# Grey Road Sections on Main Roads in Rural Areas

**- Development, application and assessment of a Category Based Identification Method**

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**This paper is based on the PhD-thesis: "Hazardous road sections in rural areas – development, application and assessment of severity based methods for identification, analysis and improvement of hazardous road sections" (Sørensen 2006) (in Danish). The project is carried out in the period August 2003 to August 2006 at the Traffic Research Group at Aalborg University in a co-operation with Ringkøbing and Viborg counties. In the project methods for identification, analysis and improvement of grey (hazardous) road sections are developed. However, focus in this paper is only on the identification method developed.**

## Aim and background

The present paper treats the site-specific traffic safety work on main roads in the rural areas with focus on the grey road section work. The goal is specifically to define what a grey road section is and to develop methods for their identification, analysis and improvement. The methods must be well founded concerning accident theory and of practical use. At the same time, the aim is to develop methods for systematically incorporating the severity of the accidents in all phases of the grey road section work.

There are principally four reasons why this work is needed. Firstly, there has been a smaller decrease in the number of accidents and personal injuries in the rural areas compared to urban areas. This is unfortunate, as accidents are generally more severe in the rural areas. Thus, three-quarters of all road deaths have their origin in the open land. Among these accidents, two-thirds take place on road sections. There is thus here a strong potential for saving road deaths and seriously injured persons.

Secondly, several objections can be raised against the present black spot work. The case here is that the method is based on an almost 40 year old theory on accidents, and that there is a discrepancy between strategy and purpose. Furthermore, the most significant black spots have been improved, and the potential of the work is therefore limited. In several of the most traffic safe countries focus is thus gradually turning on the grey road section work rather than the black spot work.

Thirdly, during the last 10 years the grey road section work is to an increasing degree turning up in the Danish road administration authorities' site-specific traffic safety work. However, a common and unambiguous definition of the concept does not exist, and common, formalized and operational methods for the identification, analysis and improvement of these road sections have not been established. As a result, the Danish road administration authorities today identify grey road sections applying obsolete methods.

Fourthly, in 2000 the Danish Traffic Safety Commission published a new traffic safety plan for the years 2001-2012. The aim of this plan is to reduce the number of people killed and severely injured on the roads by 40 %. This aim is an important change in relation to the previous one, which dealt with the total number of persons injured. Thus, the expressed aim marks a significant strategic change in the traffic safety work from Crash Prevention to Loss Reduction. This means that the need for systematically taking into account the degree of severity of the road traffic accidents in the methods applied has increased. In Denmark, however, this has not been implemented satisfactorily.

## Investigative method

In order to be able to fulfil the purpose of the project expressed, six different part examinations have been carried out. These are the following:


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1. Literature studies of 30 Danish national and county traffic safety plans and other relevant plans and projects
2. Interview with 18 Danish traffic safety employees of the Danish Road Directorate and all the Danish counties
3. Literature studies of existing foreign methods in 14 EU-countries, Norway and USA
4. Literature studies of 30 relevant historical and scientific articles, reports and textbooks from 1964 to 2000
5. Analysis of categories, where correlation between road design, traffic and accidents is analyzed and where the so-called average accident cost weighted density of accidents has been estimated and statistically assessed for 50 defined road and traffic categories
6. Test, demonstration and assessment of the method developed in a concrete case, where identification, analysis and improvement of hazardous road sections are done for the county road network in Ringkøbing and Viborg counties

The purpose of the literature studies and the interview study carried out is to gain knowledge, survey and ideas on how a Danish method for the identification, analysis and improvement should be in order to be theoretically well founded as well as useful in practice. Based on these analyses, a number of general recommendations are formulated. Starting from these recommendations a specific category and severity based identification method has been developed, which has been tested and assessed.

## Motives, philosophy and procedure

Before recommending how to identify grey road sections it has initially been determined what the motives, the philosophy and the overall procedure for the grey road section work should be, as these factors are crucial for the planning of the identification phases.

It is recommended that the motives for the implementation of the grey road section work are to contribute to fulfilling the objective of the particular road administration authority, to correct faults and deficiencies pertaining to road construction, as well as getting the best value for money in terms of traffic safety.

The basic philosophy in the grey road section work is to combine the principle in black spot action and the principle in mass action. This means that the work shall be local, remedial and retrospective as well as preventive and prospective. The identification phase is based on registered traffic accidents and therefore has a retrospective nature like the black spot safety work. In contrast the following analysing and improvement phases both have a retrospective and prospective nature, because it is recommended that these phases both are based on accidents and general traffic safety problems and standard improvements. 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.

Secondly, the philosophy is to focus on the most severe accident. These accidents should be avoided either by reducing the accident risk or by reducing the injury risk. This should be done through measures pertaining to road construction aimed at site-specific, as well as non-site-specific traffic safety problems, by making the road and its surroundings forgiving and self-explanatory. This is recommended as it is advantageous to strive at minimizing the site-specific, as well as non-site-specific problems by using road engineering measures

In the grey road section work it is recommended to take the traditional procedure as a starting point so that the work consists of different phases. Considering possible alternative procedures, applying this procedure complies best with the objective of the project and the formulated philosophy.


