses.

In addition, a broader macro view (route scale – typically 100 km) of the road network can be compiled from the details found within individual sections (TII, 2017a). Displaying the spatial distributions of particular collision types can help highlight any local concentrations within the network that may have been missed if patterns were only looked for at the micro scale. A typical output of this macro analysis is presented in Figure 4.

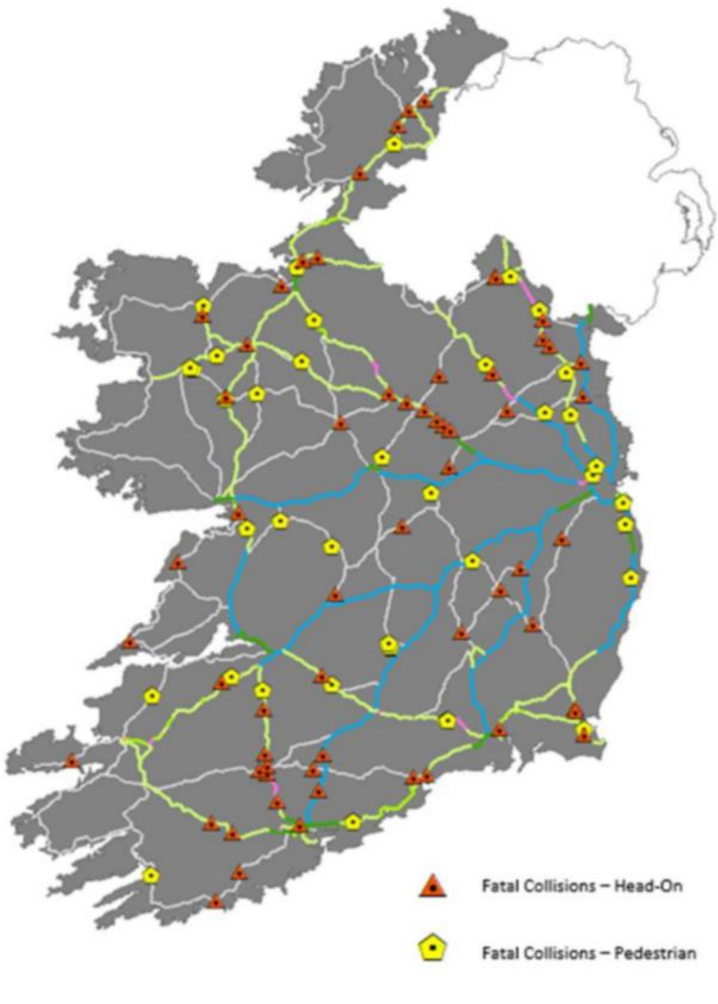


Figure 4. Spatial distribution of fatal head-on and fatal pedestrian collisions on the Irish national road network 2012-2016 (TII, 2017).

The output from this activity is a map of the studied road network highlighting with yellow colour all road sections having significantly higher expected values of ISD/km than the mean value of ISD/km of all sections of the same type. The short-listed most hazardous road sections whose hazardousness could be verified by the diagnosis of safety problems should be red coloured.

2.4 Stage 4 – Site inspection

The following material should be taken for the site visit:

- The extended collision diagram with all relevant characteristics of the section (geometrics, traffic devices, etc.) and the list of accidents, annotated with season, time, etc., and any prevalent accident type.
- List of preliminary initial diagnoses.
- List of questions about the section that could not be answered in the office.
- List of potential countermeasures to be considered in the field.

The site inspection should concern not only the possible contributory factors to the registered accidents but also general problems that, by chance, have not been a contributory factor to the recorded accidents. It should be formalised by using a checklist. See the checklist for road inspection in Appendix I.

The road inspection should be conducted by two persons; a traffic safety expert and an employee of the operating department of the road authority. The inspection should be carried out by car, driving along each direction and from relevant side roads. A stop should be made at the sites posing problems to examine the locations more closely.

After the site inspection, a final diagnosis should be made for the specific section, identifying safety issues related to road design and traffic engineering.

The output after the site visits is a short list of the most hazardous road sections whose hazardousness could be verified, accompanied by description of the safety problems for each section.

2.5 Stage 5 – Selection of countermeasures

Following the site visit to each selected section, a proposal for countermeasures is developed for each section involving technical and budgetary considerations. For each safety concern identified for the section under the diagnosis step, a list of potential countermeasures is established. If more than one concern was identified for the section in question, more than one potential countermeasure list should be made.

If there is a clear accident pattern and evidence for identified risk factors contributing to this pattern on the section in question, the most effective treatment should be identified. Cost-effective countermeasures have been composed by PIARC (2003), Elvik, et al. (2009), and SafetyCube (2023) https://www.roadsafety-dss.eu/#/.

When thinking about appropriate countermeasures, the following issues should be considered:

- Cost-effectiveness. Low-cost measures should be prioritised. Some measures may be effective, but may be unnecessarily expensive.
- Long-lasting, i.e. the initial effect does not wear off as drivers get used to them.
- Will not increase unsafety (not causing other types of accidents, or other undesirable nuisances).
- Will its implementation need considerable publicity campaign or heavy police enforcement?
- Can the necessity of its implementation be explained to decision makers?

The output from countermeasure selection should be a list of proposed countermeasures for each of the hazardous sections.

2.6 Stage 6 – Economic appraisal and priority ranking

The proposed countermeasures should be subjected to a socio-economic assessment. For each hazardous road section, costs and benefits should be addressed considering accident severity.

The proposed countermeasures for each specific road section should be ranked using the safety effectiveness estimates, and a set of countermeasures should be identified that provide maximum safety benefits within the given budget constraints.

To assess the proposed countermeasures, the economic criteria “net benefits” can be used. The net benefit approach assesses countermeasures by their safety benefits minus construction costs and it yields the most desirable alternative with the highest net benefit:

Net Benefit = Benefits – Costs

For a countermeasure to be economically justified by this criterion, its net benefits should be greater than zero. The net benefits approach allows to maximize the net benefits across all countermeasures and sections and to take budgetary constraints into consideration.

For each section with any countermeasure with negative benefits, the “do-nothing” alternative is considered more favourable.

The output from the economic analysis is a list of sections with the net benefit for each proposed countermeasure.

2.7 Stage 7 – Evaluation

The effects of the implemented measures should be subsequently evaluated. Evaluation should control for local changes in traffic volume, long term trends in accident development and regression-to-the-mean effects. The best way to do this is to employ a before-after study. An accident based evaluation of the safety effects of the implemented measures can be carried out when having access to at least three year of accident data during the after period.

To control for effects of extraneous variables, such as changes in traffic pattern, vehicle mix, and long-term safety trends, the evaluation study - besides the site in question - should include similar sites for control concerning area type, design factors and traffic volumes. The registered number of accidents at the study site is to be compared with “normal” control sites where no measures were implemented. This approach assumes that the annual average number of accidents (during the after period of 3-5 years) recorded at the study site provides an estimate of the expected number of accidents at that site. The annual average number of accidents (during the same 3-5 years period) recorded at the control sites provides an estimate of the expected number of accidents at the study site during the after period given that no measures were implemented.

Conclusions and Recommendations

The guidelines described above are based on best practice in Network Safety Management. The stepwise description of the process allows systematic and efficient work to identify hazardous road sections, analyse accident contributory factors at these sections, propose cost-effective countermeasures and design an evaluation study on the effectiveness of the proposed measures.

A fundamental prerequisite for carrying out Network Safety Management is that road accidents are recorded, and the records contain adequate information about the locality of accident, the time of occurrence, the type of accident, and the severity.

