Injury Severity Based Black Spot Identification

- Assessment of the Method in the Municipality of Hjørring

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Abstract

A new Danish road safety plan for 2001-2012 was published in 2000. The focus for the plan was to reduce the number of fatalities and seriously injured and not slightly injured. As a reaction to the new objective, a method for injury severity based black spot identification was developed at Aalborg University. In this paper the method has been tested in the Municipality of Hjørring and compared with normal black spot identification. The objectives have been to evaluate to what extent the new method increases the focus on the most severe accidents and to examine if the new method contribute to road safety work that are more cost effective.

An injury severity based and a normal black spot identification have been preformed and the number and severity of accidents on the identified locations have been compared. The comparison indicates that the injury severity based method with advantage could be used for primarily road sections, because it increases the focus on locations with severe accidents.

The evaluation also consists of an analysis of whether the identified locations are true or false black spots. The study includes too few locations to make it possible to make a final conclusion about this question. However, for the specific case it has been shown that the new method is as effective as the normal method for identifying true black spots.

Finally a comparison of first year rate for treatment for black spots from the two identifications has been made. Again, there is to little data to make a general conclusion, but among the examined locations the first year rate for the proposed treatment was highest for the locations that were identified by the injury severity based method.

The weaknesses of black spot management

For several years black spot management has been and still is an essential part of the site-specific traffic safety work done by the public road authorities. In common, treatment of black spots is acknowledged as one of the most cost-effective road safety measures. However, several points of criticism have been raised against black spot management:

1. **Old accident theory:** Danish methods for black spot identification are based on almost 40 years old accident theory although new and better theories as the empirical Bayes approach have been developed, demonstrated and proved by for example Hauer (1997), Vistisen (2002), Cheng and Washington (2005) and Elvik (2007). Thus, black spot identification on the secondary road network neither takes the general road layout nor the stochastic nature of the accidents in consideration. In some cases even the systematic variation in the number of accidents determined by the traffic volume is not taken into account (Madsen 2005, Sørensen 2006).
2. **Black spot analysis:** In both Denmark and on international level focus on development of new and improved methods for black spot analysis has been limited. Thus, no new, well-documented and satisfying methods for analysis of accident data and identification of accident and injury factors exist (Sayed et al. 1995, Hauer 1996, Sørensen 2007).

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Another essential problem of the existing analysis methods is that they do not offer the possibility to make a qualified and systematic assessment of whether the identified locations are true black spots or not (Elvik 2006).

3. **Limited potential:** After many years of black spot management in Denmark the most critical black spots have been identified and treated. In addition, implementation of road safety audit will reduce the number of black spots on new or rebuild roads. Traditional black spot management therefore has limited potential in the future (Sørensen 2005).
4. **Missing focus on severity:** The primarily focus of black spot management has been to reduce the number of accidents rather than reduce the severity of the accidents. Thus, in a period of years there has been a discrepancy between the strategy to focus on the most severe accidents and the normal used methods for black spot identification, where the identification is based on all registered accidents (Madsen 2005).

This paper focuses on the last point of criticism.

Focus on severity in black spot management

In year 2000 the Danish Traffic Safety Commission published a new road safety plan for 2001-2012. The plan was named "Each Accident is One too Many – Road Safety Begins with You" (Færdselssikkerhedskommissionen 2000). In this plan the objective is a reduction of 40 % in numbers of people killed and severely injured on the roads.

This objective is an important change in relation to the previous objective formulated by the Danish Traffic Safety Commission in 1988, which dealt with the total number of persons injured (Færdselssikkerhedskommissionen 1988). Thus, the expressed objective marks a significant strategic change in the traffic safety work from crash prevention to loss reduction. The degree of severity of road accidents thereby has to systematically be taken into account both in general and in blank spot management. In Denmark, however, black spot identification is still based on the number of registered accidents without any systematic consideration of the severity of the accidents.

In the last number of years - except for 2007 - there has been a very favourable decrease in the number of killed and severely injured road users. The objective for the year 2012 of maximum 300 people killed was almost achieved in the year 2006 which "only" had 306 killed road users. This induced that the Danish Traffic Safety Commission in May 2007 published a revised national action plan for the remaining period to the year 2012 (Færdselssikkerhedskommissionen 2007). Both objective and measures have been changed and updated. The objective is now to reduce the number of killed, severely injured and slightly injured road user by 40 % in the year 2012 compared to the number in the year 2005. This means that the number of people killed in the year 2012 should be no more than 200.

The new action plan is a return to a similar objective as in the first action plan from the year 1988 that concerned all injured with no direct focus on the most severe injured. In spite of the changed objective there is still good reason to focus on the most severe road accidents with killed and severely injured in the traffic safety work. This is illustrated in figure 1 and is explained in the following.