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## Category and severity based methods

Based on the results from the literature studies and the interview study a method for identification of grey roads sections is developed. This method will be described in the following.

### Identification principle

It is recommended that identification based on category and severity is made in such a way that the importance of the design of the road and traffic as such, as well as the severity of the accidents are taken into consideration.

Even though model based identification methods are to be preferred in theory, the development of a category based identification method will contribute with a substantial improvement of method in relation to the identification methods of grey road sections presently applied by the Danish road administration authorities. Likewise, the systematic inclusion of the severity of the accidents will be an improvement compared to the present methods and practices.

The identification as such is made based on a ranking taking into account the reduction potential index, RPI, of the road sections, which cf. table 1, is estimated as the absolute difference between the recorded accident cost weighted density of accidents for the given road section, and the average accident cost weighted density of accidents for the category to which the road section belongs.

The calculation of recorded and average accident cost weighted density of accidents is based on the formula stated in table 1. Thus the calculation comprises density of accidents with severe personal injury, minor personal injury and damage to property, weighted according to the average accident costs for the three categories of accidents for the given road and traffic categories.

### Identification criterion

By way of the absolute difference between recorded and average accident cost weighted density of accidents, the grey road sections are identified based on potential reduction of accidents. This is the obtainable reduction of accidents, if the road section in question after improvement reaches an average level of accidents. Among the different principles for identification criterion the potential reduction of accidents is recommended, as it immediately ensures the largest accident saving. In addition, the criterion creates focus on local and road section based risk factors, as well as probably yielding the most cost efficient traffic safety work.

The identification criterion itself is that the reduction potential index is to be larger than four. This applies to all road administration authorities and all road and traffic categories. Thus a common identification criterion is recommendable. This gives a mutual understanding of the concept, gives the highest impact vis-à-vis politicians, makes identifications comparable and contributes to ensuring that the road sections identified are true grey road sections. One of the reasons is that a common identification criterion would prevent the single road administration authorities from downgrading the identification criterion, which would increase the risk of identifying false grey road sections, in order to have more road sections to work with.

It is a tricky balancing act to determine the identification criterion. On the one hand it is important to identify all the true grey roads and on the other it is important to minimize the number of false grey road sections in the identification. A high identification criterion is recommended because the identification method developed only to a certain extent takes into consideration the random variation of the accidents. By using a high identification criterion identifying false grey road sections should be avoided.

### Accident period and data

It is recommended that the identification is based on police-recorded accidents involving personal injury and damage to property from the official accident statistics of the latest 5-year period.


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As for accident data it will, due to a low and lop-sided contribution ratio in the official accident statistics, however, be recommendable to supplement with accident data recorded at the emergency wards. Here there is a need for developing a mutual and nationwide system for supplementary recording of this data.

For accident data it further applies that accidents in towns and major intersections, which are used as subdivision points in the break-down of road sections are to be sorted out. Likewise, accidents in black spots are to be sorted out, but accidents in black road sections should be included.

A 5-year accident period is recommended, as it will better balance on the one hand a reliable identification based on as much accident data as possible, and on the other an actual one which is not influenced by general tendencies and specific changes at the given sites.

**Reduction potential index:**

$$RPI = RWACD - AWACD$$

**Accident cost weighted density of accidents:**

$$WACD = (W(k)_{acc,ser.} \cdot ACD_{acc,ser.}) + (W(k)_{acc,min.} \cdot ACD_{acc,min.}) + (W(k)_{acc,prop.} \cdot ACD_{acc,prop.})$$

**Weights:**

$$W_{acc,ser.} = \frac{AC_{acc,ser.}}{AC_{acc,prop.}},\ W_{acc,min.} = \frac{AC_{acc,min.}}{AC_{acc,prop.}},\ W_{acc,prop.} = \frac{AC_{acc,prop.}}{AC_{acc,prop.}}$$

**Accident costs:**

$$AC_{acc,ser.} = (CP_{kiled} \cdot x_{killed}) + (CP_{ser.} \cdot x_{ser.}) + (CP_{min.} \cdot x_{min.}) + CPr_{acc.}$$
$$AC_{acc,min.} = (CP_{min.} \cdot x_{min.}) + CPr_{acc.}$$
$$AC_{acc,prop.} = CPr_{acc}$$

