Michael Sørensen
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Institute of Transport Economics
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Best Practice Guidelines on Black Spot Management and Safety Analysis of Road Networks

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Key words:
Black spot management; Network safety management; State-of-the-art; Best practice guidelines; Hazardous road locations; Identification principles and criteria; Accident analysis; Evaluation af treatment; Road safety

Summary:
The report describes best practice guidelines for black spot management and network safety management with regard to classification of roadway elements, identification, accident analysis and evaluation of treatment. It is recommended that hazardous sites be identified by use of model based methods. The analysis should consist of a general accident analysis and a collision diagram, which are compared with the normal accident pattern for similar locations. A road inspection and relevant traffic and road analyses should also be made. It is important to assess if the identified sites are true hazardous sites. The evaluation should be made as a before-and-after-study controlling for long-term trends in the number of accidents, local changes in traffic volume and regression-to-the-mean by use of correction factors.

Tittel: Beste metoder for utpeking og analyse av ulykkesbelastede steder og sikkerhetsanalyser av vegsystemer

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Sammendrag:
Rapporten beskriver beste metoder for utpekning og analyse av ulykkesbelastede steder, sikkerhetsanalyser av vegsystemer og evaluering av tiltakenes virkninger. Det anbefales at ulykkesbelastede steder utpekes ved bruk av modellbaserte metoder. Analysen bør bestå av en generell ulykkesanalyse og ulykkesdiagram, som sammenlignes med ulykkenes normale fordeling på lignende steder. En bør også foreta en trafikksikkerhetsinspeksjon og relevante analyser av trafikk og veg. Det er viktig å vurdere om de utpekte steder er ekte ulykkesbelastede steder. Evalueringen bør gjøres som en før-etter-analyse, hvor det kontrolleres for generelle tendenser i antall ulykker, lokale endringer i trafikkmengden og regresjonseffekter i ulykkestall ved bruk av korreksjonsfaktorer.

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Preface

This report presents best practice guidelines on black spot management (BSM) and safety analysis of road networks (NSM) on the European road network.

The report is the second of three reports that will document work package 6 (Black Spot Management and Safety Analysis of road Networks – Best Practice Guidelines and Implementation Steps) of the RIP-CORD-ISEREST project (**R**oad **I**nfrastructure safety **P**rotection – **CO**re-**R**esearch and **D**evelopment for road safety in Europe; **I**ncreasing **S**af**E**ty and **RE**liability of secondary roads for a **S**ustainable surface **T**ransport).

In the first report "State-of-the-art approaches to road accident black spot management and safety analysis of road networks" (Elvik 2007) the approaches to BSM and NSM currently used in different countries as well as the state-of-the-art approaches to BSM and NSM are described and discussed.

Based on the described state-of-the-art approaches, best practice guidelines to BSM and NSM are described in the present report. The overall difference between the state-of-the-art approaches and best practice guidelines is that the state-of-the-art approaches are the best at the moment known approaches from a theoretical point of view, while the best practice guidelines are the best approaches from a more practical point of view given limited data and resources for developing, implementation and use of the method. The report describes how classification of roadway elements, identification of black spots and hazardous road sections, accident analysis and evaluation of the treatment should be made from a practical point of view.

The last report will summarize all relevant aspects of the work package and describe the necessary steps to implement the described tools for BSM and NSM.

The project has been funded by the European Commission and the Research Council of Norway. Research Engineer Michael Sørensen has written this report and chief research officer Rune Elvik has been project manager. Valuable comments to the draft of the report have been given by the members of the RIP-CORD-consortium, and Head of Department Marika Kolbenstvedt has been responsible for quality checking of the final report. Secretary Trude Rømming has prepared the text for printing.

Oslo, November 2007
Institute of Transport Economics

Lasse Fridstrøm
Managing Director

Marika Kolbenstvedt
Head of department

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Summary:

Best Practice Guidelines on Black Spot Management and Safety Analysis of Road Networks

Background and objective

For several years black spot management (BSM) has been and still is a very essential part of the site-specific traffic safety work. In the last 5 to 10 years BSM has been supplemented with network safety management (NSM) in more and more countries. However the current approaches and quality of BSM and NSM differ very much from country to country and the work can be characterised by a lack of standardised definitions and methods.

The objective of this project is thus to describe and develop state-of-the-art approaches and best practice guidelines for BSM and NSM. State-of-the-art approaches are defined as the best currently available approaches from a theoretical point of view, while best practice guidelines are the best approaches from a more practical point of view. Best practice guidelines can be used when the data and resources for developing, implementation and use of a national method are limited. State-of-the-art approaches are described in Elvik (2007). Based on these and an extensive literature survey the best practice guidelines are described in this report.

The key elements of best practice guidelines to BSM and NSM are summarized in the following with regard to classification of roadway elements, identification principles and criteria, accident analysis and evaluation of the treatment. The stage of treatment is not treated in this report.

Classification of roadway elements

In BSM the road system should be divided into smaller roadway elements as for example sections of a specified length, curves with radius within a certain range, tunnels and four-leg junctions for which the general expected number of accidents can be estimated. Use of a sliding window approach should be avoided.

In NSM the road system should be divided into longer road sections with a variable length between 2 and 10 kilometres. The sections should be homogeneous with regard to the parameters that have significant influence on the number of accidents and thus are used as independent variable in accident models.

Identification principles

The identification of black spots and hazardous road sections should rely on a traditional model based or category based method. In addition one should

examine the use of not accident based identification methods in NSM be examined.

Identification criteria

The absolute difference criterion, also named savings potential, should be used in conjunction with the model or category based method for identification of black spots and hazardous road sections. The criterion should either be a predefined number that the savings potential has to exceed, or a certain percentage of the road network with the largest savings potential depending on how BSM and NSM are organized and divided between different road administrations.

Accident severity should not be an integrated part of the identification in BSM, but should be integrated in NSM due to more accidents at hazardous road sections than black spots. Severity should be integrated by weighting of the most severely injured in the accident. The accidents should be divided into three severity categories, which are weighted by use of monetary valuations and the average number of injured of a given severity in the different categories.

Accident analysis

The analysis stage in BSM and NSM should as a minimum consist of a general accident analysis, drawing and analysis of a collision diagram, a road inspection and relevant supplementary traffic and road analyses. It is suggested that the general accident analysis and the collision diagram in NSM should be combined into an extended collision diagram to identify local accident patterns that might “drown” in the average for the whole road section.

The general accident analysis and the collision diagram should be compared with the normal pattern of traffic accidents for the given type of location.

An active and written assessment should be made of whether the identified locations are true black or hazardous locations or not. This assessment can be based on a comparison of the results from the accident analysis and the road inspection, a comparison with the normal accident pattern, and by taking the result from the traffic and road analyses into consideration.

Evaluation of the treatment

When possible an evaluation of the actual treatment should be made. The evaluation itself should preferably be made as a before-and-after-study controlling for long-term trends in the number of accidents, local changes in traffic volume and regression-to-the-mean by use of correction factors. In addition it should be examined how evaluation of combined retrospective and prospective treatment in NSM can be done in a better way.

Sammendrag:

Beste metoder for utpekning og analyse av ulykkesbelastede steder og sikkerhetsanalyser av vegsystemer

Bakgrunn og formål

Utpekning, analyse og utbedring av spesielt ulykkesbelastede steder (black spot management, BSM) har i mange år vært og er stadig en viktig del av det stedbundne trafikksikkerhetsarbeidet. I de siste 5-10 år er BSM blitt supplert med sikkerhetsanalyser av vegsystemer (network safety management, NSM) i stadig flere land. Eksisterende metoder for BSM og NSM og kvaliteten på disse varierer imidlertid fra land til land, og det finnes ingen felles definisjoner og metoder.

Formålet med dette prosjekt har derfor vært å beskrive og utvikle moderne tilnærmingsmåter (state-of-the-art approaches) og beste metoder (best practice guidelines) for BSM og NSM. Moderne tilnærmingsmåter defineres som foreliggende metoder som er best fra et teoretisk synspunkt, mens beste metoder defineres som beste metoder fra et mer pragmatisk synspunkt. Disse kan brukes når data og ressurser for utvikling, implementering og bruk av en nasjonal metode er begrensede. Moderne tilnærmingsmåter er beskrevet i Elvik (2007), og basert på disse samt omfattende litteraturstudier er beste metoder beskrevet i denne rapport.

I det følgende summeres de viktigste anbefalinger om hvordan BSM og NSM best kan foretaes i praksis med hensyn til oppdeling av vegnett, identifikasjonsprinsipper og kriterier for utpekning av farlige steder, ulykkesanalyse og evaluering av utbedringstiltak. Utbedring av farlige steder behandles ikke i denne rapporten.

Oppdeling av vegnettet

I BSM skal vegnettet oppdeles i kortere vegelementer, som for eksempel strekninger av en bestemt lengde, kurver med en bestemt radius, tunneler og kryss med 4 armer hvor det generelt forventede antall ulykker kan estimeres. Bruk av gliderstykke (sliding window approach) bør unngås.

I NSM skal vegnettet oppdeles i strekninger med en variabel lengde på mellom 2 og 10 kilometer. Strekningene bør være homogene med hensyn til parametere som har signifikant betydning for antall ulykker og som benyttes som uavhengige variable i ulykkesmodellene.

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Identifikasjonsprinsipper

Identifikasjonen av spesielt ulykkesbelastede steder og strekninger skal foretaes ved bruk av en tradisjonell ulykkesmodellbasert eller en kategoribasert metode. I tillegg skal muligheten for å bruke ikke ulykkesbaserte metoder i NSM undersøkes nærmere.

Identifikasjonskriterier

I forbindelse med den tradisjonelle ulykkesmodellbaserte eller kategoribaserte metode bør et absolutt forskjellskriterium, også kalt innsparingspotensial (savings potential), benyttes ved utpekning av ulykkespunkter eller ulykkesbelastede strekninger. Kriteriet bør enten være en predefinert størrelse som potensialet for ulykkesreduksjon skal være større enn eller en bestemt prosent av vegnettet med størst innsparingspotensial. Dette avhenger av hvordan BSM og NSM er organisert og oppdelt mellom forskjellige forvaltningsorganer for vegnettet.

Skadegraden på ulykkene bør ikke være en integrert del av selve utpekningen i BSM, men skal være en integrert del i NSM, fordi det er flere ulykker på de ulykkesbelastede strekningene enn på ulykkespunktene. Alvorlighet skal integreres ved vekting etter den mest alvorlige personskaden i den aktuelle ulykken. Ulykkene skal oppdeles i tre skadegradskategorier. Disse vektes ved bruk av samfunnsøkonomiske kostnader ved personskader i trafikken og det gjennomsnittlige antall personskader med forskjellig skadegrad i de tre kategorier.

Ulykkesanalysen

Ulykkesanalysen i både BSM og NSM bør som et minimum bestå av en generell ulykkesanalyse, tegning og analyse av et ulykkesdiagram, en trafikksikkerhetsinspeksjon og relevante analyser av trafikk og veg. Det foreslås at den generelle ulykkesanalyse og ulykkesdiagrammet i NSM kombineres til et utvidet ulykkesdiagram slik at en kan identifisere lokale ulykkesmønstre, som ellers kanskje "drukner" i gjennomsnittet for hele strekningen.

Den generelle ulykkesanalysen og ulykkesdiagrammet skal sammenlignes med ulykkenes normale fordeling på lignende steder.

Det skal også lages en aktiv og nedskrevet vurdering av hvorvidt de utpekte stedene er faktisk ulykkesbelastede steder. Denne vurderingen kan baseres på en sammenligning av resultater fra ulykkesanalysen og trafikksikkerhets-inspeksjonen, på en sammenligning med ulykkenes normale fordeling på lignende steder og ved å ta resultater fra trafikk- og veganalysene i betraktning.

Evaluering av tiltak

Hvis det er mulig, bør en også foreta en evaluering av utførte tiltak. Evalueringen bør lages som en før-etter-analyse, hvor det kontrolleres for generelle tendenser i antall ulykker, lokale endringer i trafikkmengden og regresjonseffekter i ulykkestal, ved bruk av korreksjonsfaktorer. I tillegg bør det undersøkes hvordan evaluering av kombinert proaktive og reaktive tiltak i NSM kan gjennomføres på en bedre måte.

1 Introduction

1.1 Background

For several years black spot management (BSM) has been and still is an essential part of the site-specific traffic safety work done by the public roads administration authorities in several countries in the European Union. In the last 5 to 10 years, this traditional black spot management has been supplemented with safety analysis of road networks also called network safety management (NSM) in more and more countries.

However, current approaches and quality of both BSM and NSM differ very much from country to country and the work can be characterised by a lack of standardised definitions and methods.

Within work package 6 of the RIPCORD-ISEREST project, the European Commission thus has funded a project named "Black Spot Management and Safety Analysis of road Networks – Best Practice Guidelines and Implementation Steps". The objective of this project is to develop best practice guidelines for BSM and NSM.

The work in this work package will be documented in three reports. In the first report "State-of-the-art approaches to road accident black spot management and safety analysis of road networks" (Elvik 2007) the approaches to BSM and NSM currently used in different countries as well as the state-of-the-art approaches to BSM and NSM are described and discussed. A state-of-the-art approach is defined as the best currently available approach from a theoretical point of view. These state-of-the-art approaches to BSM and NSM are finally compared with the current approaches and it is concluded that there is, in general, a considerable gap between current practice and the state-of-the-art approaches. The current approaches in many countries thus need considerable development.

1.2 Objective

This report represents the second out of three reports and follows up on the conclusions and recommendations in the first report.

Based on the state-of-the-art approaches to BSM and NSM as described in the first report the objective of this report specifically is to develop best practice guidelines to BSM and NSM.

In principle, you can say that best practice guidelines should be the same as state-of-the-art approaches, but full implementation of the best currently available approach from a theoretical point of view will require access to quite extensive data and development effort and will therefore not be realistic in many countries in the near future.

Even if not all data and resources needed are available, improved approaches to BSM and NSM can be developed. Development and use of best practice guidelines can therefore be characterized as a stepwise process moving toward the state-of-the-art approach at the top of the ladder. The objective is hence both to come closer to ideal practices and to remove the most glaring deficiencies in the currently used approaches.

1.3 Method

The report is based on an extensive literature survey with focus on different methods for primary identification and analysis of black spots and hazardous road sections including references discussing how from a theoretical and practical point of view it is assessed if a method is "better" than others. This survey will not only focus on the best methods, but primarily focus on the "second" and "third" best methods. In addition, the description of best practice guidelines is inspired by the currently available methods in different countries described in Elvik (2007).

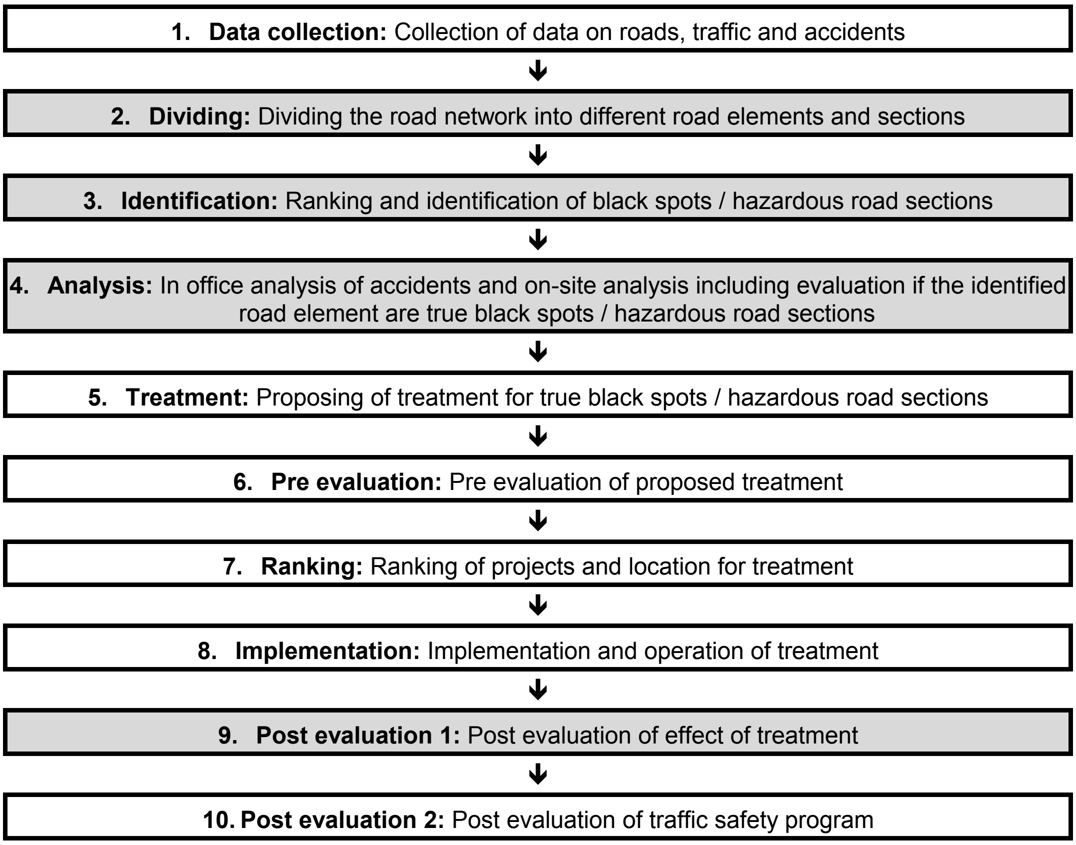

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Figure 1.1. Typical stages in BSM and NSM. Grey indicates focus in this report.

