Rune Elvik
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Institute of Transport Economics
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Road safety inspections: safety effects and best practice guidelines

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Rune Elvik

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Road safety inspections; Knowledge; Evaluation; Effects; Best practice guidelines

Summary:
The report presents the current state of knowledge regarding the practice and safety effects of road safety inspections. It is concluded that road safety inspections are likely to contribute to improving road safety. Based on this knowledge, preliminary guidelines for best practice are proposed.

Tittel: Trafikksikkerhetsinspeksjoner: effekter og retningslinjer for god praksis

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Sammendrag:
Rapporten presenterer dagens praksis og kunnskaper om effekter av trafikksikkerhetsinspeksjoner. Det konkluderes med at slike inspeksjoner kan bidra til å bedre trafikksikkerheten. På grunnlag av disse kunnskapene foreslås foreløpige retningslinjer for god praksis med hensyn til trafikksikkerhetsinspeksjoner

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Preface

This report is part of work package 5 of RIPCORD-ISEREST. It deals with the safety effects of road safety inspections.

The report has been written by Rune Elvik. Comments on an earlier draft have been provided by the members of work package 5 of RIPCORD-ISEREST. We thank all those who have commented the report and provided input to it. Quality checking of the final report was done by head-of-department Marika Kolbenstvedt. Secretary Trude Rømming prepared the text for printing.

Oslo, December 2006
Institute of Transport Economics

Lasse Fridstrøm
managing director

Marika Kolbenstvedt
head of department

Contents

TØI report 850/2006
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Oslo 2006, 25 pages

Summary:

Road safety inspections: safety effects and best practice guidelines

This report describes current practice and knowledge regarding the safety effects of road safety inspections. A road safety inspection is a systematic inspection of an existing road for the purpose of identifying traffic hazards and propose measures to correct these defects.

It is concluded that road safety inspections are targeted at elements that are known to be risk factors for accident occurrence or injury severity. Furthermore, it is concluded that road safety inspections lead to proposals for measures designed to correct the hazards identified. If these measures are carried out, one may normally expect road safety to be improved. This conclusion is based mainly on the Handbook of Road Safety Measures (Elvik and Vaa 2004), as very few evaluations of the effects of road safety inspections have been reported.

To be an effective instrument in road safety management, road safety inspections should identify known traffic hazards, should propose treatments of these and should ensure that these treatments are actually carried out. The possibility of developing best practice guidelines for road safety inspections is discussed. Some preliminary general guidelines are proposed. The details of inspections must, however, be adapted to the specific conditions of each country. There does therefore not seem to be a need for developing very detailed guidelines at the international level. An exchange between countries of experiences made is strongly encouraged.

The report can be ordered from:
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Sammendrag:

Trafikksikkerhetsinspeksjoner: effekter og retningslinjer for god praksis

Denne rapporten beskriver dagens kunnskaper om effekter på trafikksikkerheten av trafikksikkerhetsinspeksjoner. En trafikksikkerhetsinspeksjon er en systematisk granskning av sikkerheten på en eksisterende veg, med sikte på å identifisere faktorer knyttet til vegutforming, vegens omgivelser eller trafikkregulering som utgjør risikofaktorer for ulykker eller personskader. Trafikksikkerhetsinspeksjoner kan betraktes som en videreføring av trafikksikkerhetsrevisjoner; sistnevnte er et tiltak som er begrenset til vegplanleggingsfasen.

På grunnlag av norske erfaringer, kan det fastslås at trafikksikkerhetsinspeksjoner i stor grad kan identifisere risikofaktorer knyttet til vegutforming, vegens omgivelser eller trafikkreguleringen. Tiltak som kan fjerne disse risikofaktorene, eller redusere deres effekter, blir ofte også foreslått i trafikksikkerhetsinspeksjoner. Hvis de foreslåtte tiltakene blir gjennomført, er det grunn til å tro at trafikksikkerheten kan bedres. Denne konklusjonen bygger i hovedsak på Trafikksikkerhetshåndboken. Det foreligger få undersøkelser som direkte har evaluert effektene av trafikksikkerhetsinspeksjoner.

For å være et nyttig hjelpemiddel i sikkerhetsstyring av vegnettet, må trafikksikkerhetsinspeksjoner være rettet mot kjente risikofaktorer og foreslå utbedring av disse. Det må videre finnes et oppfølgingssystem som sikrer at de foreslåtte tiltakene faktisk blir gjennomført. I rapporten drøftes grunnlaget for å utarbeide retningslinjer for god praksis med hensyn til trafikksikkerhetsinspeksjoner. Det er mulig å gi visse generelle retningslinjer, men inspeksjonene må tilpasses stedlige forhold. Det synes derfor heller tvilsomt om veldig detaljerte retningslinjer på et internasjonalt nivå har så mye for seg. Det vil derimot være nyttig med en internasjonal utveksling av erfaringer med trafikksikkerhetsinspeksjoner.