People are in nature fallible. It is therefore unavoidable that road users will make mistakes while driving. It is assumed that road users make mistakes in average one out of 500 decisions that constantly have to be made while driving (EuroRAP 2002). Some of these mistakes will

be a contributing accident factor. The number of these mistakes can be reduced by not site-specific traffic safety work as education, information and campaigns, but they can never be completely prevented. At the same time it is considered as an unavoidable part of life to get some minor injuries. Less severe accidents should therefore not be prevented at any prize. Finally, several research projects (Madsen 2005) have documented that on the macro level the severity of an accident is not a coincidence. The severity of accidents is determined by factors as (Elvik and Vaa 2004):

- The weight of the vehicle and the protection it offers
- Speed in the time of the accident
- Characteristics of the road user, especially age
- Use of personally safety equipment as airbag, safety belt and helmet.

Thus, from both an ethical and methodical point of view it is recommendable to focus the traffic safety work on the most severe accidents with killed and severely injured.

Prerequisite		Consequence
Human make mistakes	⇨	Accidents can not be prevented completely
Slightly injury is a part of life	⇨	Less severe accidents should not be prevented at any prize
Severity is not a result of chance	⇨	It is possible to focus on the most severe accidents
	⇩	
Ethical and methodical recommendable to focus on accidents with killed and severely injured		

Figure 1. Illustration of why it is recommendable to focus on the most severe accidents.

Objective

As a reaction to the new formulated objective for the traffic safety work in year 2000, the Traffic Research Group at Aalborg University started a PhD project same year. The objective of this PhD project was to develop a method for injury severity based black spot identification, where the severity of the accidents is taken into consideration in a completely and systematic way (Madsen 2005). However, the developed method has only to a limited extent been tested and evaluated in practice.

The objective of this paper has therefore been to test the developed method in a concrete case and compare the results with the results from a normal identification of black spots. More precise the objective is to evaluate:

- To what extent does the new method increase the focus on the most severe accidents?
- Does the new method contribute to give more value for money in terms of safety?

The paper is based on results from the project “Injury Severity Based Black Spot Identification in New Hjørring Municipality” (Pedersen 2007) made at Aalborg University in the period September 2006 to January 2007.

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Three different methods of examination

Black spot management is normally divided into the following seven stages:

1. Collecting accident data, road data and traffic data
2. Definition and identification of black spots and ranking of locations
3. Analysis of accidents and risk factors and evaluation if the locations are true black spots
4. Proposing of treatment and pre evaluation of proposed treatment
5. Ranking of projects with regard to cost effectiveness
6. Implementation and operation of selected treatment
7. Post evaluation of effect of black spot treatment.

In this project the first four stages have been performed for the injury severity based black spot identification and for the normal black spot identification. To evaluate the two methods the following three examinations have been done:

1. Comparison of the registered number and severity of accidents on identified locations
2. Analysis and assessment of whether the identified locations are true or false black spots
3. Proposal and assessment of treatment and comparison of first year rate.

This paper focuses on the first part, but the two other parts are also described shortly.

The municipality of Hjørring

The project is based on the new municipality of Hjørring in the northern part of Jutland. The municipality is a merger of the previous municipalities of Hjørring, Hirtshals, Sindal and Løkken-Vrå.

The project focuses on the new secondary road network including previous county roads that from year 2007 have been classified as municipality roads. The road network has a length of 1,393 km of which 126 km are previous county roads.

The 10 year period 1996-2005 is used for identification and analysis of black spots. In this period 2,612 accidents have been registered by the police in the official accident statistic. These are divided into 1,068 accidents with personal injured, 1,018 accidents with property damage and 526 extra accidents. Extra accidents are accidents registered by the police without making a fully accident report, because there was no vital damage or significant violation of the law. The accidents with personal injured have resulted in 64 persons killed, 521 severely injured and 843 slightly injured.

Normal black spot identification

Black spot management is normally based on a five years accident period. However, in this project it is chosen to extend this period to 10 years. This results in more accident data to analyse and illustrate the difference between the two identification methods.

The identification is solely based on accidents with personal injured or accidents with property damage like the normal approach for black spot identification in Denmark. This excludes extra accidents in the identification. However, these accidents are included in the analysis stage.

The identification is preformed as a frequency-rate identification. Frequency is accidents per kilometre and rate is accidents per vehicle kilometre. The method is selected because it is better than independently use of either the frequency or the rate method for identification, and because it is not possible to make a model based black spot identification on the secondary road network in Denmark.

Until 2007 the municipalities in Denmark have been using the software "Vejman" or "RoSy®" for road administration. The municipality of Hjørring has used "Vejman" for automatic black spot identification, while the other three municipalities have used none of the systems. In the module for automatic black spot identification it is not possible to add extra information about severity weighting to the accident data, which is necessary in the injury severity based black spot identification. Thus, the identification has to be made manually for the injury severity based black spot method. To avoid unnecessary differences in methods, the normal black spot identification is also made manually.