**Explanatory notes:**

| | |
|---|---|
| RPI: | Reduction potential index = -6,98-13,70 (0) |
| RWACD: | Recorded accident cost weighted accident density for the given road section = 0-20,75 (3,50) |
| AWACD: | Average accident cost weighted accident density for the given category k = 0,96-11,85 (4,29) |
| WACD: | Accident cost weighted accident density, recorded or average |
| $ACD_{acc,ser}$: | Recorded or average accident density for accidents with persons killed and serious injuries |
| $ACD_{acc,min}$: | Recorded or average accident density for accidents with minor personal injuries |
| $ACD_{acc,prop.}$: | Recorded or average accident density for accidents with property damage |
| $W(k)_{acc,ser}$: | Weight of accidents with persons killed and serious injuries for category k = 17,9-79.3 (36,3) |
| $W(k)_{acc,min.}$: | Weight of accidents with minor personal injuries for category k = 4,2-6,2 (5,1) |
| $W(k)_{acc,prop.}$: | Weight of accidents with property damage for category k = 1 |
| $AC_{acc,ser}$: | Accident costs for accidents with people killed and serious injuries = 1.790.000-7.930.000 DKK |
| $AC_{acc,min.}$: | Accident costs for accidents with minor personal injuries = 420.000-620.000 DKK |
| $AC_{acc,prop.}$: | Accident costs for accidents with property damage = 100.000 DKK |
| $CP_{killed}$: | Costs related to people per person reported killed = 10.404.000 DKK |
| $CP_{ser.}$: | Costs related to people per person reported seriously injured = 1.085.000 DKK |
| $CP_{min.}$: | Costs related to people per person reported with minor injuries = 295.000 DKK |
| $CPr_{acc}$: | Costs related to property damage per accident = 100.000 DKK |
| $x_{killed}$: | Number of people killed per accident of the given severity category |
| $x_{ser.}$: | Number of people with serious injuries per accident of the given severity category |
| $x_{min.}$: | Number of people with minor injuries per accident of the given severity category |

Table 1. Formulae for calculating the reduction potential index and recorded and average accident cost weighted density of accidents. In addition, specification of estimated values, where brackets indicate mean value. The values for RPI and RWACD are indicated based on results from the specific case.


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**Severity**

One of the most important purposes of developing the method for the identification of grey road sections is to involve the severity of the accidents on a systematic and larger scale than previously.

Despite the fact that the objective specifically relates to personal injuries, it is recommended that accidents are taken as the starting point rather than personal injuries. The reason for this is that the number of personal injuries may be determined by coincidence and parameters which lie outside the road administration authorities' site-specific traffic safety work. As an example could be mentioned number of persons in the vehicles in question as well as lack of using the safety features.

The severity of the accidents is included by categorizing them in accidents with severe personal injuries, minor personal injuries and accidents with damage to property. These accidents are weighted on the basis of the average number of persons injured of varying severity in the three severity categories in each of the 50 defined road and traffic categories, and the average accident costs, connected with these personal injuries, cf. table 1.

Accidents of the same degree of severity have, in principle, cf. table 1, varying severity by way of different average number of persons injured per accident in the different road and traffic categories. Different weights have been used for the 50 road and traffic categories in order to take this into consideration.

In the accident costs related to people the unit prices, from a traffic economic perspective, for deaths, serious injuries and minor injuries are taken as the starting point, cf. table 1. However, for the accident costs related to damage to property the starting point is a combination of traffic economic unit prices and property related insurance settlements for road vehicle accidents. This combination is found to be necessary as the method used for the calculation of the traffic economic unit prices related to property make them unsuitable to be used as basis for weighting.

**Breakdown and length of road sections**

The road system is broken down into sections of approximately equal road and traffic category. That is to say that the road sections must be homogenous regarding average daily traffic, category of net, number of wheel tracks, ribbon building, speed limit and presence of bicycle lanes and side strips.

Towns, excluding towns with blue town signs, and major intersections where state and county roads cross should initially be used as categorizing points in order to reach a comprehensible breakdown. In order to ensure homogenous sections, changes in road and traffic categories should subsequently be used as categorizing points.

In order to make sure that the sections are homogenous, the sections may have different lengths. Here it is recommended that the length of the road sections varies from 2 to 10 km.

The argument for the minimum length is that the sections are not to be so short that the grey road section work will resemble the black spot work. Additionally, the road sections are to 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.

The argument for the maximum length is that the sections should not to be too long, as the consequence may be that shorter part 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. It may, likewise, in the analysing phase be difficult to get an overview of very long sections, and long sections may also be very expensive to improve, if the given precautionary measures are to be carried out in the total length of the road section.


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**Definition**

Based on the identification method developed, it is recommended that the professional definition of grey road sections in the general road system in the open land is the following:

*2-10 km long, homogenous road sections between towns and major intersections, where the reduction potential index calculated as the difference between the recorded and the average accident cost weighted accident density for the given road and traffic category is larger than four.*

For the sake of obtaining a satisfactory and operational definition a professional wording of the definition, which is primarily intended for use among experts, is necessary. A more popular version of the definition, which can be used in connection with communication with non-specialists, could e.g. be: Road sections where the potential for realising a reduction of the most serious accidents is the largest.

**Category analysis**

In order to be able to carry out the recommended category and severity based grey road section identification, it is necessary to make a category analysis, where the road system is broken down into a series of categories, for which the average accident cost weighted accident density is estimated.