After the NSM tool has been implemented, the method and the data must be maintained and updated. Hence, an essential part of the implementation of the method is to establish a procedure for maintenance. The Authority, responsible for initiating NSM should ensure that the process is repeated and that it is conducted on an annual basis. A basic issue is to allocate resources for maintaining and updating the method and the required data for its operation.

Besides continuously registering traffic accidents, it is important to maintain and update data on changes in road design. When changes are made at a certain location in the road infrastructure, it is important to record when the changes were made.

Societal costs, and statistical values of fatal accidents, accidents with severe, respective slight injuries should be established.

References

- Afukaar, F.K., Agyemang, W., Debra, E.K., Ackaah, W. (2007) The Socio-Economic Cost of Road Traffic Accidents in Ghana. Council for Scientific and Industrial Research, Building and Road Research Institute, Kumasi, Ghana.
- Elvik, R. Höje, A., Vaa, T., Sörensen, M. (2009) The Handbook of Road Safety Measures. Second Edition. Elsevier.
- FHWA (2010) SafetyAnalystTM: Software Tools for Safety Management of Specific Highway Sites. Publication No. FHWA-HRT-10-063, Federal Highway Administration, USA.
- O´Flaherty, C.A. Ed. (1997) Transport Planning and Traffic Engineering. Arnold, London.
- PIARC (2003) Road Safety Manual. PIARC Technical Committee on Road Safety, Cedex, France.
- Ragnøy, A., Christensen, P., Elvik, R. (2002) Skadegradstetthet – SGT Et nytt mål på hvor farlig en vegstrekning er. In Norwegian (Injury Severity Density. A new approach to identifying hazardous road sections). TØI rapport 618/2002. Institute of Transport Economics. Norway.
- RIPCORD-ISEREST (2011) *http://ripcord.bast.de/* http://www.ripcord-iserest.com *Brochure* "Road Infrastructure Safety Management“ (2011-12-12)
- SafetyCube (2023) The European Road Safety Decision Support System https://www.roadsafety-dss.eu/#/. (Downloaded 11/11 2023).
- Sorensen, M. (2006) Grå straekninger i det åbne land – udvikling av , anvendelse og vurdering af alvorlighedsbaseret metode til udpegning, analyseog udbedring af grå straekninger. (In Danish) PhD thesis. Department of Development and Planning, Aalborg University, Denmark.
- Sorensen, M. (2007) Best Practice Guidelines on Black Spot Management and Safety Analysis of Road Networks. TØI report 898/2007. Institute of Transport Economics. Norway.
- Sorensen, M., Elvik, R. (2007) Black Spot Management and Safety Analysis of Road Networks. Best Practice Guidelines and Implementation Steps. TØI report 919/2007. Institute of Transport Economics. Norway.
- TII (2017) Network Safety Analysis Procedures. TII Publications GE-STY-01036. Transport Infrastructure Ireland.
- TII (2017a) Network Safety Analysis. TII Publications GE-STY-01022. Transport Infrastructure Ireland.

Appendix I. Checklist for road inspection

Inspector: ________________ Date: _________ Time: _______________ Site ID: ____________

Name/km of road sector: ____

Weather: Sunny ☐ Cloudy ☐ Rainy ☐

Road surface: Dry ☐ Wet ☐

Accident sites - confirm or reject the hypotheses from the accident analysis

……………………………………………………………………………………………………

Road alignment

Is optic guidance in alignment with the horizontal and vertical alignment of the road?
Is the speed limit compatible with the alignment and sight distance?
Are safe overtaking opportunities provided?

……………………………………………………………………………………………………

Cross section

Are carriageway and traffic lane widths adequate for the traffic volume and mix?
Are shoulders wide enough for broken-down vehicles to stop safely and are they in good condition?
Do cross-falls of the carriageway and shoulder provide adequate drainage?

……………………………………………………………………………………………………

Signs and markings

Are all road signs conspicuous and clear?
Are markings and delineation appropriate and consistent along the route?

……………………………………………………………………………………………………

Curves

Are curve warning signs and advisory speed signs installed where required?
Are chevron alignment markers installed where required?
Is appropriate super-elevation provided on curves?

……………………………………………………………………………………………………

Crash barriers and clear zones

Are crash barriers installed at all necessary locations correctly?
Is the clear zone width free of rigid fixtures?
Are all power poles, trees, etc., at a safe distance from the traffic paths?

……………………………………………………………………………………………………

Road surface

Is the road surface in good condition, with good friction, and functioning drainage?

……………………………………………………………………………………………………

Intersections, crossings and access roads

Are intersections, crossings and access roads predictable, with appropriate layout, channelization and regulation?

Appendix III. Road Safety Impact Assessment Guidelines for Zambia

See separate file: App III – RSIA Guidelines for Zambia

Project report 3.2.RSIA.Z

2024-08-15

Road Safety Impact Assessment Guidelines for Zambia

Document information

Authors: András Várhelyi (Lund University, Sweden)
Susan Mawele (Zambia Road Safety Trust)

AfroSAFE - Safe System for radical improvement of road safety in low- and middle-income African countries

www.afrosafe-eu.africa

Project funding

Horizon Europe
Grant Agreement 101069500

This project has received funding from Horizon Europe, the European Union's funding programme for research and innovation under grant agreement No 101069500.

Preface

Road Safety Impact Assessment (RSIA) is a recently established tool of Road Safety Infrastructure Management (RISM). It is conducted for projects at the initial planning stage before project approval. It may apply to new infrastructure or modification to an existing road. RSIA precedes Road Safety Audit and its procedure should assist in the selection process for major road infrastructure projects. Today, RSIA is mandatory for all road infrastructure projects on the Trans-European road network. The need for its application on Trans-African road network cannot be overstated.

These Guidelines are developed within the framework of the HORIZON EUROPE project AfroSAFE - Safe System for radical improvement of road safety in low- and middle-income African countries. The guidelines are based on the best international practice.

A fundamental prerequisite for carrying out Road Safety Impact Assessment is the existence of monetary values of socioeconomic costs of accidents, fatalities, and injuries, as well as travel times. If this is not the case, cost-benefit analysis may be substituted by a simplified qualitative assessment.

Since monetary values for accidents, fatalities, and injuries are not developed yet in Tanzania/Zambia, the present guidelines follow the best practice approach where it is possible and propose a simplified qualitative assessment instead of a cost-benefit analysis.

Abbreviations and Definitions

BSM	Black Spot Management Identification and treatment of hazardous road locations (black spots) in the road infrastructure with a higher number of accidents than other similar locations.
NSM	Network Safety Management Safety analysis of road networks comprising the identification and treatment of road sections with a high concentration of injury/fatality accidents that have occurred in previous years per unit of road length in relation to the volume of traffic and, in the case of intersections, the number of such accidents per site.
RAP	Road Assessment Programme A proactive tool for assessing the safety level of a road. It involves the collection of data on road characteristics with the aim to determine the level of protection the road environment provides for the road user when a crash occurs.
RISM	Road Infrastructure Safety Management A set of procedures that support a road authority in decision-making related to the improvement of the safety of the road network.
RSA	Road Safety Audit A formal safety performance examination of planned roads by an independent audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.
RSI	Road Safety Inspection A systematic review of existing roads with the intention of identifying any potential hazards, faults or deficiencies that may lead to serious accidents.
RSIA	Road Safety Impact Assessment A strategic comparative analysis of the effects of building new roads or a substantial modification to the existing network on the safety performance of the road network. RSIA is carried out at the initial planning stage before the infrastructure project is approved to indicate the road safety considerations which contribute to the choice of the proposed solution.