To make a manual black spot identification possible, it is normal practice to divide the road network into traffic roads and local roads. The traffic roads are divided in intersections between two traffic roads and road sections between traffic road intersections (Vejdirektoratet 1987).

In some cases this division results in some very long road sections. In this project, the chosen mean for solving the problem is to divide these sections into lengths of approximately 1 km. The road network was divided into 55 intersections and 528 road sections.

In performing the actual black spot identification it is essential that the registered accidents are unambiguously located on the road network. In this project the accidents have been geographical coded in a GIS (geographic information system) based map. Depending on information about the individual accidents, the locating is done based on the following information:

- Number of the road and stationing along each road
- Name of the road and number of houses
- Name of the road and significant buildings
- Name of primary road and name of secondary road.

2,036 accidents were located. These were divided into 927 accidents with personal injured (87 %), 753 accidents with property damage (74 %) and 356 extra accidents (68 %). These are included in the black spot management.

Among the four municipalities, it was only the former municipality of Hjørring that systematically identified and treated black spots. Systematic black spot management has also been the practise of the County of Northern Jutland on the previous county roads.

Inspired by identification criteria used by the former municipality of Hjørring, it is chosen to identify intersections with a accident frequency equal to or higher than 0.5 accident per year and road sections with a accident frequency equal to or higher than 0.5 accident per year per kilometre. 13 out of 55 intersections (24 %) had over 0.5 accident per year and 55 out of 528 road sections (10 %) had 0.5 accident per year per kilometre.

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Afterwards, these locations are ranked in accordance with their accident rate. Normally 1/2 or 1/3 of the locations with highest accident rate are then defined as black spots and included in the further black spot management (Thorson 1970).

Injury severity based black spot identification

The injury severity based frequency-rate identification method differ from the normal identification method by the fact that the rate ranking is based on injury severity weighted accident rate rather than normal accident rate.

The weighting is based on accident type, which is a new definition defined on the basis of the possible combinations of the following accident characteristics; accident location, combination of vehicles involved and accident situation. Almost 500 different accident types have been defined.

Madsen (2005) has shown that it is suitable to compile these three characteristics, based on an analysis of over 131,000 police registered accident from 1996-2001. The analysis shows that these characteristics have significant influence on the severity of the accidents. Thus, some accident types as for example head on collisions and accidents between heavy vehicles and vulnerable road users averagely are more severe than other accidents. They should therefore be weighted higher than accidents that normally are less severe.

The weights for each accident type are calculated with basis in the socioeconomic cost of injuries, which is the average cost of injured road users of different severity, and the average number of injured road users of different severity. See Madsen (2005) for further clarification of the developed method.

Specifically, the use of the injury severity based identification method results in reranking of the previous frequency identified 13 intersections and 55 road sections. Locations with the highest severity weighted accident rate are now highest ranked.

Comparison of the identification of intersections

As described, an individual identification and ranking are made respectively for intersections and for road sections. These rankings are compared separately.

With regard to the ranking of intersection there is no significant difference between the two methods. A correlation test of the ranking of the 13 intersections in the two methods results in a correlation coefficient of 0.86. A correlation coefficient of 1.00 corresponds to absolute uniform ranking.

Comparison of the identification of road sections

Contrary to the intersections there are large differences between the rankings of the road sections. For the five, 10 and 15 highest ranked sections in the two methods there are only respectively three, six and 11 repetitions. The correlation coefficients for the three comparisons are only respectively 0.20, 0.38 and 0.60.

Table 1 compares the registered accidents and injured road users for the 15 highest ranked road sections in the two methods. Most accidents have been registered on road sections ranked highest in the normal method. 205 accidents have been registered on these road sections, while “only” 192 accidents have been registered on the highest ranked road sections

in the injury severity based identification method. However, these road sections have most accidents with personal injured and most injured road users.

		Normal	Injury severity based
Accidents	Accidents with personal injured	72	81
	Accidents with property damage	92	77
	Extra accidents	41	34
	Total	205	192
Injured road users	Killed	3	5
	Severely injured	22	30
	Slightly injured	51	69
	Total	76	104
Severity	The share of accidents with personal injured	35 %	42 %
	Killed per accidents with personal injured	0.04	0.06
	Severely injured per accidents with personal injured	0.31	0.37
	Slightly injured per accidents with personal injured	0.71	0.85
	Injured in total per accidents with personal injured	1.06	1.28

Table 1. The number of accidents and injured road users with different severity on the 15 highest ranked road sections in the normal and in the injury severity based black spot identification. The table also shows the accident severity as the share of accidents with personal injured compared to the total number of accidents and as the number of injured road users of different severity per accidents with personal injured.