Based on the 5-year accident period 2000-2004 such an analysis has been made for state and county roads in the rural areas in the whole country, excluding county roads in Copenhagen County. The analysis comprises 9,707 km roads, which have been broken down into 7,313 part sections. In this road network 15,826 accidents have been recorded, of which 8,354 are accidents involving personal injury, resulting in 13,025 people injured.

Based on the parameters related to roads: type of net, number of lanes, ribbon building, speed limit and the presence of bicycle lanes and side strips, this road network has been broken down into 11 road categories, which subsequently, on the basis of the amount of traffic, have been subdivided into 50 road and traffic categories. Table 2 indicates how the 11 road categories and 50 categories are defined, and what the estimated average accident cost weighted accident density for the 50 categories is.

<table>
<tr><th rowspan="5">Road category</th><th rowspan="5">Free-way</th><th rowspan="5">Motor way</th><th colspan="9">Other roads</th></tr>
<tr><th rowspan="4">4 lanes</th><th rowspan="4">3 lanes</th><th colspan="8">2 lanes</th></tr>
<tr><th rowspan="3">Rib-bon</th><th colspan="7">No ribbon</th></tr>
<tr><th rowspan="2">60 km/h</th><th rowspan="2">70 km/h</th><th colspan="5">80 km/h</th></tr>
<tr><th>Side strip</th><th>One-way bicycle lanes</th><th>Double bicycle lane</th><th>None</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td></tr>
<tr><td>Under 1.000</td><td rowspan="3">0,96</td><td rowspan="2">1,72</td><td rowspan="4">6,77</td><td rowspan="3">3,44*</td><td>3,52*</td><td>3,51</td><td>5,28*</td><td>1,19</td><td rowspan="2">2,67</td><td rowspan="2">2,05</td><td>1,01</td></tr>
<tr><td>1.000-2.999</td><td>2,05</td><td>2,25</td></tr>
<tr><td>3.000-4.999</td><td>2,80*</td><td>4,27*</td><td>7,18*</td><td>3,89</td><td>3,95*</td><td>4,03</td><td>3,67*</td></tr>
<tr><td>5.000-6.999</td><td>4,12</td><td>6,61*</td><td>6,28</td><td>5,98</td><td>11,47*</td><td>4,75</td><td>4,44</td><td>5,00</td><td rowspan="5">6,10</td></tr>
<tr><td>7.000-9.999</td><td>1,39</td><td>6,32*</td><td rowspan="4">4,46</td><td>8,80*</td><td rowspan="4">8,57</td><td>7,39*</td><td>6,93*</td><td>7,02</td><td>6,95*</td></tr>
<tr><td>10.000-14.999</td><td>2,39</td><td>10,08*</td><td>11,17*</td><td rowspan="3">9,16</td><td rowspan="3">6,74</td><td rowspan="3">7,72</td><td rowspan="3">7,85</td><td rowspan="3">10,41</td></tr>
<tr><td>15.000-30.000</td><td>5,60</td><td rowspan="2">9,39</td><td>11,85</td></tr>
<tr><td>Over 30.000</td><td>9,76</td></tr>
</table>

Table 2. The breakdown of the road network on the basis of parameters related to roads and average daily traffic in vehicles per day and the average cost accident weighted accident density for the 50 categories. * indicates that the average accident cost weighted accident density should be subject to some reservation, as the value indicated does not differ significantly from the value of the following category.


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Statistical tests of the average accident cost weighted accident densities have been made. Here it was found that among 39 relevant combinations of comparisons in pairs, there is no significant difference in the values of 17 combinations, when testing at a significance level of 0.1. It is, cf. table 2, especially road categories 7 and 4 which pose problems.

## Identification of grey road sections in Ringkøbing and Viborg counties

Based on the methods developed, specific identification of grey road sections have been made on the county road in Ringkøbing and Viborg counties. The purpose has been to have the method tested and demonstrated, and on this basis to be able to make an assessment of the method.

| | | Ringkøbing | Viborg | Total |
|---|---|---|---|---|
| **Road network** | **Total (km)** | 891 | 798 | 1.689 |
| | **In the analysis (km)** | 816 | 745 | 1.561 |
| | **Number of road sections** | 146 | 144 | 290 |
| **Section length** | **Average length (km)** | 5,6 | 5,2 | 5,4 |
| | **Percentage below 2 km (%)** | 7,5 | 7,6 | 7,6 |
| | **Percentage above 10 km (%)** | 10,3 | 5,6 | 7,9 |
| **Most abundant reason to division** | **Start or ending (%)** | 37 | 37 | 37 |
| | **Town (%)** | 23 | 19 | 21 |
| | **Main intersection (%)** | 15 | 16 | 15 |
| **Most abundant category** | **8.2 (%)** | 37 | 36 | 37 |
| | **8.3 (%)** | 30 | 19 | 24 |
| | **8.4 (%)** | 15 | 17 | 16 |
| **Homogeneity** | **Homogenous (%)** | 53 | 56 | 54 |
| | **Almost homogenous (%)** | 44 | 38 | 41 |
| | **Non-homogenous (%)** | 3 | 6 | 5 |

Table 3. Main results of the division of road network into sections in Ringkøbing and Viborg counties.