Table of Contents

1 Introduction

1.1 Road Infrastructure Safety Management Tools

Road infrastructure is one of the three main components of the human-machine-infrastructure system in road transport. Even if, most often, the human actor is (unfairly) blamed for causing accidents, there are several contributory factors to each accident and adapting the road infrastructure to the conditions of humans constitutes the cornerstone of the Safe System approach.

There are several well-established Road Infrastructure Safety Management Tools available to the road safety engineer, such as (see also Figure 1):

- **Black Spot Management (BSM)**
  Identification and treatment of hazardous road locations (black spots) in the road infrastructure with a higher number of accidents than other similar locations.
- **Network Safety Management (NSM)**
  Safety analysis of road networks comprising the identification and treatment of road sections with a high concentration of injury/fatality accidents that have occurred in previous years per unit of road length in relation to the volume of traffic and, in the case of intersections, the number of such accidents per site.
- **Road Assessment Programme (RAP)**
  A proactive tool for assessing the safety level of a road. It involves the collection of data on road characteristics with the aim to determine the level of protection the road environment provides for the road user when a crash occurs.
- **Road Safety Audit (RSA)**
  A formal safety performance examination of planned roads by an independent audit team.
  It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.
- **Road Safety Inspection (RSI)**
  A systematic review of existing roads with the intention of identifying any potential hazards, faults or deficiencies that may lead to serious accidents.
- **Road Safety Impact Assessment (RSIA)**
  A strategic comparative analysis of the effects of building new roads or a substantial modification to the existing network on the safety performance of the road network. RSIA is carried out at the initial planning stage before the infrastructure project is approved to indicate the road safety considerations which contribute to the choice of the proposed solution.

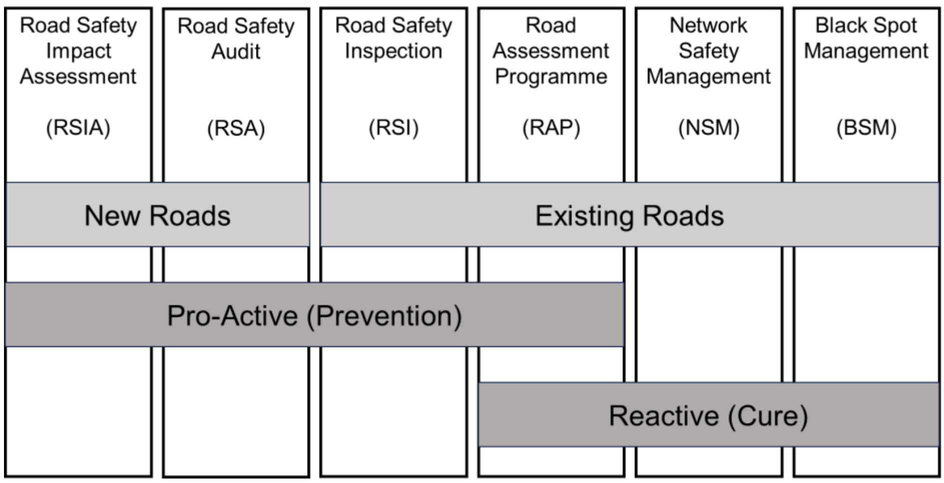


Figure 1. Road Infrastructure Safety Management Tools (Based on RIPCORD-ISEREST, 2011).

2 Road Safety Impact Assessment

Road Safety Impact Assessment (RSIA) is an active preventive tool used to assess planned road infrastructure projects at the initial planning stage before project approval. It may apply to new infrastructure or modification to an existing road. It is an integral part of the design process and is carried out by the design team and does not replace, or preclude Road Safety Audit, which is carried out at the subsequent period of the project by an audit team independent of the design process.

The RSIA procedure is meant to assist in the selection process for major infrastructure projects and should be continually reviewed during the draft design phase. RSIA specifies the road safety considerations which contribute to the selection of the best alternative solution by assembling all relevant information necessary for a cost-benefit analysis of the proposed alternatives. This allows a comparison of the impact of different road or traffic schemes on safety performance. RSIA is a beneficial too at the inceptive phase of a road project as it helps in the selection of the safest project alternative.

2.1 Projects to be assessed

Any new infrastructure project realignment or change to existing infrastructure that substantially affects the performance of the road network should be assessed. Network performance can be affected not only by amendments to the physical layout of road networks, but also by the introduction of a new or changed source of traffic generation.

2.2 When to Assess

RSIA should be carried out at the initial planning stage of a project. This assessment should consider the safety implications of the different alternatives as well as the option to not proceed with the project. As the project design progresses the road safety impact assessment should be regularly reviewed to ensure that the road safety implications of all design revisions are considered.

2.3 Assessment Team

RSIA should be an integral part of the design process. The assessment team should comprise at least two individuals and should include at least one experienced road design engineer and at least one experienced road safety auditor.

In the absence of competence in RSIA within the design team, an assessment team can be sourced from elsewhere and should join the design team for this specific task. This assessment team, where possible and to provide continuity, should carry out all further RSIA as the project progresses.

It is important to note that an RSIA is not a separate audit of the project carried out by an independent team; it is an ongoing task within the design process and carried out by the design team. If an external assessment team is brought in to provide road safety expertise, then that team should be viewed as temporarily part of the design team.

2.4 Assessment Team Approval

RSIA is an integral part of the design process and it is to be produced by the design team. The project manager of the design team should appoint the RSIA team from within the design team. The project manager should submit the names of the assessment team members to the director in charge of road infrastructure designs for approval.

2.5 Principles of Impact Assessment

The objective of RSIA is to consider the proposed project from a road safety point of view, to compare the impact on road safety of each proposed option and to determine which would give the best road safety outcome. With every project, there is the possibility that the existing situation would be preferable to any of the options considered, so it is essential that this alternative is also considered in the assessment.

Road safety impact is only one of the aspects considered by a design team when selecting the preferred option. It is important that the reasoning behind the conclusions of the impact assessment is made clear, so that it is given due weight in the selection process. This should minimise the risk of collisions occurring in the future either as a result of planning decisions or as a result of unintended effects of the design of road schemes.

2.6 Initial Assessment

The initial RSIA should be carried out while the project is still at concept stage. At this stage the assessment explores the road safety implications of each option being considered, including the "Do-Nothing" option. The assessment should provide all relevant information necessary for the comparison of the options and selection of the solution, including a comparative analysis of the road safety implications of each alternative considered and an evaluation of the road safety benefits and dis-benefits arising from each alternative.

2.7 Further Assessment

The initial RSIA should be reviewed whenever a design revision may have road safety implications. Where a project goes through more than one process of selection in its initial stages it is essential that an RSIA is done as part of each of these selection processes. Reviews should be done whenever a substantial change is made to the design and at significant milestones throughout the design process. Each review must consider the entire project when examining the road safety implications of any design change or of any additional or amended data and information. The report at each review should address only the changes to the assessment since the previous review and should be added to any previous reports to be read in conjunction with them.

3 The Process of Road Safety Impact Assessment

The stages of the Road Safety Impact Assessment process are shown in Figure 2.