1.4 Delimitation

BSM and NSM are typically divided into the 10 more or less independent stages described in figure 1.1. In the previously described state-of-the-art approaches for BSM and NSM in Elvik (2007), focus is on stage 2, 3, 4 and 9 – especially stage 3 and 4. These stages are marked grey in figure 1.1. Thus, focus in this report will also be on these four stages.

1.4.1 Prerequisite about accident data

A fundamental prerequisite for BSM and NSM is that traffic accidents are recorded, and that these records contain adequate information about locality, accident type, severity, time, road elements and the surrounding environment, circumstances and vehicles involved. In addition, the record has to have an acceptable level of reporting. However, this is not always the case (Elvik and Mysen 1999, Sørensen 2006). In this situation, neither BSM nor NSM can be done as the state-of-the-art approaches described in Elvik (2007) nor as the best practice guidelines described in this report.

The general problem of incomplete accident reporting is not treated in this project (cf. figure 1.1). This means that the results in principle only are relevant in situations where the accident record has an adequate quality.

1.5 Report structure

The report is divided in three overall parts. The first part is a brief review of the developed state-of-the-art approaches to BSM and NSM. Afterwards the differences between state-of-the-art approaches and best practice guidelines are discussed and clarified. This includes a discussion of why it is necessary and appropriate to distinguish between state-of-the-art approaches and best practice guidelines. The use of state-of-the-art approaches and best practice guidelines in different stages of BSM and NSM are also discussed. Finally, the criteria for evaluating different approaches with regard to which that can be counted as state-of-the-art approaches are specified. This is summarized because the same criteria have to be used when describing best practice guidelines. In addition, some supplementary criteria are formulated.

The second and third part focus on best practice guidelines to black spot management (BSM) respectively best practice guidelines to safety analysis of road networks (NSM). For both parts, the best practice guidelines are described and discussed with regard to the following points:

- Classification of roadway elements
- Identification principle
- Identification criteria
- Accident analysis
- Evaluation of the treatment

2 State-of-the-art and best practice

This chapter summarize shortly the developed state-of-the-art approaches to black spot management (BSM) and safety analysis of road networks also called network safety management (NSM).

Afterwards the overall difference between state-of-the-art approaches and best practice guidelines will be discussed and clarified. This includes a discussion of why it is necessary and appropriate to distinguish between state-of-the-art approaches and best practice guidelines. In addition, the use of state-of-the-art approaches and best practice guidelines in different stages of BSM and NSM are discussed.

Finally, the criteria for evaluating different approaches with regard to which that can be counted as state-of-the-art approaches and best practice guidelines are specified.

2.1 The key elements of the state-of-the-art approaches

The key elements of the state-of-the-art approach to black spot management and safety analysis of road networks are described in Elvik (2007).

For black spot management the key elements are summarised in table 2.1. For clarification for these elements, see Elvik (2007).

The state-of-the-art approach to safety analysis to road networks contains all the same elements. In addition, a state-of-the-art approach to safety analysis to road networks should include the following:

- Accident severity as a part of the identification itself, because long sections with more accidents permit a meaningful consideration of accident severity.
- A routine for merging short adjacent sections for the purpose of accident analysis. The United States' profile and peak algorithm is suitable for this purpose.

With respect to the accident analysis in both BSM and NSM it should be noted that Elvik (2007) argues that current techniques including state-of-of-the-approaches for accident analysis need to be further developed and tested, as these techniques are not currently able to discriminate between false positives and true positives with sufficient precision.

Table 2.1. State-of-the-art approach to black spot management (Elvik 2007).

Classification of roadway elements	a. Black spots should be identified by reference to a clearly defined population of roadway elements, whose members can be enumerated b. Roadway elements can for example include sections of a specified length, curves with radius within a certain range, bridges, tunnels, three-leg junctions or four-leg junctions c. Use of sliding window approach is discouraged
Identification principle	a. Black spots should be identified in terms of the expected number of accidents, not the recorded number of accidents b. The best estimate of the expected number of accidents for a single site is obtained by combining the recorded number of accidents with the normal expected number of accidents for that roadway element by using the empirical Bayes method c. To estimate the expected normal number of accidents at different sites multivariate accident prediction models should be developed
Identification criterion	a. Black spots should be identified as sites that have a higher expected number of accidents than the normal expected number on similar roadway elements due to specifically local risk factors b. Black spots cannot be reliably identified in terms of a critical count of accidents, but for the purpose of accident analysis only sites that have a certain minimum number of accidents should be identified c. Alternative minimum criteria for recorded number of accidents should be investigated in terms of sensitivity and specificity and an optimal criterion should, if possible, be chosen d. Accident severity should not be a part of the identification itself, but it should be included in a preliminary analysis of the accidents at black spots and sites that have a high mean cost per accident should be ranked high on a list for more detailed engineering analysis
Accident analysis	a. Binomial tests should be applied to determine the probability that a dominant pattern of accidents is the result of chance only b. An analysis should be made as a blinded matched-pair comparison, where hypotheses regarding risk factors are suggested by means of detailed examination of accidents and afterwards tested by a “blind” comparison of the black spot to a safe location
Evaluation	a. Evaluation of the effects of the black spot treatment should employ the empirical Bayes before-and-after design b. The evaluation should control for (a) local changes in traffic volume, (b) long term trends in accidents, (c) regression-to-the-mean and if relevant (d) accident migration

2.2 Difference between state-of-the-art approaches and best practice guidelines

The overall difference between a state-of-the-art approach and best practice guidelines is that the state-of-the-art approaches is the best at the moment known approach from a theoretical point of view, while best practice guidelines is the best approach from a more practical point of view.

A characteristic feature for the state-of-the-art approaches is in principle that all relevant data are available and of high or sufficient quality. In this case it means that data about accidents, traffic volume, roads and the surrounding environment are recorded by either the police or the public roads administration and are easy available in digital form for people working with BSM and NSM. In addition, these data have to be unambiguously located on the road network and immediately interoperable with each other, so that it is possible to integrate the data with the purpose to make accident models and comparisons of black spots or hazardous road sections and safe locations.

In contrast to the state-of-the-art approaches, the use of best practice guidelines is based on limited data with regard to both quantity, quality and interoperability. The limitation of the data determines how close the best practice guidelines can come to the state-of-the-art approaches. The more data available the closer the best practice guidelines reach the state-of-the-art approaches.

With regard to limited data, this report primarily focuses on limited data about the traffic and the roads, because it is assumed that the accident data have an adequate quality as described under “Delimitation”.

Another characteristic feature of the state-of-the-art approaches is that there are at least in principle comprehensive resources regarding time, money, personnel and professional expertise to develop, implement and finally use approaches that are equivalent to the state-of-the-art approaches. In this context, development means adjustment of state-of-the-art approaches to national and regional conditions.

By contrast, development, implementation and use of best practice guidelines are based on limited resources. The limitation of the resources determines like the limit of data how close the best practice guidelines come to the state-of-the-art approaches. The more resources applied the closer the best practice guidelines can come to the state-of-the-art approaches.

Adjustment, implementation and use of state-of-the-art approaches will typically be possible for only a national or maybe a regional public roads administration with an overall responsibility for the traffic and road sector. By contrast, implementation and use of the best practice guidelines can to a greater extent probably be done by regional and maybe local public road administrations. Therefore, the organisational system and funding of road safety measures and the responsibility for development and implementation of new methods influence the possibility to implement the state-of-the-art approaches.

In table 2.2 the primary differences between state-of-the-art approaches and best practice guidelines are summarized.

Table 2.2. Differences between state-of-the-art approaches and best practice guidelines.

	State-of-the-art approaches	Best practice guidelines
Nature	Idealistic	Pragmatic
Quality	Best from a theoretical point of view	Best from a practical point of view
Data	Comprehensive and interoperable	Limited
Resources	Comprehensive	Limited
Who	National or a regional public roads administration	Regional or local public roads administration

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2.3 Why state-of-the-art and best practice guidelines

As described in the previous chapter, the state-of-the-art approaches can be defined as the best currently available approach from a theoretical point of view if you have comprehensive and interoperable accident, traffic and road data and comprehensive resources to develop, implement and use these approaches at your disposal.

However this is seldom the case in real life, and it is therefore better to have and use some best practice guidelines rather then refrain from doing anything at all because the demands for doing the state-of-the-art approaches can not be satisfied.

In addition, the development and use of best practice guidelines can be characterized as a stepwise process moving towards the state-of-the-art approach where the first steps taken are as important as the final steps. In fact can it from a more practical point of view be argued that the first steps are the largest and that the steps are getting smaller and smaller the closer to the state-of-the-art approaches you are getting.

2.4 Use of state-of-the-art and best practice guidelines

State-of-the-art approaches are – as illustrated in figure 1.1 – described for four stages of BSM and NSM. Obviously, it is preferable that the state-of-the-art approaches are used for all four stages, but as described before, this is not always a possibility due to deficient data and resources.

When state-of-the-art approaches are not used for all stages it is recommend that the approaches as minimum are used for at least one of the stages, because it to a certain extent can compensate for the lack of use in other stages. In fact, the use of state-of-the-art approaches in one stage is even more important, when the state-of-the-art approaches are not used in the other stages. This applies especially for the identification and analysis stages with regard to ensure that it is only true black spots and hazardous road sections that are treated in the BSM and NSM (Elvik 2006, Sørensen 2006).

Table 2.3. The quality of the combination of using state-of-the-art and best practice guidelines in the identification and analysis stages of BSM and NSM with regard to focusing the work on true black spots and hazardous road sections. The numbers in parenthesis specify an (entirely) assumed percent of correctly identifications and assessments to illustrate the demanding of using state-of-the-art in minimum on stage.

Identification	Analysis	Conclusion
State-of-the-art (✓)	**State-of-the-art** (✓)	✓
Reliable identification, but will still contain false positives (90)	Reliable assessment if the identified sites are true or false positive (90)	All sites treated are true positives (99)
State-of-the-art (✓)	**Best practice guidelines** (÷)	(✓)
Reliable identification, but will still contain false positives (90)	Less reliable assessment if the identified sites are true or false positive (50)	Almost all sites treated are true positives (95)
Best practice guidelines (÷)	**State-of-the-art** (✓)	(✓)
Less reliable identification with more false positives (50)	Reliable assessment if the identified site is true or false positive (90)	Almost all sites treated are true positives (95)
Best practice guidelines (÷)	**Best practice guidelines** (÷)	(÷)
Less reliable identification with more false positives (50)	Less reliable assessment if the identified sites are true or false positive (50)	Several sites treated are false positives (75)

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This point is illustrated in table 2.3. If best practice guidelines are used in both the identification and analysis stages, you are risking that several of the treated sites are not true black spots or hazardous road sections because the methods are not reliable enough to identify true black sports or hazardous road sections. To illustrate the problem assume that half of the identified sites are false positives and only half of these are sorted out in the analysis stages. An average of 25 % of the treated locations will then be false black spots or hazardous road sections.

However if state-of-the-art approach are used in one of the stages, this failure will be significantly reduced. One can for example use best practice guidelines in the identification stage and state-of-the-art approach in the analysis stage. If assumed that the state-of-the-art approach for analysis has a capability to sort out 90 % of the false positives only 5 % of the treated locations will be false black spots or hazardous road sections.

The point can be summarized in the following way:

- The use of more primitive methods for identifying black spots and hazardous road sections place additional burdens on the following analysis of accidents to sort out falsely identified locations.
- The use of more primitive method for analysing black spots and hazardous road sections place additional burdens on the identification stage to avoid many false positive that maybe not will be sorted out in the analysis stage.

2.5 Criteria for evaluating best practice

Different criteria are used to evaluate and determine what the state-of-the-art approaches for BSM and NSM are. These criteria will also be used as basis when evaluating and determining best practice guidelines for BSM and NSM. Hence, best practice guidelines can be characterized as the guidelines that come closest to satisfying the criteria.

The criteria are the following:

1. *Random fluctuations:* It should control for random fluctuations in the number of accidents by relying on the expected number of accidents and not the recorded number.
2. *Systematic variation:* It should account for as many as possible of the factors relating to traffic volume, traffic control and road design that are known to influence road safety by use of accident prediction models.
3. *Local risk factors:* It should identify sites where local risk factors related to road design and traffic control make a substantial contribution to accidents resulting in higher expected number of accidents than normal number for similar locations.
4. *Severity:* Severity should be taken into account in a systematic way, if road safety policy seeks to prevent the most serious accidents.

2.5.1 Supplementary criteria

In addition to the four criteria described above some supplementary criteria are outlined in the following. While the criteria mentioned concern the theoretical aspect the following criteria focus on practical aspects. The more practical criteria are described with inspiration from Sørensen (2006), who in great detail has discussed criteria for evaluating methods for practical use. The criteria as follows:

1. *Flexible:* The guidelines should be so flexible so they can be used for different countries with different levels of traffic safety, geographic size, infrastructure, traffic volume and organisation of the site-specific traffic safety work. In addition, they should be applicable to all levels of public roads in both urban and rural areas.
2. *Implementable and applicable:* The guidelines should be possible to implement and applicable for each public road administration and should in principle be applicable for the financial resources, the personnel resources and professional expertise currently available in the concerned administration.
3. *Data and compatibility:* The guidelines should be based on and compatible with existing and available data about accidents, roads and traffic. Thus, it will not be necessary to allocate comprehensive resources to recording new data at the initial stage.
4. *Objective:* The guidelines should be as objective, unambiguous and formalized as possible, hence the use of subjective and perhaps biased evaluations are limited as much as possible.
5. *Reliable:* The guidelines' reliability should be maximized as much as possible. This means that the probability of identifying true black spots and hazardous road sections, true local risk factors and the "right" solutions should be maximized while false positive and false negative identified locations, risk factors and solutions should be minimized.
6. *Documented and understandable:* The guidelines should be well described and documented in earlier work. In addition, the guidelines have to be immediately understandable and acceptable for people working with traffic safety.

3 Black spot management

This chapter discusses and recommends best practice guidelines for black spot management (BSM) with regard to classification of roadway elements, identification principles, identification criteria, accident analysis and evaluation of the treatment.

3.1 Classification of roadway elements

According to the state-of-the-art approach to BSM, road accident black spots should be identified by reference to a clearly defined population of roadway elements for which the general expected number of accidents could be estimated. As described in chapter 2.1 these road elements can for examples include sections of a specified length, curves with radius within a certain range, bridges, tunnels, three-leg junctions and four-leg junctions. This means that use of a sliding window approach to identify black spots is discouraged.

3.1.1 Recommendation

With regard to best practice guidelines for dividing the road system into smaller roadway elements, the same recommendation as in the state-of-the-art approach is made. The argument for that is the following:

- Dividing of the road system into clearly defined populations of roadway elements has been found to be less resource demanding than using a sliding window approach, especially with regard to development of method (Hauer et al. 2002, Andersen and Sørensen 2004, Pedersen and Sørensen 2007).
- The principle is considered more simple and easy to understand than use of a sliding window approach.
- When black spots are to be identified by use of more or less sophisticated model based identification methods as recommend in the following chapter 3.2 it is immediately necessary that the road system is divided into clearly defined roadway elements.

However, it should be noted that there are some problems by using this approach to dividing the road system into smaller elements. This is probably the reason that the sliding window approach has been develop and is used in several countries as Austria, Denmark, Flanders, Hungary, Norway and Portugal.

The problem relates especially to road sections. If these road sections are divided into not overlapping segments with a length of for example 0,5 kilometre there is a risk that the division will not correspond to the accident pattern. Local accident peaks might also be divided between two segments and thus not identified as a black spot.

To avoid this problem the segment length can be reduced, but this increase the risk of random accidents peaks being identified as black spots (Hauer et al. 2002).

3.2 Identification principles

Different overall principles for identification of black spots can be used. In the following it is recommended what principles can used as best practice guidelines.