Initially the road system is broken down into sections. The mail result of this division is given in table 3. The county road network in the two counties is in total 1.689 km. In the analysis only sections located in the open land are included, and the length of the road network in the analysis is thus 1,561 km. These roads have been divided into 290 road sections, corresponding to an average length of 5.4 km. It is recommended that sections should have a length of between 2 and 10 km, however among the subdivided sections 8 % are shorter than 2 km, and 8 % longer than 10 km.

The most frequent reason for division is that a road section starts or ends. Then follow towns, major intersections, changes in road categories or categories or the fact that the road is crossing a county boarder.

About 77 % of the sections belong to category 8.2, 8.3 or 8.4. 55 % of the sections are homogenous, which means that they belong to the same category on more than 99 % of the length of the section. 40 %, however, are only almost homogenous. This means that on 1-20 % of the length of the section they contain other categories than the one indicated, typically in the form of short subdivided sections with ribbon building or local speed limits. Finally, 5 % of the sections are non-homogenous in the way that the section consists of two or more categories, which all account for more than 20 % of the length of the section. The criteria for section length and use of a defined method for division of the road network into sections are thus compatible for about 85 % of the road network.

The reduction potential index has been estimated for the total of the 290 sections, and sections where the reduction potential index is larger than four have been identified as grey road sections. The estimated reduction potential indexes are illustrated in figure 1 and figure 2 and some characteristics for the grey roads section are summarized in table 4 and table 5.

A total of 12 grey road sections in Ringkøbing County and six grey road sections in Viborg County have been identified. The reduction potential indexes of the sections identified are between 4.0 and 13.7 in Ringkøbing County and between 4.2 and 8.5 in Viborg Country.


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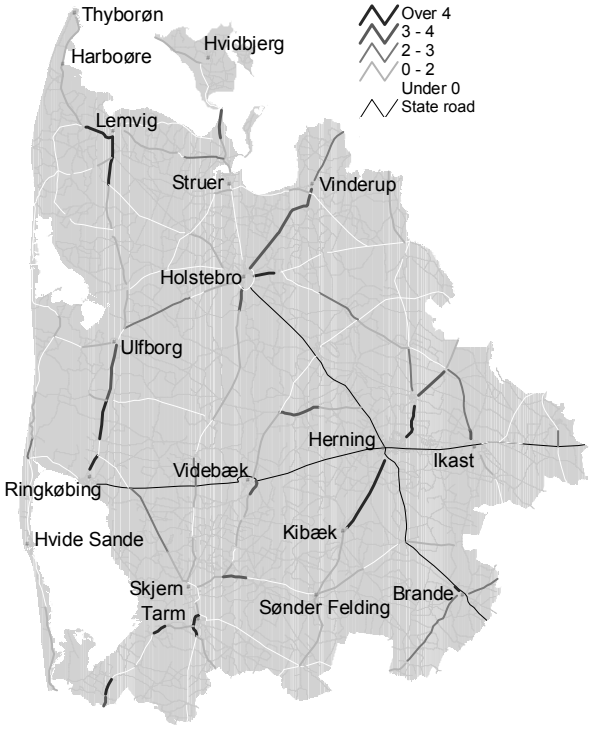


Figure 1. Reduction potential index for the 146 road sections on the county road network in Ringkøbing county.

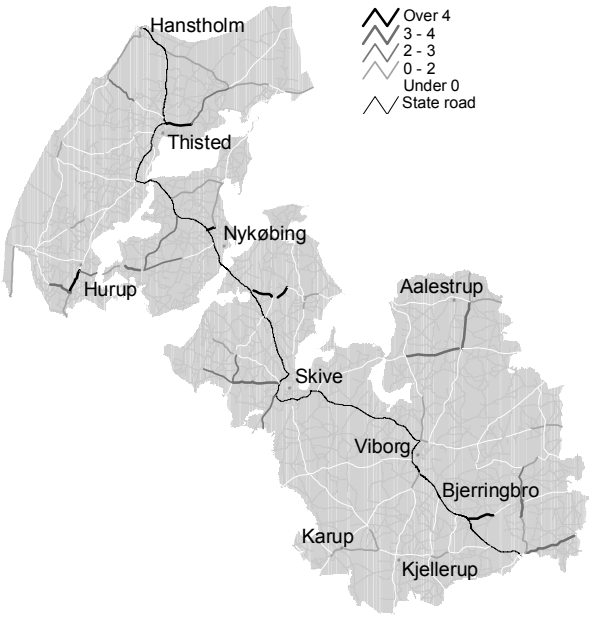


Figure 2. Reduction potential index for the 144 road sections on the county road network in Viborg county.