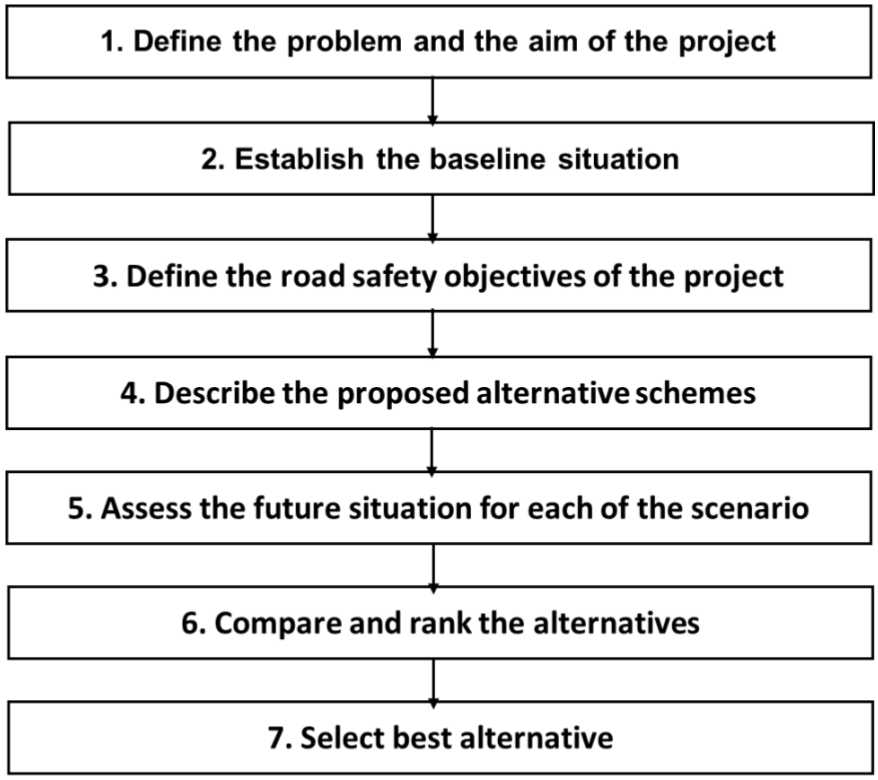


Figure 2. Stages of the Road Safety Impact Assessment process.

3.1 Define the problem and the aim of the project

Describe the safety problem and the aim of the project (it might be, e.g., to improve safety of a certain group of road users or at a certain specific site).

3.2 Establish the baseline situation

Establishing the baseline situation as it is today should be a made in terms of accidents, risk factors, and traffic volumes per road type:

- Identify any high accident locations, stretches of road or single sites, junctions or other conflict points, as well as any accident patterns.
- Establish any accident patterns over time of day or year, or any patterns involving road user type.
- Examine any road safety reviews that may have been carried out previously in the area.
- Since there may be unrecorded incidents, it is recommended to contact the local authorities/ services such as the area engineer or the emergency service who might have information on incidents that they have attended.
- Collect data on traffic composition and traffic volumes of all type of road users present in the area.

A site inspection is required to collect the necessary data. It should consider all types of road users, the connecting road network, topography, local amenities, activity centres, local weather conditions, previous road safety reviews, and any complaints received from the community regarding the site.

3.3 Define the road safety objectives of the project

This will include addressing the recognised road safety problems in the baseline analysis, but there may be further objectives, such as improving pedestrian access to an amenity or improving access to public transport. Such issues may not be explicitly manifesting in accident statistics, but may either address suppressed demand and latent road safety problems.

3.4 Describe the proposed alternative schemes

Describe each proposed alternative scheme for the project, including "Do-Nothing" scenario (which would prevail if no changes at all were to be implemented).

Indicate the investment and maintenance costs during the expected life time for each alternative.

Define the geographical extents of the area of influence, hence the study area of the project:

- Clarify the extents of the surrounding road network where any of the proposed options would affect the operation of the network.
- Check the likely changes to drivers' route choice and choice of travel mode or time, and thus the likely effects on traffic patterns.

The entire study area should be examined when assessing each proposed option, so that the same areas is compared for each scenario.

Establish the expected date of completion of the project. Forecast traffic flows are dependent on this. Other infrastructural improvements underway in the area may be complete by this time and affect forecast traffic flows.

During project definition it is important to ask certain questions (PIARC, 2024); Are the objectives realistic or too ambitious? Are the selected schemes suitable, not just in terms of safety, but in terms of other issues such as impacts on the environment, or accessibility and connectivity for all road users? Are there any associated social issues, such as e.g., lack of support from the community?

3.5 Assess the future situation for each of the scenarios

The future situation after completion of the scheme should be assessed for each of the schemes, including the "Do Nothing" scenario, accounting for expected traffic growth, traffic composition, number of accidents (fatal, with severe and slight injuries). Besides accident outcome, possible changes in travel time for all occurring road user types, accessibility and level of service, as well as environmental effects should be assessed.

For each alternative scheme, including the "Do-Nothing" scenario:

- Examine the drawings.
- Visit the site to visually establish the alignment of each proposed option and the surrounding topography. A site visit is important as it may identify existing arrangements or patterns of use that may not be evident in the drawings and other information examined. If the assessment team are from within the project design team and has all visited the site previously, a separate site visit for this purpose might not be necessary.
- Examine both existing and expected traffic flows, including pedestrian and cycle flows and public transport routes. It may be necessary to establish peak times of use for certain parts of the network, such as access to schools, sports grounds, or weekly markets, so that the appropriate flows can be examined.
- Consider patterns of use for all road users. In general, pedestrians and other vulnerable road users are affected more acutely than other road traffic by both changes in road alignment and changes to available routes of travel.

- Note the presence of safe parking areas, including the provision of safe rest stops for drivers in the wider region surrounding the proposed scheme location.

The main element of the RSIA is the comparison of the road safety effects of each alternative proposal. The effects on the entire study area must be examined for each proposed option. Where proposed alternatives differ in scale and cover differing lengths or areas of the existing network, the remainder of the road network outside the proposed works must be included in the analysis. The assessment area must be the same for all options being compared.

An assessment of the effects of each alternative must be carried out in terms of predicted accidents. Quantitative indicators can be used such as accident rates and accidents per junction type. To assess the likely accident occurrence in the proposed options, it is recommended to use established local accident rates in the surrounding area for equivalent road types or junction types.

All effects on traffic flow and traffic patterns must be considered. Any projected change in modal split as a consequence of the proposal is important as this may not only affect the mix of vehicle categories within the traffic flow, but also may impact patterns of pedestrian and cycle travel and locations where conflicts with other vehicles occur.

Seasonal and climatic conditions, such as the likelihood of flooding, should be considered, as this might differ between options. The possibility of seismic activity should also be considered.

For the effectiveness of various road safety countermeasures see Elvik, et al. (2009); and SafetyCube (2023) https://www.roadsafety-dss.eu/#/.

A cost benefit analysis for each of the schemes, including the “Do Nothing” scenario should be made. It should include the variables that can be expressed in monetary values, such as investment and maintenance costs during the life time of the scheme, costs for changes in travel time, and accident (fatal with severe injury, and with slight injury) costs.

These monetary values should have been established for the country.

Since not all variables can be expressed in monetary values, an effect profile constitutes a good basis for selection of the best alternative scheme. The effect profile should include variables, such as:

- Traffic safety in form of accidents with fatality/injury and experienced safety by the people.
- Accessibility for pedestrians, disabled, bicyclists, public transport, heavy vehicles and cars.
- Level of service for pedestrians, bicyclists, public transport, heavy vehicles and cars.
- Environmental effects, such as emissions and noise.

For an effect profile sheet see Appendix I.

3.6 Compare and rank the alternatives

All options, including the “Do-Nothing” scenario, should be ranked in terms of road safety considerations, giving an order of preference and an indication of the magnitude of difference between options. If one option, or a group of options shows considerably more or less benefit than the others, then this should be highlighted. Conversely, if there is little difference in road safety terms between two or more of the proposals, then these should be given the same ranking.