3.2.1 Different identification principles

Overall identification principles can be divided into accident based and not accident based principles. In addition the accident based principles can be divided into model based and not model based principles. Transverse to this division you can identify principles you could call accident specific principles. The not accident based principles can overall be divided into quantitative and qualitative principle. Finally, the different principles and the methods can be combined in several ways (Laughland et al. 1975, OECD Road Research Group 1976, Sanderson and Cameron 1986, Khisty 1990, Joly et al. 1992, Ogden 1996, Hauer 1996, Persaud et al. 1997, 1999, PIARC Technical Committee on Road Safety 2003, Sørensen 2006). The principles are summarized in table 3.1.

Table 3.1. Five identification principles and different identification methods.

Accident based			Not accident based		Combination
Not model	Model	Specific	Quantitative	Qualitative	
– Number – Frequency – Rate – Frequency-rate – Change – Combination	– Category – Traditional – Modern	– Theme – Type – Site-specific	– The road – The traffic – The driver – Combination		– Methods from same principle – Methods from different principles

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Not model based identification principles

The category with the not model based identification principles can be divided into the six different methods specified in table 3.1. Frequency (accidents per kilometre), rate (accidents per vehicle kilometre) or frequency-rate are most commonly used. Absolute number can be used for road elements with same length. Change in frequency, rate or number are normally not used as a distinct identification method.

Model based identification principles

These principles can be divided in the following three different ways:

1. How the model is estimated
2. What the registered or local expected accidents are compared with
3. How the registered, local expected and general expected accidents are compared against each other

In general, terms accident models can be estimated in three ways. Accident models can be made as a category analysis, where the set of accident, road and traffic data are divided into some predefined categories, and for these categories, the average numbers of accidents are calculated. Note that a category analysis is not a distinct accident model, but for reasons of completeness in the review and because the registered number of accidents are compared with an average it is judged as appropriate to characterize a category analysis as an accident model.

In the last two types of modelling, the normal expected number of accidents is estimated through regression analysis, where normally the traffic volume is used as independent regression variable. The regression analyses are done under the assumption that the accidents follow a Poisson or a negative binomial distribution (traditional approach).

The last principle is the empirical Bayes approach, where the local expected number of accidents is estimated by weighting the registered and the model estimated number of accident. This is the modern approach defined as state-of-the-art approach.

The second way to categorize the model based identification principles is to categorize by reference to what the registered or local expected accidents are compared with. It can of course be compared with the average or the general expected number of accident, but it can also be compared with a minimal number of accidents for road elements with best practise design or a target level. Note that comparison with an average number, minimal number or target level of accidents is not a distinct model based approach, because these levels are not justified by model estimation. For reasons of completeness in the review and because the registered or local expected number of accidents are compared with something it is judged appropriate to characterize these approaches as model based.

The last way to divide the model based principles is how the registered, local expected and normal expected accidents are compared against each other. This can in principle be done in the following five different ways.

1. *Expected number:* Sites are identified as sites with highest general or local expected number of accident.
2. *Ratio:* Sites are identified as sites with the highest ratio between the registered or local expected number of accidents and the general expected, average, minimal or target number of accidents.
3. *Savings potential:* Sites are identified as sites with the highest absolute different between the registered or local expected number of accidents and the general expected, average, minimal or target number of accidents.
4. *Specific or solution based:* Focus on specific accident types or site specific accidents, and sites are identified as sites with more accidents of a specific type than normal.
5. *Combination:* Combination of the four previous principles.

Accident specific identification principles

All the accident based identification principles can in principle be based on different subsets of the registered accidents. It can be all accidents, a subset of the accidents, all injured, a subset of the injured or a combination. In addition the accidents and injured can be weighted in different ways.

Finally, the identification can, under the accident specific identification principles, be based on specific themes, accident types or accidents with road related risk factors (Joly et al. 1992, Sayed et al. 1995, 1997, Kononov 2002).

Not accident based identification principles

The not accident based identification principles can be divided into quantitative and qualitative methods (Taylor and Thompson 1977). Both are based on information about the road and the surrounding environment, the traffic or the driver instead of accident data.

The road information can for example be parameters as road geometry, sight distance, friction, fixed obstacles and guardrails, number and design of intersections and access roads and facilities for cyclists and pedestrians. The traffic information can for example be parameters as near accident, speed level, variation and changes in speed, traffic volume and distribution and distances between vehicles. Information about the driver can for example be cognitive capacity and expectations (Laughland et al. 1975, Taylor and Thompson 1977, Leur and Sayed 2002, Hummer et al. 2003).

The registration will typically be done by observation, but can also be based on extraction and interpretation of different road and traffic data from relevant databases. Finally the registration can in the future probably also be done as GPS-loggings (Global Positioning System).

Combined identification principles

The last principle is to combine the other described principles in different ways. It can be done by combining methods under the same principle or methods from different principles.

GIS based identification methods

In addition to the principles described so called GIS based identification methods (geographic information system) are more and more seen, see for example Højgaard et al. (2006). In general, the principle is that the concerned area is divided into more or less squares, and the number of accidents in every square is counted. Black spots are then defined as the squares with most accidents.

These methods will not be evaluated in this report. However, the use of these methods in BSM and NSM can be questioned from a more theoretical point of view. The general problem is that accidents are attached to areas and not intersections and road sections. This makes it at first sight impossible to take traffic and road design into account in the identification of hazardous road locations.

3.2.2 Advantages and disadvantages

Advantages and disadvantages for the five identifications principles are summarized in table 3.2 and clarified in the following. Note that the advantages and disadvantages only are listed for the overall principles and not for every method under each principle.

Table 3.2. Advantages and disadvantages for the five identification principles.

	Advantages	Disadvantages
Not model based	– Easy to use and understand – Method development is undemanding – Development and use can be done by a regional or local administration – Focus on sites with most accidents – Connected accident, road and traffic data is unnecessary – Can be done without road and traffic data	– General road design and maybe traffic volume are not taken into account – No or limited attention to random fluctuations – Retrospective nature – Dependent on incomplete and imprecise accident data
Model based	– General road design and traffic volume is taken into account – More or less attention to random fluctuation – Best from a theoretical point of view	– Comprehensive and connected accident, road and traffic data is necessary – Some methods have a partly retrospective nature – Comprehensive method development – Development can only be done by a national or maybe regional administration – Dependent on incomplete and imprecise accident data
Specific	– Focus on site specific accidents – Direct link between the stages of identification and analysis	– Retrospective nature – Limited accident data – Only focus on site-specific problems
Not accident based	– Prospective nature – Independent of accident data – Use of the road administrations own road and traffic data	– Maybe a very comprehensive identification stage – Supplementary data collection and method development is necessary – Use of indirect indicators – Biased identification is a risk – In some methods experiences and local knowledge is demanded – Lack of understanding, application and accept from the users
Combi-nation	– Take advantage of the different methods advantages – Compensate for the different methods disadvantages – Possibility for united identification for areas and roads with different data	– Comprehensive identification stage – Lack of understanding, application and accept from the users – Comparison of incomparable data

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Not model based identification principles

The not model based identification principles are the most easy to use and understand. In addition, it is only necessary to have data about the accidents and maybe traffic volume and it is thus not necessary to have comprehensive and connected accident, road and traffic data. Given that the principles are relative simple and only requires a minimum of accident data it is relatively less resource demanding to develop and use these methods. Hence, the work can most likely be done by a regional or local road administration for their own road network.

A key disadvantage is that systematic variation in the number of accidents is not taken into consideration. In reality, this means that the identification is done across all types of road elements. The result is that it is not necessarily sites with local risk factors that are identified, but rather road elements that in general are problematic from a traffic safety point of view, and thus requires a general rebuild to a more safe type. This can be very expensive compared to only to have to change the detailed design of the road element, as is often the case in the traditional black spot treatment.

Another disadvantage is that random fluctuation only is taken into account by the use of an extended period in the identification stage (typical up to five years). On the one hand this means that there is a risk to make an incorrect identification of sites because of a randomly high number of accidents in the given identification period (false positive). On the other hand there is a risk that true black spots are not identified because of a randomly low number of accidents in the given identification period (false negative). With regard to the first problem, it has to be noted that these sites in principle should be identified in the analysis stages. However, it can be questioned to what extent this is done in practice.

A third problem that relates to all the accident based methods is that they have a retrospective nature. Roughly speaking people must die before anything is done. In many other sectors, this would be absolutely unacceptable.

Model based identification principles

In contrast to the not model based methods systematic variation determined by general road design and traffic volume is more or lest taken into account in the model based identification principles. This means that sites with local risk factors (true black spots) are identified.

Another essential advantage is the capability to control more or less for the stochastic nature of the accident. This ensures a relatively reliable identification with regard to identifying sites with local risk factors. Note however that errors of the type false negative and false positive can occur in model based identifications.

The model based methods – especially the empirical Bayes method – should be considered as the best from a theoretical point of view because both systematic variation and random fluctuation are taken into consideration. This is also the reason why the empirical Bayes method is descried as the state-of-the-art approach.

A disadvantage is that the method can be relatively difficult and resource demanding to understand, use and especially develop. In addition, it is necessary to have comprehensive and connected accident, road and traffic data. This requires extensive data collection and linkage.

Depending on actual identification method, the method can have a partly retrospective nature. However, it can also be argued that they have a partly prospective nature. This can be explained in terms of the fact that a higher number of accidents than normal indicate a site with local risk factors, and if nothing is done, the site will remain black.

Accident specific identification principles

Among both the not model and the model based identifications principles you find principles, which in this report are named specific identification principles.

The advantage of these principles is that the identification is based solely on site-specific accidents through specific accident themes or types or accidents associated with road related risk factors whereby all interference from not site specific accidents is removed already in the identification stage. This means that the link between the different stages in BSM and NSM will be improved, because the analysis in a way already is started during the identification stage. It can be argued that this will give a more effective traffic safety work compared to the normal division of the work in different more or less independent stages (see figure 1.1) (Sayed et al. 1995, 1997, Kononov 2002).

The accident specific identification principles have like the other accident based principles the disadvantage of being based on accidents and therefore have a retrospective nature.

In addition, it can turn out to be a problem to limit the accident data, which already is limited in many countries due to incomplete accident reporting (Elvik and Mysen 1999).

A last criticism is that focus on some certain themes and accident types can result in the failure to identify other traffic safety problems on the concerned sites.

Not accident based identification principles

The accident based identification principles have a retrospective nature, which means that people must die or get injured before anything is done. To avoid this not accident based identification methods can be used, where the principle is to identify sites for consideration before the accidents happens. This prospective nature is one of the essential advantages of the not accident based methods (Laughland et al. 1975).

The other essential advantage is that the identification does not depend on the quality of the accident data in the official accident statistics. This is very important because several studies show that the official accident statistics both have a low and unbalanced coverage in comparison with the real situation (Elvik and Mysen 1999). This means that there is a focus on some wrong locations and problems in the BSM and NSM. See an example of a study from Denmark in Andersen and Sørensen (2004).

To focus on not accident based method is according to Leur and Sayed (2002) and Hummer et al. (2003) very important at present because the tendency is that the quality of the accident data in the official accident statistics is stagnant or even falling (in North America). This can be explained with the fact that the police have other priorities than the road administrations. In contrast, the road administrations themselves have the responsibility to collect and maintain road and traffic data, and more road administrations already have road and traffic databases of high quality. In addition, it can be expected that these databases will be even better in the future with regard to both quality and quantity because the method of road data collection has improved for example by the use of GPS so the collecting is less expensive, more effective and more precise (Hummer et al. 2003).

However the advantages of the not accident based method is at the same time their disadvantages. You can say that you try to identify accident prone locations without the use of accident data, which must be considered as the best evidence on this. The not accident based methods are thus not as reliable as the accident based methods (Laughland et al. 1975).

Many attempts of not accident based identification are made, but these methods have not become an integrated part of the BSM and NSM. This indicates that it is difficult to develop and implement such a method. These methods thus need further development and evaluation (Hauer 1996, Sørensen 2006).

The not accident based methods will typically be based on some kind of observation. This causes an additional point of criticism. Identification based on inspection and registration for the complete given road network will mean that the identification stage will be very comprehensive, which is not the intension of BSM and NSM (Thorson 1970, Hauer et al. 2002).

Combined identification principles

The last principle is to combine different methods. The advantage of this is that the advantages of each of the methods are kept at the same time as compensation for the methods' disadvantages can be made.

However, you risk getting a comprehensive and incomprehensible identification stage.

3.2.3 The use of different principles

In Elvik (2007) BSM in eight European countries have been described. This is summarized in table 3.3 with focus on overall identification principles and methods. See Elvik (2007) for clarification of each method.

All the identification methods used in the eight reviewed countries are accident based principles. Not accident based principles for black spot identification are thus not used.

Four (or five, if Norway is included) countries use combined identification methods. Not model based methods (accident number or rate) are included in the black spot identification in all these five countries. This is typically used to secure a minimum number of accidents on the identified sites. Two of the five countries combine the not model based principle with an accident specific method, where there has to be a threshold value of similar accident types on the sites before the sites are considered as a black spot. In the other three countries the not model based method are combined with a model based method, where the recorded or local expected number is compared with the normal number for similar sites.

Among the three remaining countries not model based method are used in two countries (Flanders and Hungary), while both model and not model based methods are used independently of each other in the last country (Portugal).

Overall it can be summarized that not model based methods are used independently or combined with other methods in all eight countries, model based methods are used independently or combined with other methods in four countries and finally accident specific methods combined with other methods are used by two countries.

Hence, it is only half of the reviewed countries that include different kinds of model based methods in the black spot identification. Furthermore, it is only one of these countries that use a kind of empirical Bayes method, which from a theoretical point of view must be considered as the best method because random fluctuations and systematic variation are taken into account.

Table 3.3. Overview of identification principles used in selected European countries.

	Principle	Method	Reference
Austria	Combined: – Specific – Not model based	 – Accident type – Accident rate	(Austrian Guideline Code for Planning, Construction and Maintenance of roads 2002)
Denmark	Combined: – Model based – Not model based	 – Traditional model (Poisson) – Accident number	(Vistisen 2002, Overgaard Madsen 2005, Sørensen 2006)
Flanders	– Not model based	– Accident number	(Geurts 2006)
Germany	Combined: – Specific – not model based	 – Accident type – Accident number	(German Road and Transportation Research Association 2006)
Hungary	– Not model based	– Accident number-rate	(Elvik 2007)
Norway	– Not model based (followed by a model based ranking)	– Accident number	(Ragnøy et al. 2002, Statens vegvesen 2006)
Portugal	2 different principles: – Not model based – Model based	 – Accident number – Modern model (empirical Bayes)	Portuguese Highways Agency described in Elvik (2007)
Switzerland	Combined: – Model based – Not model based	 – Traditional model – Accident number	The Swiss Association of Road and Transport Experts described in Elvik (2007)

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3.2.4 Recommendation

By the previous review of BSM in different countries, it is documented that several countries are far from the state-of-the-art approach for identifying black spots. It is utopia to think that the state-of-the-art approach can be implemented immediately in all these countries because it will demand a lot of data collection and inter-connection as well as recourses for development of a "national" empirical Bayes method.

Nevertheless, there are ways to get closer to the state-of-the-art approach if the resources and the data quality and quantity are limited. Some recommendations are given below.

These recommendations will be based on the previously described identification principles and methods including their advantages and disadvantages and the described stage of the identification of black spots in the reviewed countries. In addition, the recommendations are inspired by Overgaard Madsen (2005a), who in great detail has discussed the quality of different more practical identification methods and ranked these with regard to their ability to make reliable black spot identification.

The recommendations for best practice guidelines are divided into so called second respectively third best method ranked in relation to the state-of-the-art approach, which is considered as the best method. What methods that can be considered relevant for each concerned country or road administration depend on resources, data and current stage for the BSM.

General recommendation: Accident based and not specific method

Despite problems with deficient accident databases in most European countries the recommendation is that, the BSM should be accident based, at least to some extent. This is recommended of several reasons:

- Development and use of best practice guidelines has previously been characterized as a stepwise process moving towards the state-of-the-art approach at the top of the ladder, and therefore it has to have the same character as the state-of-the-art approach to the maximum practicable extent.
- Satisfactory methods for not accident based identification have not yet been developed and implemented and accidents must hence still be considered as the best indicator for black spots.
- Despite Hummer et al. (2003) saying the opposite, we expect that the quality and quantity of accident databases will improve in the future. A central argument for this is that more and more countries or regions have or plan to supplement the police recorded accidents with hospital recorded traffic accidents.
- The problem with too “few” accidents to make a reliable black spot identification is only present in the most safe countries that have identified and improved black spots for decades, while it can be argued that there still are “plenty” of accidents in the less safe countries and regions to make a reliable black spot identification possible (in spite of low level of reporting in the official accident databases).