Severity of a group of accidents are normally described as either the share of accidents with personal injured compared to the total number of accidents or as the number of injured in total, killed, severely injured or slightly injured per accidents with personal injured.

The advantage of the first measure of severity is that it is based on all accidents. However, this can also be a disadvantage because the share of accidents with personal injured is not necessarily a measure for averagely severity of the accidents, but maybe more an evidence of different reporting level for accidents with personal injured and accidents with property damage.

It is just the opposite for the other measure of severity. It must be considered as an advantage that this measure solely focuses on accidents with personal injured. This means that the reporting level for accidents with personal injured and accidents with property damage does not influence the measure. At the same time it is a disadvantage only to focus on the accidents with personal injured because it means that the percentage of the total number of accidents is unknown (Sørensen 2006).

Due to the disadvantages for the two measures of severity it is chosen to use both measures in the comparison. Both measures show that the accidents on the highest ranked road sections in the injury severity based method in general are more severe than the accidents on highest ranked sections in the normal method. For example accidents with personal injured comprise 42 % of the accidents in the injury severity based method, while the share in the normal method is 35 %. In average there are 1.28 injured road users per accidents with personal injured in the injury severity based method, while there only is 1.06 in the normal method.

This shows that the injury severity based method for identification of black spots to a larger extent identifies sections where the accidents result in seriously injury.

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True or false

The second part of the examination consists of an accident analysis and a road inspection. The objective of this part is to assess whether the capability of the two methods to identify true black spots differs.

True black spots are locations that because of deficient, incorrect or inappropriate detailed road layout contain some locale accident or injury factors. On the contrary, false black spots are locations that wrongly have been identified due to a randomly high number of accidents in the used identification period.

The assessment of whether the identified black spots are true black spots or not is done by analysing the conformity between the results from the accident analysis, the road inspection and possible supplemental analyses of road and traffic conditions. This corresponds to the recommended method described by Sørensen (2007a).

The analysis includes road sections among the 15 highest ranked sections in the two rankings that differ from each other, because it will make no sense to make a comparison of identical road sections. In addition it has been examined if the road sections have been significant rebuilded in the last period of years.

Four road sections from each ranking have been analysed. Among these, it is concluded that two of the normal identified road sections and three of the injury severity identified road sections are true black spots.

Due to limited road sections analysed, it is not possible to make any final and general applicable conclusions. However, in this specific case the injury severity based identification method has been at least as capable of identifying true black spots as the normal identification method.

Value for money

The third part of the examination consists of an analysis of whether you get more value for money in terms of traffic safety by using the injury severity based identification method rather than the normal identification method. This is examined by proposing treatment for true black spots from the two identifications. Afterwards the profitability of the proposed treatment is compared.

Obviously, the examination is based on very few locations, and general applicable conclusions cannot be made. In the specific case the first year rate of the proposed treatment was highest for the locations identified by the injury severity based method. This can be explained by the fact that it is more severe and therefore more expensive accidents that are “saved” on the locations identified by the injury severity based method. At the same time the treatment is not more expensive for the treated locations identified by the injury severity based method than the treatment for the normal identified locations.

Conclusion

This paper describes a project where an injury severity based method for black spot identification has been tested and compared with a normal method for black spot identification.

The examination consists of three different parts. The results from the first part indicate that an injury severity based method with advantage could be used for primarily road sections

rather than normal black spot identification, because it increases the focus on locations with severe accidents.

The description of the last two parts is primarily included in the paper to demonstrate a possible study design, because it due to limited road sections analysed is not possible to make any final and general applicable conclusions.

However, for the specific case it has been demonstrated that the injury severity based identification method is as good as the normal identification method for identifying true black spots. In addition, the first year rate of the proposed treatment was highest for the locations that were identified by the injury severity based method.

To make some final and general applicable conclusions about the method it is necessary to expand the examination to a larger geographic area as for example the northern part of Jutland. Thereby it is possible to include more locations in the second and third examination.

Discussion

The primarily objective of this paper was to test and assess a new severity based method for black spot identification. It is concluded that the method increases the focus on locations with severe accidents. However, the study also shows for both of the compared methods that it is very difficult to make a reasonable accident based identification and accident analysis. The problem is that the number of police registered accidents is too limited and too random to make some reliable identifications and analyses. This means that only very few of the potential black spots in fact were true black spots. The problem has been documented in several other studies (Andersen and Sørensen 2004, Sørensen 2005, 2006, 2007).

This indicates that the main problem is not whether a severity based or a not severity based for black spot identification should be used, but more how the "problem" with too few accidents should be handled. One possibility is to supplement the official accident database with hospital registered road accidents. Another possibility is to focus more on not accident based method in the future road safety work as for example road safety inspections.

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