Comparison of the alternatives should be made based on the results of cost-benefit analysis and a qualitative assessment of benefits and drawbacks (see the qualitative assessment sheet – effect profile in Appendix I) for each alternative scheme. Cost-benefit analysis of the alternative schemes allows them to be ranked in order of effectiveness. A clear description of the net benefits of each option as well as the relative net benefit should be given so that these conclusions can be given proper consideration in the selection process.

3.7 Select the best alternative

The alternative with the combined highest net benefit and assessed best qualitative properties should be selected. The selected scheme should be optimised to achieve optimal safety effect and best cost-benefit rate.

3.8 The RSIA report

At the end of the process, a final RSIA report should be completed. It should stand alone as a separate document without the need to reference other reports on the project. This is likely to necessitate the inclusion of drawings, photographs and a summary of collision records, all of which should be included as appendices.

The main body of the report should broadly have the following outline (TII, 2016):

1. Problem definition
   Define the objective of the proposed project and list any existing road safety problems. Indicate if a major part of the stated project objectives is to address a road safety problem.
2. The area of influence
   The geographical extents of the entire area of the road network where route choice and traffic patterns would be affected by the proposals.
3. Objectives of the scheme
   Define the objectives of the scheme both in terms of infrastructure changes and road safety.
4. The options
   Describe each proposed option for the project, including the "Do-Nothing" scenario.
5. Analysis of impacts on road safety of the proposed alternatives
   Examine each option, including the "Do-Nothing" scenario and analyse how safety of the road network will be affected by the proposed scheme.
6. Comparison and ranking of the alternatives
   A quantitative cost-benefit analysis of these road safety benefits and disadvantages. A qualitative description of the road safety benefits and disadvantages of each option. Ranking the alternatives, including the "Do-Nothing" scenario in order after their net road safety benefits.
7. Selection of best alternative
   The alternative with the combined highest net benefit and assessed best qualitative properties is selected and optimised to achieve optimal safety effect and best cost-benefit rate.

The RSIA report should be submitted to the Director for comment and review. The final recipient of the report shall be the Design Project Manager, who shall use it to inform the option selection phase.

4 Conclusions and Recommendations

Road Safety Impact Assessment is one of the efficient Road Safety Infrastructure Management tools to improve safety of the road infrastructure. The stepwise description of the process allows a systematic and efficient work to select the proposed infrastructure project alternative with the highest net benefit.

The guidelines described above are based on best practice, however, since monetary values for accidents, fatalities, and injuries are not developed yet in Zambia, a simplified qualitative assessment is proposed instead of cost-benefit analysis.

To make the method more adapted to the conditions in Zambia, monetary values of and accidents (with fatality, with severe injury, and with slight injury), as well as travel time costs per vehicle should be established.

References

- Elvik, R. Höje, A., Vaa, T., Sörensen, M. (2009) The Handbook of Road Safety Measures. Second Edition. Elsevier.
- PIARC (2024) Road Safety Manual. https://roadsafety.piarc.org/en/planning-design-operation-risks-issue-identification/proactive-identification. (24/01 2024).
- RIPCORD-ISEREST (2011) *http://ripcord.bast.de/* http://www.ripcord-iserest.com *Brochure "Road Infrastructure Safety Management“.* (12/12 2011).
- SafetyCube (2023) The European Road Safety Decision Support System https://www.roadsafety-dss.eu/#/. (Downloaded 11/11 2023).
- TII (2016) Road Safety Impact Assessment Guidelines. PE-PMG-02005. Transport Infrastructure Ireland.

Appendix I. Effect profile sheet

	Effect profile						
	Negative			0	Positive		
	---	--	-		+	++	+++
Traffic safety							
Injured/killed							
Subjective (experienced safety)							
Accessibility							
for pedestrians							
for disabled							
for bicyclists							
for public transport							
for heavy vehicles							
for cars							
Level of service							
for pedestrians							
for bicyclists							
for public transport							
for heavy vehicles							
for cars							
Environmental effects							
Emissions							
Noise							

Appendix II. Example of a RSIA

In this example, simplified cost-benefit analyses are made with arbitrary values for monetary values of accident costs and travel time costs. These values are as follows:

- A fatal accident: $ 200,000
- An accident with severe injury: $ 20,000
- An accident with slight injury: $ 2,000
- Travel time costs for motorised vehicles $ 1.5 per hour per vehicle.

1. The problem and project objectives

The heavily trafficked north-south road passes through village "X" with about 800 inhabitants. During the last 3 years, 15 accidents were registered along the through road in the village. One fatal accident, 5 accidents with severe injuries, and 9 accidents with only slight injuries. Besides the accidents, the heavy through traffic deteriorates the level of service for the inhabitants of the village by constituting a barrier for those who need to cross the road. It also creates heavy pollution and noise disturbances.

The aim of the project is to address the road safety problems in the village, but also to mitigate the other nuisances for the inhabitants of the village.

2. The baseline situation

The length of the through road in the village is 1 km, and there are six T-junctions along it, see Figure II.1.

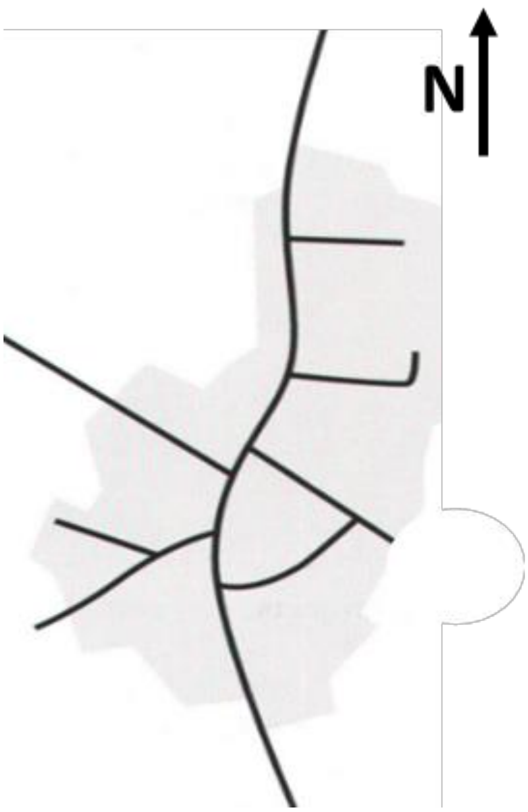
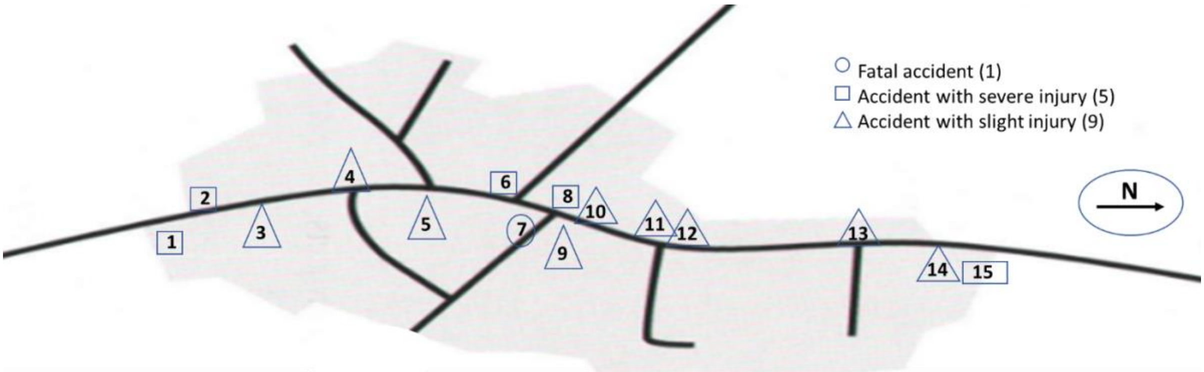


Figure II.1. The through road with 6 T-junctions in the village.