At the same time accident specific methods are not recommended. The reasons for that are the following:

- Best practice guidelines are characterized as a stepwise process moving towards the state-of-the-art approach, and therefore it has to have the same character as the state-of-the-art approach (the same argument as the argument for the use of accident based method).
- A significantly high number of accidents at a location compared to similar locations must indicate that there are local risk factors and it is thus unnecessary to limit the identification to road related accidents to find sites with road related traffic safety problems (Thorson 1970).

– An accident specific identification will demand a relative comprehensive identification stage. For instance it is necessary to analyse what accidents have road related risk factors. However, the normal procedure and philosophy for BSM is that the identification should demand relatively little resources (Thorson 1970, Hauer et al. 2002).

Second best method: Traditional, simple model based method

Model based methods are the best to make reliable identification of sites with local risk factors related to road design and traffic control, because systematic variation and partially random fluctuation are taken into consideration.

The second best method after the state-of-the-art approach is thus a simpler and traditional model based method. Table 3.4 summarizes characteristics of the traditional model based method in comparison with the state-of-the-art approach.

Table 3.4. Characteristics of the second best method: Traditional, simple model based method in comparison with the best method: State-of-the-art approach with regard to identification principle, quality (criteria for evaluation), demand for data and resources for development and implementation.

Principle	– Ratio or absolute difference between the registered and general expected number of accidents instead of ratio or absolute difference between the local expected and general expected number of accidents
Quality	– Systematic variation in the number of accidents due to general road design and traffic volume are taken into account – Random fluctuation due to the stochastic nature of accidents is only partly taken into account – Sites with local risk factors related to road design and traffic control are identified (if the problem of random fluctuation are ignored)
Data	– Same data demands as state-of-the-art approach (Comprehensive and connected accident, road and traffic data)
Resources	– Probably less resources (time, money, personnel and professional expertise) for development, implementation and application than the state-of-the-art approach

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The main difference between the traditional model based method and the empirical Bayes method is that the registered number of accidents and not the local expected number is used to compare with the general expected number of accidents. This means that the general road design and traffic (systematic variation) are taken into account, so sites with local risk factors related to road design and traffic control are identified, which match the overall philosophy for BSM. However, the stochastic nature of the accidents is only partly taken into account. Compared with the state-of-the-art approach there is thus an increased risk of making errors of the type false positive and false negative in the identification.

To make a traditional model based identification the same data about accidents, road design and traffic volume are needed, but the resources for development and use of the method are apparently smaller, because the calculations are less comprehensive and advanced.

In Elvik (2007), some general recommendations for making an accident model are described. In addition, inspiration can be obtained from countries that already are making traditional model based black spot identification as for example Denmark.

As stated before the traditional model based method can also and often is combined or supplemented with the use of not model based method to ensure a minimum of accidents on the identified locations. How many accidents there should be on the location depend on general traffic safety level and resources for BSM. In Denmark, a supplementary criterion on minimum four or five accidents during five years is used.

Finally it should be noted that the state-of-the-art approach is preferable from a theoretical point of view, but some studies have indicated that there in practise only is limited difference between simple and advanced accident models with regard to locations identified (Maycock and Hall 1984, Kulmala 1995, Peltola 2000).

Third best method: Category based method

The simple version and a precursor for the model based identification method is the category based method and this is therefore classified as the third best method. Some characteristics for the category based method are summarized in table 3.5.

Table 3.5. Characteristics of the third best method: Category based method in comparison with the best method: State-of-the-art approach with regard to identification principle, quality (criteria for evaluation), demand for data and resources for development and implementation.

Principle	– Ratio or absolute difference between the registered and average number of accidents instead of ratio or absolute difference between the local expected and general expected number of accidents
Quality	– Systematic variation in the number of accidents due to general road design and traffic volume are taken into account – Random fluctuation due to the stochastic nature of accidents is not taken into account – Sites with local risk factors related to road design and traffic control are identified (if the problem of random fluctuation is ignored)
Data	– Less data demands with regard to traffic volume and the same data demands with regard to road data as the state-of-the-art approach
Resources	– Less resources (time, money, personnel and professional expertise) for development, implementation and application than the state-of-the-art approach

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The main difference between the model and category based method is that the registered number of accidents is compared to the general expected respectively the average number of accidents for similar locations. The average number of accidents is the average for a traffic volume interval, while the general expected number is the number for a specific traffic volume.

This means that the general road design and traffic (systematic variation) are taken into account, while the stochastic nature of the accidents only can be taken very partly into account by the use of longer identification periods.

Less precise data about the traffic volume are needed, because it is not necessary to know the exact traffic volume as the volume is divided into different intervals. However, information about the road design is still necessary, because it is used to divide the road network into different road categories.

A last very important point is that fewer resources, especially for developing the method, are needed because no regression analyses have to be made. This also means that more people can make the analysis and immediately understand the results.

In Sørensen (2006, 2006a) a very detailed description is given of what a category analysis is and how it is made as well as how a category based identification can be made.

Fourth best method: Frequency-rate method

The fourth best method from a theoretical point of view, is a not model based frequency-rate method. Neither systematic variation nor random fluctuations are here taken adequately into account, so this method will normally not be recommendable. However, in a few cases, it can be necessary to use this method in a transition period until necessary road and traffic data are collected and connected with the accident data permitting as a minimum the development and use of the category based identification method.

3.3 Identification criteria

In the previous, it is recommended that black spots are identified by a more or less advanced model based method. Model based identification methods allow for the use of different overall identification criteria. What identification criteria should be used according to the recommended best practice identification method is described in the following.

3.3.1 Different identification criteria

In total, many different identification criteria exist (Sørensen 2006), but within the recommended model based identification method primarily two different types of criteria are relevant. It is the so called ratio criterion and absolute difference criterion also named savings potential.

The ratio criterion

The first criterion is the ratio criterion. Black spots are identified as sites with the highest ratio between the registered or local expected number of accidents and the general expected, average, minimal or target number of accidents. The identification is thus done by the following generalized formula:

$$\text{Ratio} = \frac{\text{Registered or local expected number of accidents}}{\text{General expected, average, minimal or target number of accidents}}$$

The absolute difference criterion

The second criterion is the absolute difference criterion also named as the savings potential criterion. Black spots are identified as sites with the highest absolute difference (not ratio) between the registered or local expected number of accidents and the general expected, average, minimal or target number of accidents. The identification is thus done by the following generalized formula:

Absolute difference = (Registered or expected number of accidents) – (general expected, average, minimal or target number of accidents)

What parameters one should use in the two criteria depend of the quality of the accident model used. In simple models as recommended as best practice guidelines it is the registered number of accidents which is compared with the general expected number of accidents (traditional model based identification) or the average number of accidents (category based identification), while it is the local expected number of accidents which is compared with the general expected number of accidents in the empirical Bayes identification method.

Besides comparison with the expected number of accidents a comparison can be made with the so called minimal number of accidents, with is the number of accidents on different locations with best practice design. The logic for this is that a minimal number of accidents are to aim at, and therefore it also has to be the basis for the identification. Alternatively, a target number of accidents for different types of location can be used.

Severity

For the state-of-the-art approach for BSM, it is concluded that accident severity should not be a part of the identification itself. It is simpler to exclude accident severity in the identification than include it, so this recommendation will also stand for the best practice guidelines for BSM.

It is however also recommended that accident severity should be included in a preliminary analysis of the accidents at black spots for ranking them for more detailed engineering analysis. How to include accident severity is discussed under NSM. It is here recommended that severity is included by a weighting principle where fatal accidents and accidents with seriously injuries are weighted more than accidents with minor injuries and accidents with only property damage, if recorded. See chapter 4.3 for more details about how to weight the accident.

3.3.2 Advantages and disadvantages

Advantages and disadvantages of the two overall identification criteria are summarized in table 3.6 and clarified in the following.

The ratio criterion

The primary advantage by the ratio criterion is that the identification is focused on locations, which have the largest probability to be true black spots, because they have the largest relative difference between registered and general expected number of accidents. You could say that some attention to random fluctuation is made.

The disadvantage is on the other hand that the largest relative difference not necessarily ensures focus on the location where absolute largest reduction in the number of accidents can be achieved.

The absolute difference criterion

The use of this criterion ensures focus on locations, which have the largest saving potential in the number of accidents if the number after improvement of the identified locations is reduced to the general expected, average or minimal number of accidents for similar types of locations. Assuming that locations identified by this criterion not being more expensive to treat than other locations this criterion will also ensure largest cost-effectiveness.

The disadvantage compared with the previous criterion is that only limited attention to random fluctuations is made.

Table 3.6. Advantages and disadvantages for the two relevant identification criterions.

	Advantages	Disadvantages
Ratio	– Focus on most problematic locations – Focus on local risk factors	– Partly retrospective nature – Not necessarily greatest reduction in the number of accidents
Absolute different	– Greatest reduction in the number of accidents – Probably most cost-effective – Focus on local risk factors	– Retrospective nature – No or limited attention to random fluctuations

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3.3.3 The use of different principles

Only half of the eight reviewed countries include more or less advanced model based methods in the black spot identification (Denmark, Norway, Portugal and Switzerland).

The ratio criterion is used in Denmark and Switzerland, while the absolute difference criterion is used in Norway and Portugal. In addition, it should be noted that the absolute difference criterion also is used in Germany in the NSM and suggested used in Denmark by Sørensen (2006).

3.3.4 Recommendation

Based on the previous review it is recommended that the absolute difference criterion is used in relation with the traditional model based and category based method for identification of black spots.

The argument for this is that the criterion ensures focus on the locations with the largest potential to "save" most accidents and probably ensures most traffic safety for the money used for BSM.

It is not possible for the more simple model based identification methods to make a complete and clearly attention to control for random fluctuations as in the empirical Bayes method. Therefore, the ratio criterion is more relevant for the modern model based identification methods, while the absolute difference criterion is considered as the most relevant for the more simple methods.

However, this means that there is a risk to make errors of the type false positive and false negative in the identification. To make up for that it is very important that the analysis stage evaluate if the identified locations are true black spots or not. This will eliminate the problem with false positives, but not the problem with false negatives.

As stated under the state-of-the-art approach the absolute difference criterion can, for the purpose of accident analysis, be supplemented by a criterion regarding the registered number of accidents on the identified sites.

Finally, it should be noted that absolute difference or savings potential is not necessarily the same as the actual number saved if proposed improvements are implemented. The savings will often be larger because the sites after improvement typically will be better than the average or what is generally expected for similar sites.

Specific identification criterion

Given that the absolute difference criterion is used as identification criterion, it has to be considered how big the absolute difference should be, before a concerned location is identified as a black spot.

What concrete criterion that should be used depends on general policy for the future number of accidents and what is regarded as an acceptable accident level, staff and economic resources, accident data and desired reliability of the identification (O'Flaherty 1967, Thorson 1970, Joly et al. 1992). This means that you cannot make one common criterion, which has validity for all the countries and road administrations in Europe. However, it is possible to conduct some more general discussions and recommendations.

The criterion for identification can be divided in the following two principles (Sørensen 2006):

- A predefined number that the savings potential has to exceed
- A certain percentage of the road network with the largest savings potential

What principle should be used depends on how the BSM is organized and divided between different road administrations.

A certain percentage of the road network with the largest savings potential can be used at national and large regional black spot identifications as is for example done in Norway in the NSM (Ragnøy et al. 2002).

If the black spot identification is done independently for several smaller regions, the predefined number is recommended. The reason for that is (Sørensen 2006):

- If the same percentage is used in all regions you risk that the most safe regions mostly identify (and maybe treat) false black spots.
- The definition of black spots will vary from region to region. This means that it will be complicated to get a common understanding for the work.

3.4 Accident analysis

State-of-the-art approaches for accident analysis are in detail described in Elvik (2006, 2007). Here it is also described that use of the recommended approach is more demanding than more traditional approaches for accident analysis.

As recommended for the identification stage it is necessary to have some best practice guidelines for the analysis stage. These are described in the following.

3.4.1 Research, development and testing

Research, development and testing of new and better methods in BSM and NSM have focused on the identification stage and evaluation stage. With regard to the identification stage, this means that methods have continuously been developed, improved, compared and evaluated. Therefore, we know a lot about the advantages and disadvantages of the different methods and what method is the best, second best and third best.

It is a different case with the analysis stage. For this stage research, development and testing of new and better methods has only been done to a minor extent. Thus, it is more or less the same method that has been used for the last over 40 years, and the work is to a large extent based on tradition, procedures and experience in each individual road authority. This means that further research, development and testing is needed better to be able to distinguish between false positives and true positives and secondly to be better able to identify accident and injury risk (Sayed et al. 1995, Hauer 1996, Sørensen 2006, 2006a, 2007, Elvik 2006, 2007). It also means that the best practice guidelines described in the following are very inspired by the more traditional approaches. The traditional approaches have however been combined with aspects of the state-of-the-art approach.

3.4.2 Objective of the analysis stage

In the analysis stage, the designated and presumed black spots and hazardous road sections have to be analyzed in order to firstly ascertain whether they are true or false hazardous road locations, and, if so, secondly assess why they have become black or hazardous.

With reference to the first objective, it has to be noted that it empirically can be questioned if all people working with BSM and NSM are conscious of this objective. This means that in some cases false black spots are treated, which give an ineffective traffic safe work (Elvik 2006, Sørensen 2006, 2007). The objective is for example not mentioned in either some central international textbooks and manuals as (Khisty 1990, Ogden 1996 and PIARC Technical Committee on Road Safety 2003) or some central more national manuals as (Harwood et al. 2002a, Statens vegvesen 2006 and Højgaard et al. 2006). However, the objective is described in some few textbooks as (Thorson 1970, O'Flaherty 1997 and Elvik 2004).

This objective is very important especially – as described in chapter 2.4 – when best practice guidelines and not the state-of-the-art approach is used in the identification stage. It is therefore recommended that the question about true and false is raised for every location analysed. You can say that it is better to make the assessment by use of the second or third best method than completely omit to do it.

About the second objective, it should be clarified that it concerns both identification of accident factors (why the accident happened) and injury factors (why the accident became serious). The last part is especially central if the road safety policy focuses on the most serious accidents.

This is specified because it has essential meaning for the following treatment stage. This stage can thus include elimination and/or minimization of both accident and injury factors, see the Haddon-Matrix (see table 3.7) which specifies nine different approaches to traffic safety work (Haddon 1970). BSM and NSM can include both crash prevention and loss reduction, and this is important to remember also in the analysing stage.

Table 3.7. The Haddon-Matrix, which specifies nine different approaches to traffic safety work (Haddon 1970).

	User	Vehicle	Road	Method
Pre-crash phase	1a	1b	1c	Crash prevention
Crash phase	2a	2b	2c	Loss reduction
Post-crash phase	3a	3b	3c	Damage control
Method	Not site specific		Site specific	

3.4.3 Recommendation

Overall, the analysis methods can be divided into office and field analyses with focus on accidents, the road and its surroundings, the traffic or a combination of the three elements (Sørensen 2007). Se table 3.8.

Table 3.8. Overall site specific analysis methods divided into office and field analyses.

	Office analyses	Field analyses
Accident	– General/statistical accident analysis – Specific/detailed accident analysis – Collision diagram	–
Road	– Condition diagram – Curve analysis	– Inspection – Observation
Traffic	– Traffic analysis (e.g. speed)	– Traffic conflicts
Combination	– Blinded-match-pair-comparison (state-of-the-art)	–

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When conducting analysis and inspection of identified (presumed) black spots and hazardous road sections it is on the one hand important to make detailed analyses of the sites for example by use of all the different analysis approaches. On the other hand it is also important that the analysis stage is not too resource demanding, because the road authorities do not have unlimited resources.

Among the different analysis methods the general accident analysis, the collision diagram, the road inspection as well as relevant road and traffic analyses are considered as the most relevant. It is therefore recommended that these methods are used in the analysis stage. In the following, it is specified why and how these methods should be used.

General accident analysis

Among all the reviewed textbooks and manuals, it is a common recommendation that the analysis stage should include a general or statistical accident analysis (Khisty 1990, Ogden 1996, O'Flaherty 1997, Harwood et al. 2002a, PIARC

Technical Committee on Road Safety 2003, Statens vegvesen 2006 and Sørensen 2006).

This analysis is particularly important for sites with many accidents where it is difficult to recognize the accident pattern.

In the general accident analysis, information about the registered accidents should be arranged in a way that makes it easy to identify different accident patterns. Depending on quality and quantity of accident data, the data can be described in tables or histograms.