| Name | Road | From | To | Length | Category | ADT | Homogeneity | Accidents | injuries | RPI |
|---|---|---|---|---|---|---|---|---|---|---|
| Ulfborg-Lemvig | 502 | 49,011 | 51,800 | 2,8 | 8.4 | 6.200 | Almost | 12 | 10 | 13,7 |
| Viborg-Holstebro | 417 | 46,940 | 49,693 | 2,8 | 10.5 | 10.600 | Almost | 18 | 16 | 10,3 |
| Viborg-Herning | 439 | 38,923 | 44,770 | 5,8 | 10.5 | 10.700 | Almost | 26 | 44 | 8,7 |
| Tarm-Nr. Nebel | 521 | 16,258 | 18,750 | 2,5 | 8.2 | 2.500 | Almost | 5 | 11 | 8,3 |
| Skjern-Varde | 333 | 28,191 | 31,295 | 3,5 | 8.3 | 4.000 | Almost | 8 | 14 | 8,2 |
| Lemvig-Thyborøn | 476 | 0,126 | 4,125 | 4,0 | 8.4 | 5.900 | Almost | 13 | 10 | 7,3 |
| Ulfborg-Lemvig | 502 | 45,108 | 48,957 | 3,8 | 8.3 | 4.500 | Yes | 9 | 6 | 6,6 |
| Ringkøbing-Holstebro | 418 | 1,805 | 4,274 | 2,5 | 8.3 | 4.700 | Almost | 7 | 4 | 6,0 |
| Tarm-Nr. Nebel | 521 | 5,176 | 6,840 | 1,7 | 10.2 | 3.600 | Yes | 3 | 3 | 6,0 |
| Brande Nord | 559 | 41,602 | 42,520 | 0,9 | 8.3 | 3.200 | Almost | 3 | 1 | 5,1 |
| Herning-Varde | 370 | 1,000 | 11,961 | 10,9 | 8.4 | 6.800 | Almost | 41 | 60 | 4,8 |
| Ringkøbing-Holstebro | 418 | 6,990 | 12,481 | 5,5 | 8.4 | 5.600 | Yes | 12 | 14 | 4,0 |

Table 4. Characteristic of the 12 identified grey road sections in Ringkøbing County. The sections are ranked after RPI.

| Name | Road | From | To | Length | Category | ADT | Homogeneity | Accidents | injuries | RPI |
|---|---|---|---|---|---|---|---|---|---|---|
| Nykøbing-Elsø | 614 | 3,478 | 4,731 | 1,3 | 8.2 | 2.500 | Yes | 6 | 2 | 8,5 |
| Harre-Roslev | 531 | 0,794 | 3,227 | 2,9 | 8.2 | 1,500 | Yes | 7 | 7 | 6,5 |
| Thisted-Fjerritslev | 427 | 0,000 | 4,300 | 4,3 | 8.3 | 4.500 | Yes | 14 | 10 | 5,7 |
| Ulstrup-Rødkærsbro | 546 | 34,164 | 38,738 | 4,6 | Mixed | 4.200 | No | 8 | 7 | 5,2 |
| Thisted-Oddesund | 426 | 29,462 | 33,566 | 4,1 | 8.3 | 3.900 | Yes | 10 | 9 | 4,3 |
| Vium-Sundsøre | 472 | 4,882 | 7,135 | 2,3 | 11.2 | 1.600 | Yes | 4 | 4 | 4,2 |

Table 5. Characteristic of the six identified grey road sections in Viborg County. The sections are ranked after RPI.

The 18 grey road sections correspond to 6 % of the 290 road sections being identified. The average length, however, of the sections identified, is only 3.4 km, which means that only 66 km of the road network in the analysis have been identified. This corresponds to 4 % of the total length of the road network in the analysis.

For both counties it applies that the grey road sections primarily belong to categories 8.2 and 8.3. Half the road sections identified are homogenous, while the rest are either almost homogenous or non-homogenous.

## Assessment of the methods

Based on the results from the specific identification of grey road sections in Ringkøbing and Viborg counties, supplementary analyses and results from subsequent accident analyses and road inspections of four selected grey road sections an assessment has been made of the described philosophy for the grey road section work and the method for identification.

The assessment of the identification method developed consists of a total of 10 different part assessments. The results from the most important assessments are summarized in the following. The assessment focuses on reported accidents on the identified grey road sections, comparison with alternative identification methods and assessment based on the results from the analysis and improvement phases of the grey road section work.

### Accidents on the grey road sections

For the grey road sections it applies that their accident density on an average is 2.9 times higher than the average level, while the density of fatal accidents and accidents with seriously injured people is 3.5 times higher than average. Thus, road sections with many accidents and especially many serious accidents have successfully been identified. The requirement for getting more focus on road sections with severe accidents is thus achieved.