The accident distribution along the road through the village is shown in Figure II.2.



No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Type	B-C	P-C	P-C	C-C	C-C	P-C	P-C	P-C	P-C	P-C	C-C	B-C	C-C	P-C	B-C
Year	2019	2020	2021	2020	2023	2019	2022	2021	2023	2019	2020	2022	2023	2019	2021
Month	4	10	2	2	3	10	9	9	9	9	1	5	6	2	5
Day	Sat	Fre	Wed	Fre	Thu	Tue	Mo	Fre	Thu	Mo	Wed	Sat	Tue	Sat	Fre
Hour	19	16	17	22	21	8	8	15	16	8	11	19	22	19	20
Light	D	L	L	D	D	L	L	L	L	L	L	D	D	D	D

B=Bicycle
C=Car
P=Pedestrian

Figure II.2. Accident distribution along the road through the village.

As it can be seen in Figure II.2., eight of the accidents involved pedestrians. Most of these occurred during daytime and in connection with children going to and from school in the centre of the village and during the opening season of the school period. All bicycle accidents occurred on the through road in darkness.

No previous road safety review was carried out in the village.

Traffic counting shows a daily traffic of 12 000 motor vehicles (both directions) per day. Heavy goods vehicles amount to ten percent of the traffic volume. Some bicycle traffic is present both along the main road and crossing it. The mean speed of free vehicles is 50 km/h, which is too high considering the closeness of unprotected road users.

A site visit revealed that the heavy traffic through the village creates a barrier for those who will cross the main road, especially for children, some of them arriving by bus and have to cross the main road to go to the school in the centre of the village. There is a bus stop in the centre and the stopping bus creates disturbance for the traffic flow. Drivers passing the stopping bus create additional risk for crossing pedestrians.

3. The road safety objectives of the project

The safety objective of the project is to improve the safety situation for unprotected road users in the village, especially for pedestrians generally, and for children going to and from school specifically, but also for bicyclists moving along and crossing the main road.

A secondary objective is to improve pedestrians' level of service to easier reach amenities on either side of the main road.

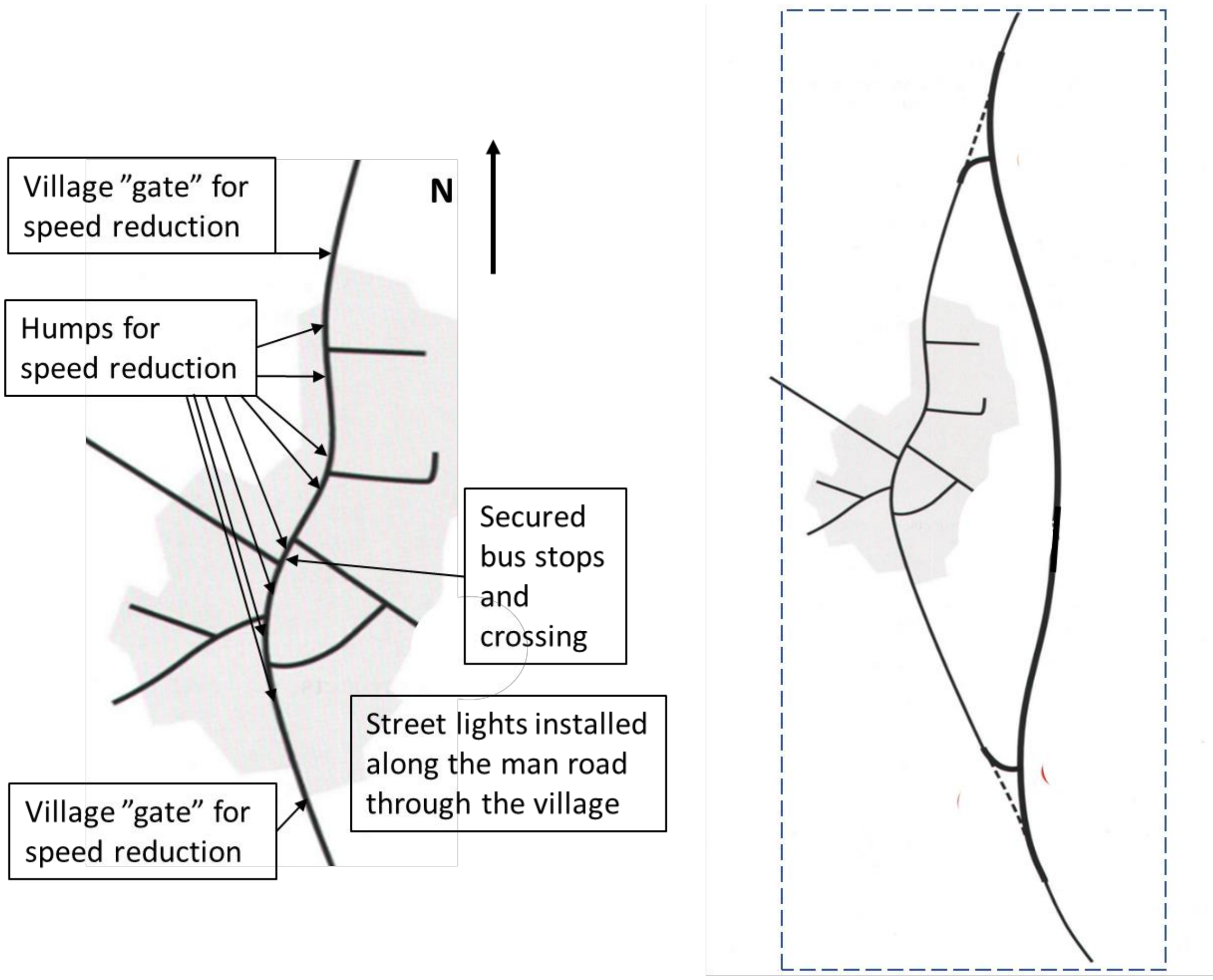
4. The proposed alternative schemes

There are three alternative proposed schemes:

1. "Do-Nothing" scenario, i.e. no changes will be implemented.
2. Constructing an "environmentally adapted through road" with repeated speed reducing measures along the whole section of the road through the village, and specific measures in the centre to

accommodate stopping buses, safeguarding for crossing pedestrians. Street lights to be installed along the whole main road through the village, see Figure II.3.a.

3. A new parallel north-south bypass road of 3 km length to be constructed about 600 metres to the east of the village with two connections to the road through the village, one about 1 km to the north of the village and one about 1 km to the south of the village, see Figure II.3.b.



Alt. 2: “environmentally adapted through road”

Alt. 3: bypass road

Figure II.3. The alternative proposed schemes.

The geographical extents of the area of influence, hence the study area of the project are defined by alternative 3 having the largest influence area. The study area is marked by a rectangle with stretched lines in Figure II.3.b.

The expected date of completion of the project is June 2025.

5. The future situation for each of the proposed alternative schemes

Future traffic volumes are predicted to increase by 5 % and based on the increase in traffic volumes, accident outcome during the after period of three years is expected to increase by 5 % in all three alternative schemes. Thus, the predicted future number of accidents due to the increase in traffic volumes are: 1.05 fatal accidents, 5.25 accidents with severe injuries and 9.45 accidents with slight injuries, resulting in a total of 15.75 injury accidents.

Alternative 1 – “Do-Nothing” scenario

Cost–benefit analysis

Investment and maintenance costs

There are no investment or new maintenance costs in the “Do-Nothing” scenario.

Travel time costs

There are no increased travel time costs in the “Do-Nothing” scenario.