The philosophy underlying the analysis is that frequent accident situations and circumstances indicate problems and similar accidents will probably occur again if nothing is done.

Table 3.9 summarizes what overall circumstances should be included in the general accident analysis. To get an increased focus on severity the analysis should be undertaken for both accidents and injured road users.

Table 3.9. Circumstances, which should be included in the accident analysis.

Recorded accidents: Number of accidents distributed according to personal injury and damage to property, as well as personal injury distributed according to persons killed, seriously injured and persons with minor injuries
Variation over time: Accident distribution during the day, week, year and accident period
Type of accident: Accident distribution on situation and combination of parties involved
Site: Accident distribution on by roadside development, layout of road and speed limit
Circumstances: Accident distribution by weather, lighting conditions, visibility, illumination, state of the roads, accident in school zones, road works, accidents due to drunk driving, obstacles on or outside the roadway and speed estimate
Means of transport: Accident distribution by element and vehicle
Characterization of persons: Accident distribution by blood alcohol content, gender, age, nationality, illness and use of safety equipment of the parties involved

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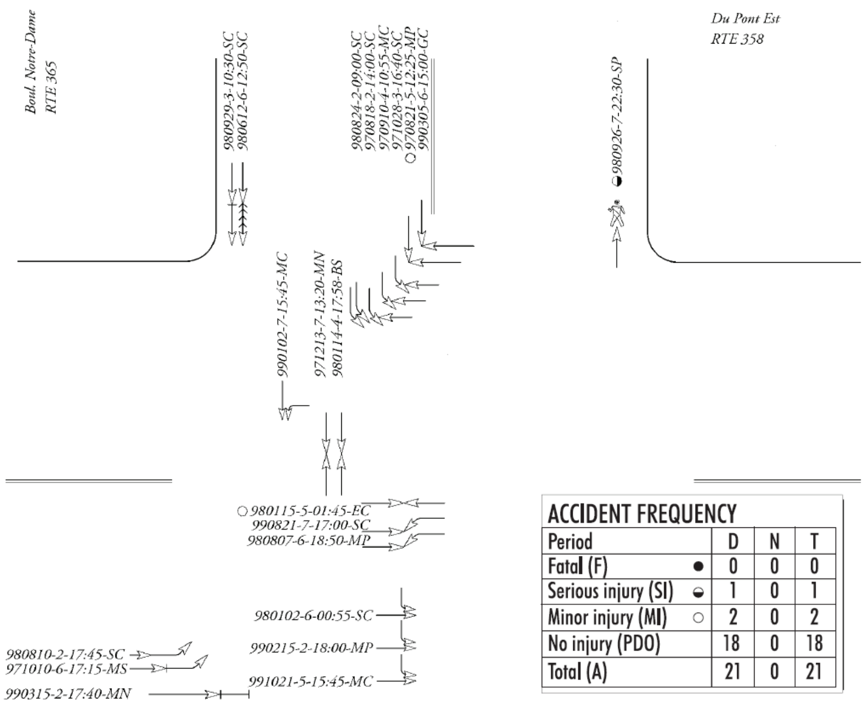
Collision diagram

Drawing and analyses of collision diagrams has for many years been a very important analysis tool, and it is still considered as such.

A collision diagram is a graphic representation that displays all the registered accidents at the concerned site, where different parameters of the accidents can be interpreted. This gives a good overview of what accident situations that are frequent and over-represented at the location. This offer an essential contribution to the identification of traffic safety problems and the assessment of whether the location is a true or false black spot. In for example Ogden (1996), O'Flaherty (1997) and PIARC Technical Committee on Road Safety (2003) you can see examples of how collision diagrams can be drawn. The example from PIARC Technical Committee on Road Safety (2003) is shown in figure 3.1.



ACCIDENT FREQUENCY				
Period		D	N	T
Fatal (F)	●	0	0	0
Serious injury (SI)	◒	1	0	1
Minor injury (MI)	○	2	0	2
No injury (PDO)		18	0	18
Total (A)		21	0	21

Figure 3.1. An example on a collision diagram (PIARC Technical Committee on Road Safety 2003).

Drawing of collision diagrams is a resource demanding work, because it normally has to be done manually. To eliminate this problem, pc-based programs for drawing and partly analyse collision diagrams have been developed in for example USA (Harwood et al. 2002a). Such programs can advantageously be used in the analysis stage. Note however that some people working with accident analyses think that the drawing itself is an important part of the analysis (Sørensen 2006).

Normal accident pattern

To identify local risk factors it is not enough to identify possible accident patterns because these can in principle be consistent with the normal pattern for the given type of location. It is hence recommended to compare both the general analysis and the information from the collision diagram with the normal pattern of accidents for the given type of location (Harwood et al. 2002a, PIARC Technical Committee on Road Safety 2003, Overgaard Madsen and Lahrmann 2003, Statens vegvesen 2006 and Sørensen 2007). An overrepresentation of a given accident pattern will indicate that there is a safety problem.

In Elvik (2007), it is suggested that black spots should be compared with a safe location with the same characteristics with regard to traffic and road design. This means that you for every black spot analysed have to find one location, which is very similar to the given black spot. This is very resource demanding. As a replacement, it is here recommended that the accidents are compared to a normal pattern, because this is considered less resource demanding. However, this comparison requires that the normal accident pattern is known and that the given black spot belongs to the same category as that used in the calculation of the normal accident pattern.

It is recommended that the categorization of sites and the calculation of the normal accident pattern for these sites should be done by a central (road) authority for whole the public road system and made available for all on for example the internet.

A given overrepresentation can be a result of chance. In Elvik (2007), it is thus recommended that binomial tests are applied in the comparison to determine the probability that a dominant pattern of accidents is the result of chance only. This is a relatively difficult statistical examination and will therefore not be a part of the best practice guidelines. However it is very important that the people working with accident analysis are aware of the opportunity and at least make a qualitative and subjective assessment of the possibility.

Road inspection

In spite of the fact that it is very resource demanding it is recommending that the in office analyses are supplemented by a road inspection. There are several reasons for that:

- It is important to confirm or invalidate the hypotheses from the previous accident analysis to increase the reliability of the analysis stage and to assess whether the given site is a true or false black spot.
- It is important to identify problems that do not appear from the accident analysis and hence give the analysis stage a more prospective perspective.
- It is important to make it independent of a typically low and skew level of reporting in the official accident statistics.

The road inspection should be made relatively formalized to ensure objectivity, completeness, reproducibility, comparability and good opportunity for further treatment and documentation. To ensure that the use of checklist is recommended. A lot of checklists have been development for example in relation with road safety audit/inspection of exiting road sections (RSI) and it is recommend that one of the already existing checklists is used, see for example Ogden (1996), Gaardbo and Schelling (1997), PIARC Technical Committee on Road Safety (2003), Statens vegvesen (2006a) and Sørensen (2006).

Traffic and road analyses

The accident analysis and the survey should be supplemented by traffic counts for the primary road and relevant side roads, speed measurements and possibly some relevant road analyses according to specific themes. It could for example be measurement of road friction.

True or false black spots

As described already it is very important that the analysis stage tries 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 in the identification period. This assessment is always important, but it is especially important if the state-of-the-art approach for identification is not used.

For assessing, whether identified sites are true black spots there are four sources of information, i.e. the result of the identification, the results of the accident analysis (general analysis and collision diagram), the results of the road inspection and finally the result of the traffic and road analyses.

Based on this information it is recommended that the assessment is done by comparing the results from the accident analyses and the road inspection. The accident analysis is used to generate hypotheses about risk factors contributing to accidents, while the road inspection is used to test these hypotheses. Conformity between the results from these analyses will indicate that the given site is a true black spot.

A problem with this approach is that the analyst's expectations from the accident analysis can influence and bias findings in the road inspection (Elvik 2006). To avoid this problem the two analyses can be done by two independent engineers like it is done in the BSM in Switzerland. The procedure is described in Elvik (2007).

In addition, the comparison of the results from the accident analysis and the normal pattern of accidents for the given type of location will indicate whether the given site is a true black spot.

As earlier described there is a risk that the assessment will not always be correct, but the point is that it is better to make an active and relatively systematic assessment with a risk to make some mistakes than refrain from doing the assessment because the demands for doing the state-of-the-art approaches can not be satisfied.

In this context it is recommend that the assessment is recorded in the report of the analysis, because it ensures an active assessment.

3.4.4 The treatment stage

Provided that the identified sites are found to be true black spots, the analysis stage is followed by a treatment stage. This stage comprises a presentation and prior assessment of proposals for the minimization or elimination of the problems found. This stage is not treated in this project (cf. figure 1.1).

However, it should be noted that if there is a very clear accident pattern, and strong evidence for risk factors contributing to this pattern, there is usually little doubt about what the most effective treatment will be (Elvik 2006). In addition a lot of so called troubleshooting tables have been developed, see for example Ogden (1996), PIARC Technical Committee on Road Safety (2003) and Elvik and Vaa (2004).

The prior assessment should include a socio-economic assessment of the proposed solutions and as minimum a qualitative consideration of whether the measures will have a positive, neutral or negative effect on mobility, accessibility, security, aesthetics and noise. The assessment can be made by use of Elvik and Vaa (2004).

3.5 Evaluation of the black spot treatment

According to the state-of-the-art approach to BSM, the post evaluation of the effects of the black spot treatment should employ the empirical Bayes before-and-after design. This is recommended because it offers the opportunity to control for the following confounding factors:

1. Regression-to-the-mean
2. Local changes in traffic volume
3. Long-term trends in the number of accidents

If accident migration is an issue, an attempt to control for this should also be made. Failure to control for all these known confounding factors may result in grossly erroneous estimates of the effects of black spot treatment and thus give misleading information about the work.

However use of the method requires good data and relatively comprehensive statistical analyses, and like the other stages of the BSM it can hence not always be done like described in the state-of-the-art approach. In addition, the state-of-the art approach for evaluation can only be applied if the empirical Bayes method is used in the identification stage, which is still rarely the case.

Use of the state-of-the-art is not feasible under the following circumstances (Elvik 2006a):

1. A meaningful comparison group does not exist
2. A meaningful basis for assessing regression-to-the-mean does not exist
3. Data on traffic exposure do not exist

3.5.1 Criteria for doing the evaluation

The data limitations mentioned above are often found. However, evaluations are demanded anyway and the question then is what to do. In principle, there are two options (Elvik 2006a):

1. Do the evaluation by use of the second or third best method (the best practice guidelines) like it is recommend for the other stages of the work
2. Refrain from doing the evaluation at all

The first opportunity is recommended in the other stages of the BSM based on the philosophy that it is better to do something rather then refrain from doing anything, because the worst that can happen is that the work does not have any effect. It is assumed that people working with traffic safety know so much about the subject that measures that will increase the number and severity of accidents are not used.

The evaluation stage of the BSM differs in a way from the previous stages because the traffic safety work is done, and the objective of this stage is to get further knowledge about the effects of the measures. In contrast to the previous stages, it is not considered recommendable just to do something because no knowledge must be considered as better than to have wrong knowledge. In a situation where the data and resources are very limited and near to impossible to obtain it is thus recommendable that the evaluation studies are not done.

How "bad" evaluation studies we can tolerate has been discussed by Elvik (2006a). Nine criteria to assess the given evaluation have been formulated. These are:

1. *Statistical relationship (3):* A good evaluation should be able to detect effect of a size that has practical interest.
2. *Strong relationship (1):* A strong effect is more likely to be causal than a weak effect.
3. *Internally consistent relationship (1):* A good evaluation should be able to measure the internal consistency of an effect.
4. *Clarity of causal direction (5):* A good evaluation should be able to make an unambiguous determination of the causal direction.
5. *Control for confounding (30):* A good evaluation should control for all confounding factors.
6. *Analysis of causal mechanism (5):* A good evaluation should identify the mechanism that produces the effect.
7. *Support by theory or other studies (5):* A good evaluation should be based on theory or results from other studies.
8. *Dose-response relationship (5):* A good evaluation should show any Dose-response relationship.
9. *Specificity of effect (5):* A good evaluation should show specificity of effect.

The different criteria are not equally important and different weights/points have been assigned to the criteria to reflect their importance. How many points fulfilment of a criterion may give are specified in parenthesis.

It is recommended that these criteria are evaluated when making an evaluation study where the state-of-the-art approach is not used.

3.5.2 Different traditional evaluation studies

The more traditional and simple evaluation studies can be divided into the following three types (Hauer 1997, Overgaard Madsen 2005a):

1. Naive before-and-after studies
2. Before-and-after studies using a comparison group
3. Evaluation studies based on traditional accident models

The three study designs and their advantages and disadvantages are described in the following and summarized in table 3.10.

Table 3.10. Advantages and disadvantages of the three different designs for evaluation studies (Overgaard Madsen 2005a).

	Advantages	Disadvantages
Naive	– Simple – Easy to understand – Very data non demanding – Accident data is the only data needed	– No control for regression-to-the-mean – No control for long-term trends in accident number – No control for local changes in traffic volume – No control for other changes at the location – Not possible to isolate the effect of more measures
Comparison group	– Control for trends in number of accidents and local changes – Relatively simple – Relatively easy to understand – Relatively data undemanding	– No or limited control for regression-to-the-mean – Wrong estimate of effect if not all parameters with significant influence on the number of accidents are identified and the same for the location evaluated and the reference location – Identifying of similar comparison location is necessary – Relatively detailed data for the road system is necessary to find a good comparison location
Model	– Control for regression-to-the-mean – Control for long-term trends in the number of accidents – Control for local changes in traffic volume – Control for other general changes at the location	– Can only be used to evaluate general changes – Can not be used to evaluate parameters that not are included in the model – Can only be used to evaluate the general expected number of accidents and not the local expected number – Necessary to have or develop an accident model

Naive before-and-after studies

In the naive before-and-after study, the average registered number of accidents before and after the measure is implemented are directly compared. It is assumed that the annually average number of accidents after the measure is implemented provides an estimate of the local expected number of accidents on the location after the treatment. At the same time, it is assumed that the annual average number of accidents before the measure was implemented provides an estimate of the local expected number of accidents on the location if the measure was not implemented (Overgaard Madsen 2005a).

The advantages of this approach are that it is simple and easy to understand and the demands for data are very limited, because the only data needed is accident data from the before and after period. However it is suffering from some severe deficiencies, because it controls neither for regression-to-the-mean, long-term trends in the number accidents nor local changes in traffic volume or other changes at the location.

Before-and-after studies using a comparison group

In this approach, the registered number of accidents on the location with the implemented measure is compared with a comparison location where the measures are not implemented.

The assumption of the approach is that the annual average number of accidents after the measure is implemented provides an estimate of the local expected number of accidents on the location with the measure. The annual average number of accidents in the after period on the comparison location provides an estimate of the local expected number of accidents on the location under evaluation given that the measure had not been implemented (Overgaard Madsen 2005a).

The advantage of this approach is that it controls for long-term trends in the number of accidents and local changes in the traffic volume and other general changes. In addition it is relatively simple and easy to understand, however not as simple as the previous approach.

The disadvantage is that it provides no or limited control for regression-to-the-mean. Another disadvantage is that there is a risk of making a wrong estimate of effect if not all parameters with significant influence on the number of accidents are identified and are the same for the location evaluated and the location used for control. Finally, it is necessary to identify one or more locations, which are very similar to the location evaluated, which means that it is necessary to have detailed data for the road system.

Evaluation studies based on traditional accident models

This approach consists of a comparison of the model estimated number of accidents for the given location with and without the measure implemented. This means that the expected number of accidents with the measure is estimated by setting the independent variables in the accident model in accordance with the characteristics of the location in question. Likewise, the expected number of accidents without the measure is estimated by setting the independent variables in the accident model in accordance with the characteristics for the location without the measure (Overgaard Madsen 2005a).

The advantage is that the method controls for regression-to-the-mean, long-term trends in the number of accidents and local changes at the location. However, the disadvantage is that the approach only can be used to evaluate general changes. It cannot be used to evaluate parameters not included in the model. This also means that it only can be used to evaluate the general expected number of accidents and not the local expected number. Finally it is necessary to have or develop an accident model, which can be very resource demanding.

3.5.3 Recommendation

None of the three approaches is directly recommendable as best practice guidelines for evaluation of the effects of the black spot treatment, because they all have some essential deficiencies.

Instead, it is recommend to use a kind of combination of especially the first two approaches to try to compensate for the disadvantages of the different methods.

More specifically, it is recommended to make a before-after-study, which controls for long-term trends in the number of accidents, local changes in traffic volume and regression-to-the-mean by use of the correction factors C_{trend}, $C_{traffic}$ and C_{reg} (Overgaard Madsen 2005a).