Even though road sections with many serious accidents in general have been identified, thee are single sections, cf. table 4 and table 5 with only few reported accidents and personal injuries. It can therefore be considered to supplement the identification criterion used with a criterion that a certain minimum number of accidents and personal injuries during the identification period has to be reported. The argument for this is that the accident analysis has to be based on a minimum number of accidents to give valid results and to be assured that it is possible to get a reduction in the number and severity of accidents. Finally, it is important for pedagogical reasons.

On the other hand the accident analysis and road inspection in the grey road section work is more systemic than the traditional black spot work. Therefore, it is not to the same extent necessary to have a minimum number of accidents. Secondly, a supplemental criterion will result in a more complex and difficult identification procedure.

### Comparison with alternative rankings

For further assessment the identification method developed is compared with 10 alternative rankings. The 10 rankings are the following:

1. **RWACD/AWACD:** Ranking based on the ratio between recorded and average accident cost weighted accident density rather than absolute difference
2. **RWACD:** Ranking based on recorded accident cost weighted accident density without taking the average accident cost weighted accident density into account
3. **ACD:** Ranking based on recorded non-weighted accident density
4. **PIACD:** Ranking based on recorded non-weighted personal injury accident density
5. **SPIACD:** Ranking based on recorded non-weighted serious personal injury accident density
6. **ACF:** Ranking based on recorded non-weighted accident frequency
7. **PIACF:** Ranking based on recorded non-weighted personal injury accident frequency
8. **SPIACF:** Ranking based on recorded non-weighted serious personal injury accident frequency
9. **PIACD-EPIACD:** Ranking based on the absolute difference between expected and recorded personal injury accident density, where expected personal injury accident density is estimated by existing accident models
10. **PIACD/EPIACD:** Ranking based on the ratio between expected and recorded personal injury accident density, where expected personal injury accident density is estimated by existing accident models


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The comparison serves to purposes. The first purpose is to assess whether the identified grey road sections are also ranked high in the other rankings. This will indicate that the "right" road sections have been identified. The second purpose is to assess whether the identification method developed is "better" than the alternative rankings meaning by way of better identifying road sections where the potential to reduce the number of serious accidents is the greatest.

| | | RWACD/ AWACD | RWACD | ACD | PIACD | SPIACD | ACF | PIACF | SPIACF | PIACD-EPIACD | PIACD/EPIACD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Repetitions** | **R** | 7 | 11 | 6 | 7 | 10 | 2 | 3 | 5 | 8 | 6 |
| | **V** | 3 | 5 | 3 | 2 | 4 | 3 | 2 | 3 | 2 | 2 |
| **Ranking of grey road sections (%)** | **R** | 16 | 10 | 27 | 27 | 10 | 36 | 36 | 39 | 60 | 50 |
| | **V** | 8 | 8 | 16 | 14 | 7 | 31 | 31 | 17 | 22 | 26 |
| **Difference on ∑RPI for grey road sections (%)** | **R** | 25 | 1 | 54 | 20 | 9 | 101 | 102 | 51 | 19 | 28 |
| | **V** | 22 | 10 | 104 | 67 | 15 | 57 | 79 | 30 | 57 | 64 |

Table 6. Main results of the comparison between the recommended ranking and 10 alternative rankings. Repetitions specify the number of grey road sections, which also is ranked among the 12 highest ranked road sections in Ringkøbing County and among the six highest ranked road sections in Viborg County. Ranking of grey road sections specify in which percentage the grey road sections are found in the alternative rankings. Difference on ∑RPI specify how much the sum of RPI is higher in percentages for the grey road sections than the highest ranked section in the alternative ranking. R = Ringkøbing County and V = Viborg County.

The main result of the comparison is summarized in table 6. Is focus initially on the first eight alternative rankings it can be concluded that the grey road sections belong to those with the highest ratio between recorded and average accident cost weighted accident density (RWACD/AWACD), highest recorded accident cost weighted accident density (RWACD) and highest serious personal injury accident density (SPIACD). This indicates that it is the "right" road sections that have been identified in the method used. At the same time it can be concluded that the grey road sections are also ranked relatively high when ranking is based on traditional density and frequency of accident (ACD and ACF) and personal injury accident (PIACD and PIACF). With regard to comprehensibility, acceptance and implementation of method this is very important.

In addition the recommended method can be considered as better than the eight alternative rankings because the potential to reduce the number of serious accidents is highest on the grey road sections. The reduction potential index is thus 1-104 % higher on the grey road sections than on the highest ranked road sections in the eight alternative rankings. The rankings based on recorded accident cost weighted accident density (RWACD) and serious personal injury accident density (SPIACD) are, however, almost as good as the recommended method. Despite the fact that these rankings are more simple and easy to make, the method developed will still be recommended because there is a risk of identifying road sections with a low or in worst case negative reduction potential index in the ranking based on RWACD or SPIACD.