Accident costs

There are costs for increased number of accidents. The increase in fatal accidents by 0.05 (due to expected increase in traffic volumes) in a three year period will give a cost of 5*0.05 = 0.25 fatal accidents during a 15 years period (the life time of scheme 2). In the same way, accidents with severe injury increase from 5 to 5.25, i.e., by 0.25 in a three year period and will give a cost of 5*0.25 = 1.25 accidents with severe injuries during a 15 years period. Accidents with slight injury increase from 9 to 9.45, i.e., by 0.45 in a three year period and will give a cost of 5*0.45 = 2.25 accidents with slight injuries during a 15 years period, see Table II.1.

Table II.1. Assessed accident outcome during the after period for alternative 1 – “Do-Nothing”.

Accident severity	Number of accidents				Costs due to change in accidents
	During 3 years			difference during 15 years	
	baseline	due to traffic increase	difference		
fatal	1	1,05	0,05	0,25	50000
with severe injury	5	5,25	0,25	1,25	25000
with sligt injury	9	9,45	0,45	2,25	4500
all	15	15,75	0,75	3,75	79500

The calculated costs from accident increase during a 15 years period are:
0.25*200,000+1.25*20,000+2.25*2000 = $ 79,500

Total benefits/costs

The total costs of the “Do-Nothing” scenario amount to $ 79,500 due to increase in the number of injury/fatal accidents.

Effect profile

Traffic composition through the village is forecasted to remain unchanged. The situation regarding accessibility remains unchanged, however, the level of service further degrades for pedestrians and bicyclists due to the increase in traffic volumes. The increase in traffic volumes also entails a slight deterioration in emissions and noise through the village.

For the effect profile with all the assessed effects see Figure II.4.

	Effect profile						
	Negative			0	Positive		
	---	--	-		+	++	+++
Traffic safety							
Injured/killed			■				
Subjective (experienced safety)			■				
Accessibility							
for pedestrians				■			
for disabled				■			
for bicyclists				■			
for public transport				■			
for heavy vehicles				■			
for cars				■			
Level of service							
for pedestrians			■				
for bicyclists			■				
for public transport				■			
for heavy vehicles				■			
for cars				■			
Environmental effects							
Emissions			■				
Noise			■				

Figure II.4. Effect profile for alternative 1 - “Do-Nothing” scenario.

Alternative 2 – Environmentally adapted through road

Cost–benefit analysis

Investment and maintenance costs

The total investment costs for converting the through road and its maintenance during the expected 15 years lifetime of the measures are $ 96,000 and consist of the following:

- street lights installed along the main road through the village – investment costs: $ 40000
- two entry gates to the village – investment costs: $ 10000
- eight speed humps along the main road – investment costs: $ 16000
- secured bus stops and pedestrian crossing – investment costs: $ 10000
- maintenance costs during the expected 15 years lifetime of the measures: $20000.

Travel time costs

According to the “Handbook of Road Safety Measures” (Elvik, et al. (2009), on average, for all studies where information about speed was available, the mean speed was reduced by 24% along speed reduction zones. This effect applied to the through road, gives a change of mean speed from 50 to 38 km/h, which implies an increase in travel time by 22.7 seconds per motorised vehicle along the 1 km long through road in the village. For the predicted future traffic volume of 12,600 motor vehicles per day, travel time losses will amount to 12,600*22.7 = 286,020 seconds per day, i.e. 79.45 hours. During the 15 years life time of the scheme (working days counted) it will give 79.45*260*15 = 310,358 hours. Counted with travel time cost of $ 1.5 per hour per vehicle, it will amount to 310,358*1.5 = $ 465,537.

Accidents costs

According to the “Handbook of Road Safety Measures” (Elvik, et al. (2009), installing street lights on previously unlit roads is assessed to decrease the number of injury accidents in darkness in urban areas by 29 %.

The speed reducing entry gates and speed humps along the through road, as well as the secured bus stops and pedestrian crossing in the centre comprise a so called speed reduction zone. According to the “Handbook of Road Safety Measures” (Elvik, et al. (2009), speed reduction zones are assessed to decrease the number of all injury accidents by 27 %.

The overall combined effect of all the measures of the environmentally adapted through road scheme on accidents is assessed according to the following, see Table II.2.:

- Seven injury accidents occurred in darkness in the baseline situation and these are affected of both the introduction of street lights along the through road and the speed reducing measures.
- The remaining 8 daytime injury accidents are only affected of the speed reducing measures.

The number of 15 injury accidents during a three year baseline period is assumed to be reduced to 9.94 for a three year period. Fatal accidents are predicted to decrease to 0.77, accidents with severe injuries to 3.39 and accidents with slight injuries to 5.79, see Table II.2.

Table II.2. Assessed accident outcome during the after period for alternative 2 - Environmentally adapted through road.

		number of accidents during 3 years								difference during 15 years	costs due to change in accidents
			after implementation								
accident severity	Light condition	baseline	due to traffic increase		due to speed reducing measures -27% (*0,73)	due to street lights -29% (*0,71)	overall assessed		difference		
fatal	daylight	1	1,05	1,05	0,77	-	0,77	0,77	-0,28	-1,42	-283500
	darkness	0	0		0,00	0,00	0,00				
with severe injury	daylight	3	3,15	5,25	2,30	-	2,30	3,39	-1,86	-9,31	-186207
	darkness	2	2,1		1,53	1,09	1,09				
with sligt injury	daylight	4	4,2	9,45	3,07	-	3,07	5,79	-3,66	-18,31	-36629
	darkness	5	5,25		3,83	2,72	2,72				
all		15	15,75	15,75	11,50		9,94	9,94	-5,81	-29,04	-506336

Fatal accidents that decrease from 1.05 to 0.77, i.e., by 0.28 in a three year period will give a benefit of 5*0.28 = 1.42 fatal accidents during the 15 years life time of the scheme. In the same way, accidents with severe injury that decrease from 5.25 to 3.39, i.e., by 1.86 in a three year period will give a benefit of 5*1.86 = 9.31 accidents with severe injuries during the 15 years life time of the scheme. Accidents with slight injury that decrease from 9.45 to 5.79, i.e., by 3.66 in a three year period will give a benefit of 5*3.66 = 18.31 accidents with slight injuries during the 15 years life time of the scheme. Based on these assumption, the calculated benefits from accident reductions during the 15 years life time of the scheme are 1.42*200,000+9.31*20,000+18.31*2000 = $ 506,336.

Total benefits/costs

The total benefit is estimated by deducting the investment and maintenance costs of $ 96,000, and the costs for increased travel times of $ 465,537from the benefits by the reduction of accident costs of $ 506,336, which gives **a remaining cost of $ 55,201**.

Effect profile

Traffic composition through the village is forecasted to stay unchanged. Accessibility is considered to remain on the same level for all road user types. The level of service in the after period increase for pedestrians, but deteriorates sharply for motor vehicles along the through road.

Regarding environmental effects, according to the “Handbook of Road Safety Measures” (Elvik, et al. (2009), the few available studies on the effects of environment streets on pollution have contradictory results. However, the increase in traffic volumes and the frequent accelerations and decelerations entail a significant deterioration in emissions and noise through the village.

For the effect profile with all the assessed effects see Figure II.4.

	Effect profile						
	Negative			0	Positive		
	---	--	-		+	++	+++
Traffic safety							
Injured/killed							■
Subjective (experienced safety)						■	
Accessibility							
for pedestrians				■			
for disabled				■			
for bicyclists				■			
for public transport				■			
for heavy vehicles				■			
for cars				■			
Level of service							
for pedestrians						■	
for bicyclists				■			
for public transport	■						
for heavy vehicles	■						
for cars	■						
Environmental effects							
Emissions		■					
Noise		■					

Figure II.4. Effect profile for alternative 2 - Environmentally adapted through road.