By use of the correction factor C_{trend} you correct for the influence of long-term trends in the number of accidents as a result of more safe vehicles, traffic safety campaigns, better road user etc. The factor is estimated on basis of the trend in the number of accidents on some comparison locations where the given measure have not been implemented.

The factor $C_{traffic}$ corrects for the influence of local changes in traffic volume. The factor can be estimated by use of traditional accident models if such are available. However, it should be noted that the correction only should include changes that have nothing to do with the given measure (Amundsen and Elvik 2004).

The last factor C_{reg} controls for the influence of regression-to-the-mean. However, this cannot be estimated by use of simple accident history. Instead, it is suggested that it is decided arbitrarily. By experience, the factor is assumed to be around 0,7-0,8 for black spot work in Denmark (Greibe and Hemdorft 2001). It should be noted that this is a very simple assumption, because the regression-to-the-mean will vary a lot from location to location, and it should thus be assessed individually for each location (Hauer 1997, 2001, Vistisen 2002).

In overall terms, it is suggested that the effects of the black spot treatment are estimated by use of the following formula (Overgaard Madsen 2005a):

$$\text{Effect} = \frac{(\text{Average number of accidents, after})}{(\text{Average number of accidents, before}) \cdot C_{trend} \cdot C_{traffic} \cdot C_{reg}}$$

Despite the use of correction factors, it should be noted that there still is a considerable risk of making a wrong estimate of the effect, but the method is considered as the best practice guideline when the data and the resources for the evaluation study are limited.

3.6 Summary

The key element of best practice guidelines to black spot management (BSM) can be summarized as follows:

1. *Classification of roadway elements:* Black spots should be identified by reference to a clearly defined population of roadway elements as for example sections of a specified length, curves with radius within a certain range, bridges, tunnels, three-leg junctions and four-leg junctions for which the general expected number of accidents can be estimated. Use of a sliding window approach should be avoided. This recommendation is equivalent to the recommended state-of-the-art approach.
2. *Identification principle:* The identification of black spots should rely on an accident based, not accident specific method. The identification should be made by a more or less advanced model based method. Use of not model or category based approaches should be avoided.
3. *Identification criterion:* The absolute difference criterion should be used in conjunction with the traditional model based and category based method for identification of black spots. The criterion should either be a predefined number that the savings potential has to exceed or a certain percentage of the road network with the largest savings potential depending of how BSM is organized and divided between different road administrations.

4. *Accident analysis:* The analysis stage should as a minimum consist of a general accident analysis, drawing and analysis of a collision diagram, a road inspection and relevant supplementary traffic and road analyses. The general accident analysis and the collision diagram should be compared with the normal pattern of traffic accidents for the given type of location. An active and written assessment of whether the presumed black spot is a true black spot or not should be made. This assessment can be based on a comparison of the results from the accident analysis and the road inspection, the comparison with the normal accident pattern and by taking the result from the traffic and road analyses into consideration.
5. *Evaluation of the black spot treatment:* When possible an ex post evaluation of the black spot treatment should be made. To help guide the evaluation nine criteria are described. The evaluation itself should be made as a before-after-study controlling for long-term trends in the number of accidents, local changes in traffic volume and regression-to-the-mean by use of correction factors.

4 Safety analysis of road networks

In chapter 4, the best practice guidelines for safety analysis of road networks or network safety management (NSM) are discussed and recommended. The subjects examined in the previous chapter will also be examined here.

4.1 Classification of roadway elements

A central question in relation to application of NSM in practice is how the road system should be broken down into road sections and how long these sections should be. This will be discussed in the following.

The United States' profiles and peaks algorithm is recommended in Elvik (2007) as state-of-the-art approach for merging short adjacent sections. However, this is primary for use in the analysis stage and is also a relatively complicated method. It is necessary to have a more simple method to be used in the identification stage.

It should also be noted that the following recommendations primarily apply to not motorways, because the motorways differ quite much from the not motorways with regard to both the traffic, the road design and the near surroundings. Typically the motorways will be homogeneous on longer sections than the not motorways, and therefore the section length sometimes advantageously can be longer than the section length recommended in the following.

4.1.1 Constant or variable length

The first question to be asked is if the road sections should have constant or variable length, because this has essential implications for how the road system should be divided.

Constant length means that all the sections have the same length, for example five kilometres. This means that the sections are probably not homogeneous with regard to different relevant traffic and road design characteristics. Variable length means that the road sections have different lengths for example between one and five kilometres. This offers the opportunity to ensure more or less homogeneous sections.

Among the reviewed references the question is discussed by Deacon et al. (1975), Baerwald et al. (1976), Hauer et al. (2002) and Sørensen (2006).

The reason that constant length is suggested in the oldest American references is that accident, traffic and road design data back then did not have the quality that made use of variable length possible. This problem is probably not the case in the European countries at present time.

The problem in using variable length is that short road sections tend to be more often identified than long sections. This can be explained by the fact that short sections in comparison with long sections usually have more traffic and road related "disturbances" through for example intersections and access roads, what can result in more traffic conflicts.

In addition, the problem is that there is a risk that local accidents peaks on long sections not will be identified because they will drown in the average for the whole section, while local maybe random accidents peaks on short sections will result in an identification of the section.

Recommendation

Despite the objections to divide the road system in road sections with variable length, this division is recommended. The reason is that it is necessary to have more or less homogeneous sections to make a model based identification of hazardous road sections, which is recommended in chapter 4.2.

4.1.2 Division of road system

The road sections have to be homogeneous in order to make a model based identification, but what do we mean by homogeneous and how can the road system in practice be divided into homogeneous sections?

Division principles

Division can be done by relying on the following four principles (Sørensen 2006):

1. Section based principle
2. Point based principle
3. Accident based principle
4. Combination

The two first principles can be characterized as road and traffic based division principles. In the *first principle*, the road system is divided into sections that are homogeneous with regard to selected traffic and road design parameters. Normally the selected parameters are some that have significant influence on the number of accidents. Several of the following parameters are normally used (Sørensen 2006):

- Road category, type, status or function
- Cross section including number of lanes, lane width, shoulder and the presence of bicycle lanes and side strips
- Possibility for oncoming traffic
- Speed limit
- Number and design of intersections and access roads
- Alignment including hills and bends
- Roadside buildings
- Traffic including AADT and type

The *second principle* is a point based principle, where intersections, towns or other "points" are used as division points. Intersections will typically be defined as larger intersections to ensure that the sections between will get a minimum length. Larger intersections can be defined by relying on the following principles (Sørensen 2006):

- *Road category or road authority:* Larger intersections are defined as crossings where intersecting roads belongs to a certain road category or road authority.
- *Traffic:* Larger intersections are defined as crossings where intersecting roads have a certain AADT as for example 500 vehicles per day.
- *Design:* Larger intersections are defined as intersections with a certain design or regulation as for example roundabouts or signal control.

Division by use of towns as divisions "points" is primarily relevant if the NSM only focuses on rural areas. Like for intersections it can also be discussed and defined what towns should be used as division points. To define a "division town" following parameters can be used (Sørensen 2006):

- The length of the section in the town
- Number of buildings or houses in the town
- Changing of road design including speed limit
- Road sign with town and the character of the sign

The *third principle* is based on registered accidents in the identification period. The following two principles can be used (Sørensen 2006):

- There has to be a certain number of accidents on each road section. This means that the road system is divided every time a road section has a certain number of accidents for example 10 accidents in five years.
- There has to be a uniform accident concentration on each road section or the character of the accidents has to be the same. This means that the road system is divided when a change in the accident level or character can be identified.

The *fourth principle* is to combine the previously described principles. An obvious opportunity is to combine the first two principles. The two principles differ a lot from each other, but in practice, they will result in more or less the same division and can therefore advantageously be combined. The reason that the two principles approximately give the same result is that major changes in road design and traffic obviously coincide with larger intersections and towns. By using a point based division principle the road design and traffic for the intermediate road section are indirectly taken into account.

To ensure reliable identifications and a potential for reducing the number of accidents the first two principles can be combined with the last principle that each road section has to have a certain number of accidents. Note that the principles about homogeneous road sections and a certain number of registered accidents can be conflicting (Lynam et al. 2003, 2003a).

Advantages and disadvantages

Table 4.1 summarizes the advantages and disadvantages of using different principles to divide the road system into road sections.

Table 4.1. Advantages and disadvantages of the different road division principles.

	Advantages	Disadvantages
Section based principle	– Can be used in a model based identification – More or less the same division for different time periods	– Possibly a non-uniform accident character
Point based principle	– Rational, easy and natural division – Can more or less be used in a model based identification – More or less the same division for different time periods	– Possibly a non-uniform accident character
Accident based principle	– Reliable identification (many accidents) – Uniform accident character	– Can not be used in a model based identification – Possibly a not rational, easy and natural division – Comprehensive division stage – Not the same division for different time periods
Combi-nation	– Takes advantage the advantages of the different methods – Compensate for the disadvantages of the different methods	– Comprehensive division stage – Conflicting demands

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Both the section based and partly the point based divisions principle can be used together with the model based identification method, where it is essential to have homogeneous road sections for the estimation of the general expected number of accidents. A further advantage is that the section based and the point based principles more or less will result in the same division of the road system for different time periods, which make it possible for each road section to compare the accident level for different time periods. Finally, the advantage of the point based principle is that it gives a rational, easy and natural division.

A possible disadvantage of the two road and traffic based division principles is that the registered accidents are not taken into consideration. This means that the accidents can have very different character on the single road sections, and therefore it is very difficult to find a pattern in the analysis stage.

In contrast, the advantages of the accident based division principles are that the accidents are taken into consideration. This means that you already in the division stage start the analysis, because you try to define road sections as sections with a uniform accident pattern. Another advantage it that you avoid that a part of the road section with none or very few accidents entails that another part of the road section with more accidents than expected is not identified because the total number of accidents is lower than the identification criterion. Finally, a division based on the number of accidents will ensure potentials for reducing the number of accidents on every road section.

The disadvantage is that the principle cannot directly be used as basis for a model based identification and the division can also be very comprehensive. Another disadvantage is that the principle probably not will result in the same division of the road system for different time periods. This means that it is not possible to compare the accident level for each road section for different time periods.

Recommendation

For both BSM and NSM a more or less advanced model based identification method is recommended. In such methods it is appropriate to have homogeneous road sections, and thus it is recommended that the road and traffic based division principles are used.

With regard to what parameters that should be homogeneous for the single road section the following can be said:

- The road sections should be homogeneous with regard to the parameters used as independent variable in the accident model or category analysis. This means that the road sections should be homogeneous with regard to parameters that have significant influence on the number of accidents.
- The selection of parameters depends on road and traffic data available, which can differ from country to country.
- Parameters that not are expected to be changed in the solution stage of the NSM as for example road category, number of lanes, alignment and AADT can be used, while parameters that maybe have significant influence on the number of accidents but can be expected to be changed in the solution stage should not be used. This could for example be the number of access roads. This is important to make it possible to distinguish between prerequisites and measures.

To make the division simple and not resource demanding it is recommend that the point based division method is used at first, whereafter it is controlled if the defined road sections are homogeneous.

Accidents should not be used as a supplementary division principle because this principle will often conflict whit the road and traffic based principles. In addition, it is assumed not to be necessary to have this supplementary criterion because focus in NSM is on the road sections with most accidents, whereby a minimum of accidents indirectly is ensured.

4.1.3 Length of road sections

In the previous, it is described and recommend how the road system should be divided into road sections. Because the recommendation has a relatively general character and the road systems vary from country to country, the use of the principle can result in road sections with varied length. In the following it will therefore be discussed what length the road sections should have.

Different sections length used

In table 4.2 the used and recommended section length in 20 different methods from 10 different countries from the period 1964-2007 are summarized.

The section lengths differ very much in the reviewed studies. The shortest section is 0.5 kilometre and the longest is 107 kilometre. The longest section is hence over 200 times longer then the shortest. This shows that there is a clear difference of opinion with regard to what NSM and a hazardous road section is.

Overall, the section lengths can be divided into "short" and "long" section lengths (see table 4.2). The "short" section lengths have typical a minimum length of 0.5-3 kilometres and maximum length of 8-11 kilometres. These road system divisions among others include the Norwegian, the German and the American method for NSM reviewed in Elvik (2007), and the Danish PhD.-project (Sørensen 2006), where the use of different section length in NSM is discussed in great detail.

The "long" section lengths have typically a minimum length of 10-20 kilometres and a maximum length of typically 50-60 kilometres, where the longest section length is more than 100 kilometre. The long sections are used in Denmark, Finland, France and Sweden (Mertner et al. 2006, European Commission 2003, Setra 2003).

Table 4.2. Different section lengths used and recommended in the reviewed references. The lengths are listed by country, and "long" sections are specified with italics. Note that some lengths are specified as intervals or only minimum or maximum length, while others are specified as average. Some lengths are lengths from concrete examples, while others are recommendations.

Country	Roads	Length (km)	Reference
Australia	-	Interval: 1-10	(Ogden 1996)
Canada	*Roads in rural areas*	*Average: 8*	*(Persaud 1990)*
Denmark	Main roads in rural areas	Interval: 2-10	(Sørensen 2006, 2006a)
Denmark	*National roads*	*Interval 27-107*	*(Mertner et al. 2006)*
Denmark	Main roads	Interval: 1-2	(Thorson 1970)
Finland	*Main roads*	*Interval: 20-50*	*(European Commission 2003)*
France	*Main roads in rural areas*	*Interval: 10-60*	*(Setra 2003)*
Germany	Main roads in rural and urban areas	Interval: 0.5-10	(German Road and Transportation Research Association 2003)
Norway	National roads	Interval 0.5-11	(Ragnøy and Elvik 2003)
Scotland	All roads	Up to 8.5	(McGuigan 1982)
Sweden	*Main roads*	*Interval: 10-50*	*(European Commission 2003)*
USA	Minor roads in rural areas	Interval: 1-8	(Hummer et al. 2003)
USA	All roads	Several miles	(Harwood et al. 2002)
USA	-	Interval 1.6-8	(Kononov 2002)
USA	Main roads in rural and urban areas	E.g. 5	(Leur and Sayed 2002)
USA	Main roads in rural and urban areas	Interval: 1-5	(Baerwald et al. 1997)
USA	County roads	E.g. 0.8	(Renshaw and Everett 1980)
USA	Main roads in rural areas	Interval 3-8	(Deacon et al. 1975)
USA	Main roads in rural and urban areas	More than 0.8	(Laughland et al. 1975)
USA	Main roads in rural areas	Interval: 8-16	(May 1964)

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Recommendation

The use of "short" and "long" sections length can be explained in terms of different basic philosophy for the work.

The basic philosophy for the division of the road system into “short” sections is to identify road sections with local road related risk factors. This philosophy builds on the fact that local road related risk factors by definition would vary a lot on a very long section. In addition the philosophy is consistent with the recommendation that the identification should be model or category based.

By contrast, the basic philosophy for the division of the road system into “long” sections is to identify the most problematic general road types and designs, and change them to more safe general road types.

The philosophy for NSM is in this project considered to belong to the first described philosophy and therefore it is recommended that short section lengths are used in the NSM.

More specifically it is recommended that the section length should be in the interval between 2 and 10 kilometres, with an average section length around 5-6 kilometres. This corresponds roughly to the used section length in the Norwegian and the German NSM described in Elvik (2007).

In addition it corresponds to the recommendation from Sørensen (2006), who as one of the very few has examined explicitly, systematically and in great detail what section length that in practice should be used in the NSM. The recommendation has also been tested in specific cases and it has been concluded that the recommendation together with recommended division method is directly suitable for use for approximately 85 % of the road system (Sørensen 2006).

The argument for the minimum length is that the sections are not to be so short that NSM will resemble BSM. Additionally, the road sections must have a certain length in order to make it possible to identify some general problems, and in order for general measures to have an effect. Finally, the sections have to have a certain length to avoid too great sensitivity to each accident (Renshaw and Everett 1980).

The argument for the maximum length is that the sections should not to be too long, as the consequence may be that shorter sub sections presenting problems will not be identified, as the many accidents on these sections “drown” in the overall average for the road section as a whole. Likewise, it may in the analysis stage be difficult to get an overview of very long sections. Long sections may also be very expensive to improve, if the given measures are to be carried out on the total length of the road section.

The interval from 2 to 10 kilometres can be considered as a large interval, but even so, it is recommended to make sure that it is possible to get homogenous sections. The large interval is also recommended, so the method can be adapted to different national conditions with regard to for example geographical conditions, infrastructure and density of intersections and towns. It can for example be assumed that the average section length is shorter in small countries than in large countries. Finally, the large interval offers the opportunity to choose section length depending of measures. Short sections are best suited for expensive measures, while long sections can be used for more inexpensive measures.