In the last two comparisons the identification of grey road sections have been compared with identifications based on the model estimated personal injury accident density. Here the conclusion is that there is a significant difference between the recommended and the model based identification methods. This is important because it, in principle, would not have been necessary to develop a new identification method if it gave the same result as the existing method. Secondly, it can be concluded that the category based method where severity systematically is taken into account is better than the model based method where severity only is taken into account to a very modest extent. It is thus very important that severity is taken into account in the category analysis or in the accident modelling.

About the assessment based on the summarized reduction potential index it is important to note that the reduction potential index by definition always will have the greatest value for the road sections identified by the recommended identification method because the ranking here is based on exactly the reduction potential index.


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**Analysis and suggestions for improvement work**

Among the 18 road sections identified, four road sections have been singled out for further analysis. The road sections are the following:

1. Ulfborg-Lemvig, road 502, stationing 49,011-51,800, Ringkøbing County
2. Ringkøbing-Holstebro, road 418, stationing 6,990-12,48, Ringkøbing County
3. Harre-Roslev, road 531, stationing 0,794-3,227, Viborg County
4. Thisted-Fjerritslev, road 427, stationing 0,000-4,300, Viborg County

In order to test and demonstrate the methods under various conditions, the four analysis sections have been singled out, in such a way that they differ in character regarding length, category, number of accidents and personal injuries, reduction potential index, ranking and proportion of black spots and road sections.

The analysis itself consists of a general accident analysis, which is compared with "normal distribution of accidents", a rendering and analysis of so called extended collision charts, relevant road and traffic analyses and road inspections. Analysis and road inspection was made in a cooperation with traffic safety employees from Ringkøbing and Viborg Counties. In the PhD-thesis (Sørensen 2006) there is further information on the analysing methods and the result of the analysis of the four road section.

On the four road sections several faults and deficiencies with regard to traffic safety were identified and different solutions to eliminate or minimize the problems are proposed. If the problems identified, however, are examined according to how they are identified the, conclusion is that they mostly are identified in the road inspection and to a minor extent through the accident analysis.

At the same time a similar examination of the solutions proposed shows that a majority 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. This is summarized in table 7. Here it is shown that among the 54 overall proposed solutions only one quarter relates to the recorded accidents, while the remaining three-quarters have nothing directly to do with the accidents.

An illustrative example of this problem is the analysis of road section 4. Here most of the accidents happened in intersections on the road section, but according to the results from the road inspection the proposed solutions are mainly focused on problems on the road sections between the intersections, while only a few minor errors, deficiencies and inexpediencies in the intersections are identified.

| **Analyses road section** | **1** | **2** | **3** | **4** | **Total** |
|---|---|---|---|---|---|
| **Remedial and preventive** | 7 | 3 | 1 | 3 | 14 |
| **Only preventive** | 9 | 11 | 7 | 13 | 40 |

Table 7. The number of solutions proposed on the four road sections analysed which have remedial and preventive nature or only have preventive nature.

Subject to only four road sections being analysed, this shows that it is very difficult to find local and road section based accident factors on the identified grey road sections according to the accident history. The analysis of the road sections is thereby to a greater degree in the nature of a general road examination with special attention on standard improvements rather than restoration of local and road section based accident factors.

## Conclusion

During the last 10 years the grey road section work has increased in the Danish road administration authorities' site-specific traffic safety work. However, a common and unambiguous definition


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of the concept does not exist, an overall philosophy has not been formulated, and common, formalized and operational methods for the identification, analysis and improvement of these road sections have not been established.

In this paper an overall philosophy for the grey road section work has therefore been formulated. At the same time a method for identification of grey road sections on main roads in rural areas have been developed, tested and assessed.

A category and severity based method for identifying grey road sections has been developed. In overall terms, the analyses and assessments made of the identification method point in the direction that the road administration authorities through the identification method developed will have a reliable and practicable method at their disposal for the identification of grey road sections, which is better than the identification options, which the Danish road administration authorities have at the present moment.

However, the actual accident analyses and road inspections show that it based on the recorded accidents is very difficult to identify site-specific local accident and damage factors on the grey road sections. The analysis of the road sections thereby gets the nature of being a general road examination with special attention on standard improvements. In relation to the formulated philosophy for the grey road section work where it is attempted to combine the principle in black spot action and the principle in mass action this is a problem. The problem is that a prime requisite for the formulated philosophy is that there is correlation between the identification, analysis and improvement phases, which in practice is probably not the case.

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 than the accident based identification method developed, for instance a non accident based method.

The desirability to let the grey road section work be part of the site-specific traffic safety work can thus be questioned because the resources probably can be used in a better way for road examination and standard improvements.

## Literature

**Sørensen 2006:** ”Grå strækninger i det åbne land - Udvikling, anvendelse og vurdering af alvorlighedsbaseret metode til udpegning, analyse og udbedring af grå strækninger” (Hazardous road sections in rural areas – development, application and assessment of severity based methods for identification, analysis and improvement of hazardous road sections), Sørensen, Michael, PhD-thesis, Traffic Research Group, Division of Urban Planning, Roads and Traffic, Department of Development and Planning, Aalborg University, August 2006.