Alternative 3 – Bypass road

Cost–benefit analysis

Investment and maintenance costs

The investment costs for the 3 km long bypass road with two T-junctions are assessed to $ 1 million. Maintenance costs of the bypass road during a 15 year period (the lifetime of scheme 2) are assessed to $60, 000. Total investment and maintenance costs are: $ 1,060,000

Travel time costs

The baseline mean speed for motorised vehicles, along the 1 km through road in the village was 50 km/h. This mean speed is expected to increase along the bypass road to 80 km/h. This change in mean speed implies a decrease in travel time by 27 seconds per motorised vehicle along the comparable 1 km road length. For the predicted future traffic volume of 12,600 motor vehicles per day, travel time benefits will amount to 12,600*27 = 340,200 seconds per day, i.e. 94.5 hours. During the 15 years period (the life time of alternative 2 scheme) (260 working days per year counted) it will give 94.5*260*15 = 368,550 hours. Counted with travel time cost of $ 1.5 per hour per vehicle, the benefits will amount to 368,550*1.5 = $ 552,825.

Accident costs

According to the "Handbook of Road Safety Measures" (Elvik, et al. (2009), on average, a decrease in the number of injury accidents of around 25 % was found following the construction of bypasses. This figure include accidents both on the old through road and on the bypass. The effect of bypasses on the number of accidents varies from place to place. The more traffic shifted to the bypass road, the greater the decrease in the number of accidents usually is. If the accident rate is reduced on the old road through the town, for example using speed-reducing measures, greater decrease in the number of accidents can be attained. The design of junctions built between the old road and the bypass also influence the accident rate.

Fatal accidents are predicted to decrease to 0.79, accidents with severe injuries to 3.94 and accidents with slight injuries to 7.09 during the 3 year after period, see Table II.3.

Table II.3. Assessed accident outcome during the after period for alternative 3 - Bypass road.

accident severity	Number of accidents					costs due to change in accidents
	During 3 years			difference	difference during 15 years	
	baseline	due to traffic increase	due to effect of bypass -25 %			
fatal	1	1,05	0,79	-0,26	-1,31	-262500
with severe injury	5	5,25	3,94	-1,31	-6,56	-131250
with sligt injury	9	9,45	7,09	-2,36	-11,81	-23625
all	15	15,75	11,81	-3,94	-19,69	-417375

Fatal accidents that decrease from 1.05 to 0.79, i.e., by 0.26 in a three year period will give a benefit of 5*0.26 = 1.31 fatal accidents during the 15 years comparison period. In the same way, accidents with severe injury that decrease from 5.25 to 3.94, i.e., by 1.31 in a three year period will give a benefit of 5*1.31 = 6.56 accidents with severe injuries during the 15 years period. Accidents with slight injury that decrease from 9.45 to 7.09, i.e., by 2.36 in a three year period will give a benefit of 5*2.36 = 11.81 accidents with slight injuries during the 15 years period. The net benefits from accident reductions during the 15 years period are 1.31*200,000+6.56*20,000+11.81*2000 = $ 417,375.

Total benefits/costs

The total costs are is estimated by deducting the benefits due to decrease in travel times amounting to $ 552,825 and the benefits from reduction in accidents amounting to $ 417,375 from the investment and maintenance costs of $ 1,060,000, which gives a **remaining costs of $ 89,800**.

Effect profile

Traffic volume and traffic composition through the village is expected to change due to moving of through traffic to the bypass road. Only motorised vehicles with origin and destination in the village will move around the village. Busses of public transport will continue to enter and drive through the village.

Accessibility is considered to remain on the same level for all road user types. The level of service in the after period increases significantly for pedestrians, bicyclists and busses in the village and also for motor vehicles shifting to the bypass road.

Environment impacts include reduced traffic volume on the through road, which in turn reduces air pollution, traffic noise, and barriers to local travel. On the other hand, any new road involves intruding the landscape and increasing the area used for transport facilities. (Elvik, et al. (2009).

For the effect profile with all the assessed effects see Figure II.5.

	Effect profile						
	Negative			0	Positive		
	---	--	-		+	++	+++
Traffic safety							
Injured/killed						■	
Subjective (experienced safety)							■
Accessibility							
for pedestrians				■			
for disabled				■			
for bicyclists				■			
for public transport				■			
for heavy vehicles				■			
for cars				■			
Level of service							
for pedestrians							■
for bicyclists							■
for public transport							■
for heavy vehicles							■
for cars							■
Environmental effects							
Emissions						■	
Noise						■	

Figure II.5. Effect profile for alternative 3 - Bypass road.

6. Comparison and ranking of the alternatives

According to the cost-benefit analyses, alternative 2 - Environmentally adapted through road gives the largest reduction in accident costs, and alternative 3 – Bypass road gives the second largest reduction, see Table II.4. The difference in magnitude of the reduction in accident costs between these two alternatives is not large (18 %). The "Do-Nothing" scenario gives an increase in accident costs.

Table II.4. Total costs (and benefits) in $ of the three alternative schemes.

Type of costs	Alternative scheme		
	1 "Do-Nothing"	2 Environmentally adapted road	3 Bypass road
Investment and maintenance	0	96000	1060000
Cange in travel time	0	465537	-552825
Change in accidents	79500	-506336	-417375
Total costs	79500	55201	89800

The ranking of the alternatives in order of their net road safety benefits are as follows:

1. Alternative 2 – Environmentally adapted through road
2. Alternative 3 – Bypass road
3. Alternative 1 – "Do-Nothing"

The benefits of alternative 2 - Environmentally adapted through road are as follows, see Table II.6:

- Accidents along the through road in the village decrease significantly.
- Subjective (experienced) safety for inhabitants of the village increases somewhat.
- The level of service for pedestrians increases somewhat.

The benefits of alternative 3 – Bypass road are as follows, see Table II.6:

- Accidents along the through road in the village decrease.
- Subjective (experienced) safety for inhabitants of the village increases significantly.
- The level of service increases for all types of road users.
- Environmental effects, emissions and noise improve somewhat.

Tabell II.6. Effect comparison of the three alternatives.

Effects	Alternative scheme		
	1 "Do-Nothing"	2 Environmentally adapted road	3 Bypass road
Traffic safety			
Injured/killed	-	+++	++
Subjective safety	-	++	+++
Accessibility			
for pedestrians	0	0	0
for disabled	0	0	0
for bicyclists	0	0	0
for public transport	0	0	0
for heavy vehicles	0	0	0
for cars	0	0	0
Level of service			
for pedestrians	-	++	+++
for bicyclists	-	0	+++
for public transport	0	- - -	+++
for heavy vehicles	0	- - -	+++
for cars	0	- - -	+++
Environmental effects			
Emissions	-	- - -	++
Noise	-	- - -	++

Conclusion

Even if alternative 3 – Bypass road gives somewhat smaller (18 % less) reduction in accident costs than alternative 2, it gives significantly more positive results regarding level of service and environmental effects. It fulfils the secondary objective of the project, i.e., "to improve pedestrians' level of service to easier reach amenities on either side of the main road".

The total net costs of alternative 3 are also higher by $ 35,600, but it can be compensated for by installing secured bus stops and pedestrian crossing in the centre of the village, where five of the injury accidents occurred in the before period for an investment cost of $ 10000.

The recommendation of the Road Safety Impact Assessment team is to adopt alternative 3 – Bypass road with complementary instalment of secured bus stops and pedestrian crossing in the centre of the village.