A problem in using a large interval is that short sections are compared with long sections. Depending on identification method there is a risk that short sections are identified more often than long sections (Sørensen 2006). This can as earlier described be explained in terms of more traffic and road related “disturbances” on short sections than long sections. In addition local accident peaks on short sections can result in an identification, which is not normally the case on long sections.

On Danish main roads in rural areas, it was found that it is impossible to get all road sections to be 100 % homogeneous, because it will result in too many very short road sections. In the specific case, 55 % of the roads sections were homogeneous, while 40 % only were partly homogeneous. This means that up to 20 % of the road sections differs from the rest of the section. The inhomogeneous parts are typically sub sections with roadside buildings or local speed limits in small intersections (Sørensen 2006).

In addition, it is probably impossible to divide the road system into sections that all have a length between 2 and 10 kilometres. In the Danish case, 15 % of the sections were a bit shorter than 2 kilometres or a bit longer than 10 kilometres.

4.2 Identification principles

The state-of-the-art approach for BSM and NSM with regard to identification principle is the same. The recommendation with regard to best practice guidelines will thus be the same. However, in accordance with new research (Sørensen 2006, 2006a) there are some differences between BSM and NSM that means that the recommendation of use of an accident and model or category based identification of hazardous road sections probably is not suitable for use in all countries. This will be discussed in the following.

4.2.1 Difference between BSM and NSM

The basic philosophy in route action (NSM) is typically to combine the principle in black spot action (BSM) and the principle in mass action. This means that the work both has a reactive nature as BSM because the identification stage is based on the traffic accident history and a proactive nature as mass action because the analysis and improvement stage typically are based on both accidents and general traffic safety problems and standard improvements. You could say that the idea is that remedial improvements on accident locations are spread out on the whole road section and thereby also gets a preventive and prospective nature (Sørensen 2006, 2006a).

This philosophy has been examined for nine hazardous road sections on main roads in rural areas in Denmark, which have been identified by use of accident based methods.

On these road sections, several faults and deficiencies with regard to traffic safety have been identified and different solutions to eliminate or minimize the problems have been proposed and implemented. However an examination of the more than 100 solutions proposed shows that a majority (over 75 %) of these only are of a preventive and prospective nature because they only relate to problems identified during the road inspection. There are thus only few proposed solutions, which both have a remedial and retrospective nature and a preventive and prospective nature through relating to problems identified in both the accident analysis and in the road inspection (Sørensen 2006, 2006a).

This shows that it is very difficult to find local and road section based accident factors on the identified accident road sections according to the accident history. The analysis of the road sections has thereby to a greater degree character of a general road examination with special attention on standard improvements rather than treatment of local and road section based accident factors.

There is no doubt that general road examination and standard improvements contribute to traffic safety improvements, but since the standard improvements in principle are independent of the accident history the ranking may be done in a better way as a non accident based method. The desirability to let the NSM be part of the site-specific traffic safety work like BSM can thus be questioned since the resources might be used in a better way for road examination and standard improvements.

4.2.2 Recommendation

The research in Denmark about the basic philosophy for NSM is based on an examination of nine road sections in one country and the conclusion can therefore not be generalized to be valid to all European countries. Further research is therefore needed. Until such research is done, it is recommended that identification of hazardous roads is done by more or less advanced model based methods like identification of black spots.

4.3 Identification criteria – including severity

Providing that the NSM is accident based it has been recommended that identification of hazardous road sections is done by use of traditional model based or category based method like BSM.

In this context, it is also recommended that the same identification criterion recommended for identification of black spots broadly speaking is used for identification of hazardous road sections. Hazardous road sections should therefore be identified as the sections with the largest safety potential. The safety potential is calculated as the absolute difference between the registered and the general expected or average number of accident, and thus indicates the obtainable reduction of accidents, if the road section in question after treatment reaches a general expected or average level of accidents. Note that this criterion also is recommended by the European Commission (2006).

However, there is one big difference between the identification criterion for BSM and NSM and that is the attention to accident severity. Accident severity should not be a part of the black spot identification itself, whereas it should be an integrated part of the identification of hazardous road sections. The argument is that longer sections with more accidents permit a more meaningful consideration of accident severity than short sections and intersections with fewer accidents.

In the following it is discussed how accident severity could be included systematically and completely as an integrated part of the identification stage of NSM.

4.3.1 Accidents or injured road users

More and more European countries and road administrations focus or injuries especially killed and/or seriously injured (European Commission 2007). On the contrary, methods used for BSM and NSM are normally based on accidents. However, some countries for example Norway, Sweden, Portugal and Belgium have developed methods for identification of black spots or hazardous road sections based on injured road users instead of accidents (Ragnøy et al. 2002, European Commission 2003). This raises the question, whether the identification should be based on injured road users or still should be based on accidents.

Advantages and disadvantages

Table 4.3 summarizes the advantages and disadvantages of using accidents respectively injured road users as basis for the identification stage in NSM.

Table 4.3. Advantages and disadvantages of making an accident respectively an injured road user based identification in the NSM.

	Advantages	Disadvantages
Accidents	– Independent of a randomly high number of injured in one accident – Directly based in the professional and institutional responsibility	– Possibly limited focus on severity – Not direct linked to policy
Injured road users	– Focus on severity – Direct linked to policy	– Can be determined by chance and parameters beyond the road related and site specific traffic safety management

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The advantage of using accidents instead of injured road users is that the identification is not influenced by a randomly high number of injured in one or more accidents. Additionally the identification is based on the professional and institutional responsibility of the road administrations, which is an essential motive for both BSM and NSM. Professional and institutional responsibility refers to the responsibility to recognize and treat sites that are deficient either because of how they were built or because they have deteriorated while in use (Hauer 1996).

The disadvantage can, depending on method, limited focus on severity and hence limited consistency with the policy to focus on the most severe injuries.

The advantage of using injured road users as basis for the identification is that it is directly consistent with the police. The disadvantage is that the identification can be determined by chance and parameters beyond the road related and site specific traffic safety management.

Recommendation

In spite of the fact that the most policies for traffic safety concerns the number and severity of injured the identification stage of NSM (and BSM) should still be based on accidents.

The argument is that NSM should be based on the professional and institutional responsibility of the road administrations (Sørensen 2006). This means that the road administrations have the responsibility to ensure that there are no deficiencies and faults in the road design and the surroundings, which can be a risk factor.

In this context use of injured road users as basis for the identification can give misleading results because the number can be a result of parameters that have nothing to do with the road design such as number of passengers, deficient use of seat belts or helmets, characteristics of involved persons such as age and shape and characteristics of involved vehicles.

4.3.2 Weighting principle

The next question to be raised is what accidents with different severity should be included in the identification and how should they be weighted to get increased focus on severity. In a literature review the following six weighting principles where identified (Deacon et al. 1975, Baerwald et al. 1976, Taylor and Thompson 1977, Ogden 1996, Ragnøy et al. 2002, Hauer et al. 2002, European Commission 2003, German Road and Transportation Research Association 2003, Overgaard Madsen 2005, Sørensen 2006):

1. Same weight for all accidents
2. Only the most severe accidents included
3. Weighting by number of vehicles
4. Weighting by accident type
5. Weighting by injured road users
6. Combination

Same weight for all accidents

In the first principle no weighting is done. All registered accidents are thus an integral part of the identification, and severity is not taken into consideration.

Only the most severe accidents included

Unlike the first principle, the second principle focuses directly on the most severe accidents. This is done by sorting out the less severe accidents for example accidents with only property damage or minor personal injuries, and hence only base the identification on the most severe accidents as for example fatal accidents or accidents with seriously injured road users. You could also say that the less severe accidents are weighted with zero as a weight.

Weighting by number of vehicles

In the third principle, the accidents are weighted by the number of vehicles involved in the accident or by the most severely injured road users in each involved vehicle (Baerwald et al. 1976). In the first case, a head on collision is for example weighted twice a single accident.

Weighting by accident type

In the fourth principle, the accidents are weighted by the accident type's average severity. Accident type can for example be described as a combination of accident situation and involved vehicles (Overgaard Madsen 2005). This means for example that head on accidents are weighted more than single accidents, and accidents between heavy vehicle and pedestrian are weighted more than accidents between two cars.

Weighting by injured road users

In the last independent weighting principle, the accidents are weighted by the severity of the most severely injured road users. This means that fatal accidents, accidents with seriously injured road users, accidents with minor injuries and accidents with only property damage (if registered) are weighted differently.

Combination

In addition to the five independent principles, it is possible to combine some of the principles in different ways.

You could for example combine the second and fifth principle. It means that the accidents with only property are sorted out and that the remaining accidents are weighted by the severity of the most severely injured road users.

Another possibility used in for example Germany (German Road and Transportation Research Association 2006) and Switzerland (Elvik 2007) is to have different threshold values for registered accidents of different severity.

Advantages and disadvantages

In table 4.4 the advantages and disadvantages for the six principles are summarized.

The advantage of using the *first principle* is that incorrect or imprecise information about accident severity does not influence the result of the identification. In addition, few maybe random fatal accidents will not dominate the result of the identification. Finally, the principle can be used, if the traffic safety policy concerns all accidents.

However if the policy only concerns the most severe accidents, which it normally does, the principle is problematic, because no especial attention is paid to the more severe accidents. This means that there is a discrepancy between policy and method.

Concerning identification based on equal weighted accidents it should be noted that accidents typically are indirectly weighted by severity. The weighting occurs because the level of reporting for accidents with different severity in official accident databases varies, so the most severe accidents have a high level of reporting, while less severe accidents typically have a lower level of reporting.

Advantages and disadvantages of the *second principle* depend on how much is sorted out. If only accidents with property damage (if registered) are sorted out the advantage is that incorrect information about injuries do not influence the result of the identification. In addition, few maybe random fatal accidents will not dominate the result of the identification. However, the lack of focus on the most severe accidents is a central problem.

Table 4.4. Advantages and disadvantages for the six overall weighting principles.

	Advantages	Disadvantages
Same weight	– Attention to data quality – Not high weight to fatal accidents – All accidents included – Useful when the policy concerns all accident	– No focus on severity – Discrepancy between policy and method
Only most severe accidents	– Partly attention to data quality – Maybe not high weight to fatal accidents – Maybe too much focus on severity	– Limits the data quantity – Maybe limited focus on severity – Maybe high weight to fatal accidents
Weighting by vehicles	– Focus on severity – Random high number of injured do not influence the result – All accidents included	– Maybe misleading weighting
Weighting by accident type	– Focus on severity – Random high number of injured do not influence the result – Not high weight to fatal accidents – All accidents included	– Model based identification is not possible – Difficult to understand
Weighting by injured	– Focus on severity – All accidents included – Easily to understand	– A randomly high number of injured road users will maybe influence the result – Maybe high weight to fatal accidents
Combination	– Takes advantage of the different methods advantages – Compensate for the disadvantages of the different methods	– Comprehensive and not understandably identification stage

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If the identification is based only on for example fatal accidents the advantage is exclusive focus on the most severe accidents. However, this is also a problem because few maybe random fatal accidents will dominate the identification and maybe give misleading results.

A general disadvantage of the second weighting principle is that the data quantity to a greater or lesser extent is limited whereby the reliability of the identification also is reduced. An other problem is that road sections with many registered accidents are not identified if there maybe by chance did not occur any fatal accidents or accidents with seriously injured road users.

The advantage of the *third principle* is increased attention to the most severe accidents. Another advantage is that a maybe random high number of injured road users in some accidents does not influence the result of the identification. Finally, the advantage is that data quantity is not limited and all registered accidents are thus included in the identification.

The disadvantage is that the principle can give some misleading weightings. For example, single accidents will often be more severe than rear end accidents, where two or more vehicles are involved.

The advantage of the *fourth principle* is increased attention to the most severe accident types, without randomly high number of injured road users in some accidents influencing the result of the identification. Likewise, fatal accidents will not dominate the result. The advantage is also like the third principle that all accidents are included in the identification (Taylor and Thompson 1977, Ogden 1996, Overgaard Madsen 2005).

The disadvantage is that the principle cannot immediately be used in a model based identification because it will require that the general expected number of each accident type is estimated, which in practise is not possible, because of deficient accident data. In addition, the principle can be difficult to understand (Sørensen 2006).

The advantage of the *fifth principle* is like the two previous principles the attention to the most severe accidents and that all accidents are included in the identification. In addition, the principle is considered as easy to understand among people working with BSM and NSM (Sørensen 2006).

The disadvantage of the principle is, depending on specific weighting method, that there is a risk that accidents with randomly high number of seriously injured or fatal accidents are given a very high weight and therefore will dominate the identification too much.

Typical weights are calculated on basis of the average accident costs for different injuries. This means that fatal accidents often will get a very high weight and these accidents will therefore dominate the result of the identification. This can be a problem because risk factors leading to accidents with killed or injured often are the same and on the micro level it is hence a matter of chance if an accident results in for example killed or seriously injured. At the same time, the number of fatal accidents is comparatively small and fatal accidents will hence only in rare situations happens the exactly same place more times (Ragnøy et al. 2002). An identification based on fatal accidents with a very high weight can therefore give misleading results where false hazardous road sections are identified (Ogden 1996, Persaud et al. 1997).

To avoid this problem it is advisable to make a combined weighting of fatal accidents and accidents with seriously injured. In general extreme weights directly calculated by use of the average accident costs should be avoided (Ogden 1996).

The *sixth principle* is to combine the previously described method. The advantage of this is that the advantages of the combined methods are taken into account at the same time as compensation for the disadvantages is accomplished. However, you risk getting a comprehensive and incomprehensible weighting.

Recommendation

It is recommended that severity is integrated in the identification stage of NSM by use of the fifth weighting principle; weighting by the severity of the most severely injured road users.

In general, the third, fourth and fifth principles are considered as the most relevant because all accidents are included. This means that both number and severity of registered accidents are taken into consideration.

The main determinant for the recommendation of the fifth principle is that it offers the possibility to be included in a model based identification, which is not immediately possible for the other principles.

The problem with the principle is that there is a risk that accidents with randomly high number of seriously injured or fatal accidents are given a very high weight and therefore will dominate the identification too much. How to avoid this problem is discussed in the next chapter.

4.3.3 Severity categories and weights

It was recommended that severity is included in the identification by weighting the accidents by the severity of the injured. This leads to the third question. What severity categories should the accidents be divided into and what specific weight should be applied to each category? This will be discussed in the following.

Severity categories

Table 4.5 and table 4.6 summarises the different severity categories and weights used and described in the methods reviewed in Elvik (2007) and some additional reviewed methods.

Table 4.5 concerns identification method based on injured, while table 4.6 concerns identification method based on accidents. According to the previous recommendation, focus in the following will be on table 4.6.

In the reviewed methods, the accidents are divided into two to four severity categories with different weights. This is done with basis in fatal accidents, accidents with seriously injured, accidents with minor injuries and accidents with property damage, which are merged in different ways.

Note that some countries like Norway, Germany and USA also operate with other categories. Norway divides seriously injured into very seriously injured and seriously injured (Ragnøy et al. 2002), Germany divides accidents with only property damage into three different categories (German Road and Transportation Research Association 2003), and USA divides minor injury in minor injury and probably minor injury (Khisty 1990).

The most frequently used number of severity categories is three. This is the case in five of the seven methods. In three cases fatal accidents and accidents with seriously injured are merged and in two cases accidents with seriously injured road users and accidents with slightly injured road users are merged.

The argument for merging two or more categories into one severity category with same weight is to get more accident data in the given category. This can especially be relevant for fatal accidents, which as mentioned is a relatively rare event.

It can also be argued that at the micro level it can be a matter of chance if an accident results in for example killed or seriously injured.

Finally, the argument can be that the data do not have a quality to be divided into more than for example three categories. In for example Denmark it is in practice not clearly defined what a serious and a minor injury is, and that can be an argument to merge them (Sørensen 2006).

Table 4.5. Severity categories and weights in reviewed identification methods in BSM and NSM based on injured road users road users.

	Killed	Very seriously injured	Seriously injured	Slightly injured
Flanders (Geurts 2006)	5	3		1
Norway (Ragnøy et al. 2002)	33.2	22.7	7.6	1
Portugal (European Commission 2003)	100	10		1
Ringkøbing County, Dk (Sørensen 2003)	33	15		1

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Table 4.6. Severity categories and weights in reviewed identification methods in BSM and NSM based on accidents. Denmark and Germany use different weights for different roads and the average weights are shown.

	Fatal accidents	Accidents with seriously injured	Accidents with slightly injured	Accidents with property damage
Denmark (Sørensen 2006)	36.3		5.1	1
Germany (German Road and Transportation Research Association 2003)	21.4		1.4	1
England and USA (O'Flaherty 1967)	12	3		1
England (O'Flaherty et al. 1997)	900	100	10	1
USA (Khisty 1990)	9.5		3.5	1
USA (Deacon et al. 1975)	2			1
Canada (Persaud et al. 1997)	140	5		1

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Weights

As shown in table 4.6 there is a radical difference between the weights used for the same severity categories in the different methods. In the three methods with fatal accidents as a separate category, the weight varies between 900, 140 and 12. The largest weight is hence 75 times larger then the smallest weight. In the first two methods, fatal accidents will be very dominant in the identification. In the first method, a fatal accident will for example be equivalent to 90 accidents with minor injuries or 900 accidents with only property damage. In comparison, fatal accidents equal four accidents with serious or slight injuries in the last method.

The use of very high weights for fatal accidents should be avoided (Ogden 1996, Persaud et al. 1997). On the other hand the weights for fatal accidents and other accidents with serious injuries should not be too small, because then the whole idea of weighting will be wasted. Thus, it is a tricky balancing act to find the appropriate weights.

In addition to the different weights for fatal accidents, it should be noted that the other weights also differ a lot. An example is the German method and the American method described in Khisty (1990). The weight for accidents with seriously injured is 2.3 times higher in the German method than in the American method, while the reverse is the case for accidents with minor injuries, where the weight is highest in the American method.

Another example is the methods described in O'Flaherty (1967) and Persaud et al. (1997). In spite of the very different weight for fatal accidents in these two methods, they have almost the same weight for accidents with serious and minor injuries. In the first method accidents with serious and minor injuries are weighted high in comparison with fatal accidents (0.25 times as high), while they have a very small weight in the last method (0.04 times as high).

It can be concluded that there is a very big difference in how heavily severe accidents are weighted and how accidents in different severity categories are weighted relative to each other.

The weights are and can be determined in the two following methods:

1. *Cost of injuries:* The weights are calculated with basis in the socioeconomic cost of injuries, which is the average cost of accidents or injured road users of different severity, which have been calculated in several countries.
2. *Arbitrary:* The weights are decided arbitrarily with basis in for example political goals to focus on certain severity categories in the safety work.

A specific example of the use of these principles is the three methods with an independent severity category for fatal accidents. Here the weights are 900 and 140 based on English respectively Canadian standard prices, while the weight of 12 is arbitrarily decided. Use of standard prices in England and Canada, where the prevention of traffic fatalities is highly valued (Sælensminde 2003) therefore gives very high weights for fatal accidents, while the weight of 12 in contrast is arbitrarily decided to eliminate the problem of very high weights for fatal accidents (O'Flaherty 1967).

Arbitrarily determined weights can be used, if you wish to have another focus in the identification than the use of standard princes will give. The arbitrarily decided weights will typically be smaller then the weights derived from monetary valuations, but it could also be the other way round.

The weights in the accident based method described in O'Flaherty (1997), Persaud et al. (1997), German Road and Transportation Research Association (2003) and Sørensen (2006) are calculated by use of monetary values. Despite use of the same calculating method the weights vary a lot between the four examples of accident based methods (see tøi report 898/2007
table 4.6). These variations can be explained in the following two ways:

1. Difference in the monetary valuation of injuries of different severity
2. Difference with respect to how many people that in average are injured in each accident of a given severity

In Sælensminde (2003) the monetary valuation for fatalities in traffic are reviewed in 22 countries and the highest value were found for USA and Norway, where the valuation in 1999 prices were 3,660,000 $ respectively 2,121,000 $, while lowest value were found in Spain and Portugal where the value in 1999 prices were 56,000 $ respectively 97,000 $. The price is thus 66 times higher in USA than in Portugal.

The difference can be explained in terms of different calculations methods and differences in what parameters are included. An important parameter is whether the human costs are included or not and how the value is estimated.

Recommendation

It is recommended that the accidents are divided into three severity categories. This is assumed to give the best balance between getting a varied, a reliable and a practical division. Depending on accident level, accident data and policy the division can be done in the following two ways:

1. Accidents with killed and seriously injured
2. Accidents with slightly injured
3. Accidents with property damage

1. Fatal accidents
2. Accidents with seriously injured
3. Accidents with slightly injured

If possible is the first method recommendable because fatal accidents and seriously accidents are merged, whereby the problem with high weight to maybe random fatal accidents is eliminated. Likewise, it is very difficult for many countries to make a reliable estimate of a general expected number of fatal accidents, because it is a rare event, and an estimate is necessary to be able to develop a model based or category based identification of black spots or hazardous road sections.

In addition, it is recommended that the weights for the different severity categories are calculated by use of the monetary valuations and the average number of injured road users of different severity in the different severity categories. This is similar to the method described in German Road and Transportation Research Association (2003) and Sørensen (2006).

The argument for the weighting by use of monetary valuations is that it is a more objective and professional method than the arbitrary decision, which can be very biased and political. Note, that monetary calculation also consists of some different assumptions, that can be biased.

4.4 Accident analysis

The state-of-the-art approach for BSM and NSM is the same with regard to the analysis stage. The recommendation with regard to best practice guidelines will thus be the same, with the exception of some few points. These points will be clarified in the following.

4.4.1 Difference between BSM and NSM

As described in chapter 3.4.1 the analysis stage can be characterized by the absence of research, development and testing of new and better methods. This applies particularly to the analysis of longer hazardous road sections in the NSM and how this work differs from BSM. This means that the work is done just like one's usual routines for black spots although there are some central differences (Sørensen 2006).

The black spots and the hazardous road sections primarily differ from each other with regard to length of locations and overall philosophy for the work.

Black spots normally have a length of up to 0.5 kilometres, while hazardous road sections according to the recommendations have a length of between 2 and 10 kilometres, with an average section length of around 5-6 kilometres. This means that there is a risk on that local accident patterns and peaks on long road sections are not identified if only the normal black spot analyses are used, because the problem will "drown" in the average for the whole section (Hauer et al. 2002 and Sørensen 2007).

The difference between BSM and NSM with regard to overall philosophy for the work is that BSM has a remedial and retrospective nature, while NSM typically both have a remedial and retrospective nature like BSM and a preventive and prospective nature like mass action. This means that the analysis stage in NSM not only should include analysis based on the registered accidents as in BSM, but also should include a more general road examination or inspection and an assessment of the possibility of making some standard improvements on the given road section (Sørensen 2006, 2006a).

4.4.2 Recommendation

In the following, a description is given how the accident analysis and road inspection in NSM should differ from the approaches in BSM to minimize the problems described.

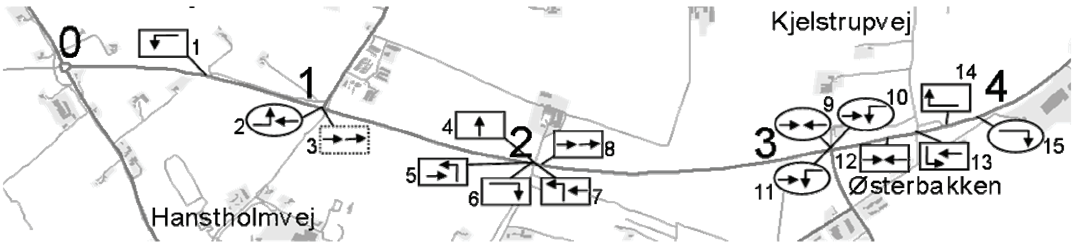
Accident analysis

To avoid the problem that some local accident patterns "drown" in the average for the whole section it is recommended to combine the general accident analysis and the traditional collision diagram into a so called extended collision diagram (Sørensen 2006, 2007).

The extended collision diagram covers a traditional collision diagram, which has been amplified with information from the general accident analysis that normally not can be interpreted from the collision diagram.

Accident severity, accident situation, place and means of transportation can normally be read from a collision diagram. This should be supplemented with the most relevant information from the general analysis i.e. information about time (time of day, weekday, month and year), circumstances (weather, light, state of the roads etc.), drink driving, speed and maybe characterization of a person (sex, age, nationality, illness and use of safety features).

In the interest of clarity, which is the most central point in using a collision diagram, it is recommend that the described data are added to the diagram by use of a table besides the traditional collision diagram (Sørensen 2006, 2007). Figure 4.1 shows an example of a fictitious extended collision diagram. Here one can see that it looks like that there are some problems with wet road surface in the east end of the road section, some problem with accidents in dark in the middle of the road section and some problems with drink driving in the west end of the road section despite the fact that these problems can not be identified in the overall average for the road section.



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	-	-	-	-	-	-	-	-	-

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Figure 4.1. A fictitious extended collision diagram for an around 4 kilometre long road section with 15 accidents. Number on the map is kilometre, ellipse indicate accidents with injured and rectangle indicate accidents with property damage, L = light and D = dark.

Road inspection

The road inspection for a hazardous road section differs from a road inspection for a black spot in two ways. The first difference is the length. This means that it is recommendable only to make a road inspection of one hazardous road section per working day, while it is possible to inspect several black spot in one day (Sørensen 2006, 2007).

The other difference is as described the difference in overall philosophy. This means that the road inspection both should concern on traffic safety problems that have been a contributing factor in registered accidents and more general problems that by chance have not been a contributing factor in any accidents in the given accident period.

Based on extensive literature survey and interviews Sørensen (2006, 2007) has recommended how a road inspection of a hazardous road section should be made. This will also be recommended here. The recommendation is the following:

The road inspection should be made relatively formalized by use of a checklist. An example of a checklist developed for road inspection of hazardous roads is shown in table 4.7.

The road inspection should be made by two persons, one being a traffic safety employee, and one an employee of the road administration authorities' operating or project department. The road inspection should be carried out by car, and at the sites posing problems the surveyors should stop to examine the localities more closely. The surveyors should drive through in each direction and from relevant side roads. The road inspection should not be made at a specific time of the day and should not last longer than a working day (Sørensen 2006, 2007).

Table 4.7. Parameters, which should be included in the road inspection (Sørensen 2006).

Accident sites: Confirm or deny hypotheses from the analysis.
Curves: Course, marking and road surface.
Cross section: Road area, shoulder and central verge, bicycle lane and pavement as well as ditches and slopes.
Intersections, driveways and crossings: Number, layout, channelization and regulation.
Road surface: Friction, drainage, maintenance, edge drop off and high road verges.
Message signing and marking: State and correctness.
Crash fence and fixed objects: Masts, signs, trees, road stones, buildings etc.
Sight conditions: On the road section, from the byroads, optic guidance, illumination and dazzling

4.5 Evaluation of the treatment of hazardous road sections

The state-of-the-art approach for BSM and NSM with regard to evaluation of the effects of the implemented measures, and the recommendation with regard to best practice guidelines will be the same. However, there are some difference between BSM and NSM that give cause for a discussion whether this recommendation can be copied directly.

4.5.1 Difference between BSM and NSM

As described in chapter 4.2.1 BSM can be characterized as having a retrospective nature, while NSM can be characterized as having both a retrospective and a prospective nature.

This mixture implies that it is more difficult than for black spot treatment to evaluate the effect of implemented measures by using simple methods. At least the estimated effect of the measures will probably be smaller. The explanation of this is that the measures both are implemented on accident locations and on other relevant locations where no accidents have been recorded. Based on the described guidelines for best practice evaluation these measures will have no effect on the non accident locations.

4.5.2 Recommendation

Studies on how measures with both retrospective and a prospective nature should be evaluated are very rare, and thus it is recommended that such studies are made. Until then it is recommended that the approach for BSM is used.

4.6 Summary

The key element of best practice guidelines for safety analysis of road networks or network safety management (NSM) are summarized in the following with focus on the points that differ from black spot management (BSM):

1. *Classification of roadway elements:* The road system should be divided into road sections with variable length to ensure homogeneity with regard to the parameters that have significant influence on the number of accidents and are used as independent variable in accident models. The section length should be in the interval between 2 and 10 kilometres, with an average section length around 5-6 kilometres.
2. *Identification principle:* The identification should be made by a more or less advanced model based method like the black spot identification. However, the use of not accident based identification methods should also be examined.
3. *Identification criterion:* If the identification is done by a traditional model based approach, the absolute difference criterion should be used. In contrast to BSM, accident severity should be an integrated part of the identification criterion. Severity should be integrated by weighting by the severity of the most severely injured in the accident. The accidents should be divided into three severity categories, which are weighted by use of monetary valuations and the average number of injured of a given severity in the different severity categories.
4. *Accident analysis:* The same analyses method as in BSM should be used, but results from the general accident analysis and the collision diagram should be combined into an extended collision diagram to identify local accident patterns that "drown" in the average for the whole road section. In addition, the road inspection should be more general then the inspection of black spots and thus concern accident locations and general problems.
5. *Evaluation of the hazardous road section treatment:* For the present, the evaluation of the treatment should be done like evaluation of black spot treatment. In addition it should be examined how evaluation of combined retrospective and prospective treatment can be done in a better way.

5 Conclusions

For several years black spot management (BSM) has been and still is a very essential part of the site-specific traffic safety work. In the last 5 to 10 years, BSM has been supplemented with safety analysis of road networks (NSM) in more and more countries. However, the current approaches and quality of BSM and NSM differ very much from country to country and the work can be characterised by a lack of standardised definitions and methods.

This project has described state-of-the-art approaches and best practice guidelines for BSM and NSM with regard to classification of sites, identification principle and criterion, accident analysis and evaluation of the treatment.

State-of-the-art approaches are defined as the best currently available approach from a theoretical point of view while best practice guidelines are the best approach from a more practical point of view. State-of-the-art approaches are described in Elvik (2007) and based on these the best practice guidelines are described in this rapport. These are summarized in the following and in table 5.1.

Table 5.1. Characteristics of state-of-the-art approach and best practice guidelines for black spot management (BSM) and safety analysis of road networks (NSM).

	State-of-the-art	BSM	NSM
Classification of sites	– Dividing of road system into clearly defined sites	– Same as state-of-the-art	– Dividing of road system in 2-10 km homogeneous sections
Identification principle	– The empirical Bayes method	– Simple model based method	– Simple model based method – Use of not accident based method should be examined
Identification criterion	– Higher expected accident number than the normal expected number on similar sites – Severity is not included in BSM but included in NSM	– The absolute difference criterion – Predefined number or a certain share – Severity is not a part of the identification	– The absolute difference criterion – Severity is integrated in the identification by weighting the severity categories according to monetary valuations
Analysis	– Binomial tests of accident patterns – Blinded matched pair comparison	– General accident analysis, collision diagram, inspection, traffic and road analyses – Comparing with normal accident pattern – True/false assessment	– Extended collision diagram, general inspection, traffic and road analyses – Comparing with normal accident pattern – True/false assessment
Evaluation	– Empirical Bayes before-and-after design – Should always be made	– Before-after-study with correction for trends, traffic and regression – Should not always be made, it depends of data	– Same as BSM – Should not always be made – Further research how to evaluate combined retro- and prospective treatment

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Black spots should be identified by reference to a clearly defined population of roadway elements as for example curves, bridges or four-leg junctions, while hazardous road section should be identified by reference to 2-10 kilometres homogeneous road sections. This makes it possible to estimate the general expected number of accidents by use of an accident model. Use of a sliding window approach should be avoided, because it has been found to greatly inflate the number of false positives.

The identification of both black spots and hazardous road section should rely on a more or less advanced model based method. The argument for that is that model based methods are the best to make reliable identification of sites with local risk factors related to road design and traffic control, because systematic variation and partially random fluctuation are taken into consideration. Use of not accident based identification methods in NSM should also be examined.

The absolute difference criterion should be used in conjunction with the traditional model based method for identification of black spots and hazardous road sections. The criterion should either be a predefined number that the savings potential has to exceed or a certain percentage of the road network with the largest savings potential depending of how BSM and NSM is organized and divided between different road administrations.

Due to more accidents, accident severity should be an integrated part of the identification criterion in the NSM, but not in the BSM. Severity should be integrated by weighting by use of monetary valuations and the average number of injured of a given severity in different severity categories.

The analysis stage should as a minimum consist of a general accident analysis, drawing and analysis of a collision diagram, a road inspection and relevant supplementary traffic and road analyses. In NSM should results from the general accident analysis and the collision diagram be combined into an extended collision diagram to identify local accident patterns.

The general accident analysis, the collision diagram and the extended collision diagram should be compared with the normal pattern of traffic accidents for the given type of location.

An active and written assessment of whether the presumed black spot or hazardous road section is a true hazardous location or not should be made.

When possible an ex post evaluation of the treatment should be made. To help guide the evaluation nine criteria are described. The evaluation itself should be made as a before-after-study controlling for long-term trends in the number of accidents, local changes in traffic volume and regression-to-the-mean by use of correction factors. With regard to NSM it should be examined how evaluation of combined retrospective and prospective treatment can be done in a better way.

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