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1 Background and research problem

Road safety inspections are increasingly used as a part of road safety management. A road safety inspection is a systematic assessment of the safety standard of an existing road, in particular with respect to hazards related to traffic signs, roadside features, environmental risk factors and road surface condition. The objective of a road safety inspection is to identify traffic hazards and suggest measures to correct these hazards. Road safety inspections are, to a large extent, based on similar checklists and procedures as those applied in road safety audits. Road safety audits are applied during the planning of new roads, whereas road safety inspections are carried out on existing roads. A review of the current practice of road safety inspections in Europe has been presented by Nadler and Lutschounig (2006).

This report has two objectives. The first is to summarise knowledge regarding current practice and safety effects of road safety inspections. The second is to propose best practice guidelines for road safety inspections. These objectives are closely related. If certain elements of road safety inspections are found to be more important for safety than others, these elements should be emphasised in guidelines designed to promote best practice. The main questions that are discussed in the report are:

1. Do road safety inspections address hazards that are known to contribute to accidents or injuries?
2. Do road safety inspections successfully identify hazards? What are the most common road safety problems pointed out in road safety inspections?
3. Do road safety inspections result in measures designed to correct defects or remove traffic hazards that have been identified by inspectors?
4. Are the safety treatments introduced as a result of road safety inspections effective in improving road safety?
5. What guidelines for best practice with respect to road safety inspections can be proposed on the basis of current practice and knowledge of the safety effects of road safety inspections?

These questions refer to stages of a causal chain that determines the effects of road safety inspections. This causal chain is shown in Figure 1.

The first stage of the chain refers to the targets of road safety inspections. Road safety inspections should be targeted at known traffic hazards.

The second stage refers to the outcome of road safety inspections. If a road safety inspection does not identify any correctable traffic hazards, it is unlikely that it will lead to measures designed to improve safety.

Thirdly, measures that are proposed to improve safety must be implemented, otherwise safety may not improve as intended.

Finally, the safety measures that are carried out as a result of road safety inspections must be effective in improving road safety. The fact that a measure is targeted at a known traffic hazard is a necessary, but not sufficient condition for it to improve road safety. Measures taken to improve safety must not only influence target risk factors favourably, but should not elicit unfavourable changes in other risk factors, that are not the primary target of the measures.

Stage 1	Road safety inspections should be targeted at hazards known to be risk factors for accidents or injuries
Stage 2	Reports from road safety inspections should identify treatable traffic hazards and propose corrective measures
Stage 3	There should be a check that the measures proposed by road safety inspectors are actually implemented
Stage 4	Measures implemented as a result of road safety inspection should not elicit behavioural adaptations that offset the intended effects of the measures

Figure 1: Stages of road safety inspections and their intended effects on road safety

This report presents a first attempt to evaluate the safety effects of road safety inspections. It is not based on an extensive literature survey, but relies on easily available studies to illustrate key points. As more studies of the actual impacts of road safety inspections become available, a more comprehensive evaluation will be possible.

It should be noted that the current practice of road safety inspections differs in many respects between different European countries. There is therefore a need for identifying best practice, or at least good practice with respect to road safety inspections.

2 Risk factors surveyed in road safety inspections

The items that are covered in road safety inspections may vary from one country to the other. This chapter briefly presents the items addressed in Austria, Germany, Norway and Portugal.

2.1 Austria

In Austria, the first pilot cases of road safety inspections (RSI) began in 2003. Until now, around 270 km of the Austrian motorway network have been inspected and some are still under inspection. Since the implementation of this new road infrastructure management tool, the RSI-instrument has been fully accepted by the Austrian Ministry of Transport as well as by the motorway operator ASFINAG. The adaptation of RSI for the secondary road network and the draft of a national guideline on RSI are currently under preparation.

Table 1 shows a check list used in Austria for road safety inspection of a motorway. The table shows both the items included in the inspection and the results of it.

The inspection included highway design parameters, an analysis of traffic operations, light conditions, weather management and the surroundings of the road. Each item was rated as highly important, of middle importance or of low importance for road safety. For each item rated as highly important, measures were proposed to reduce the hazard associated with the problem. Some of the measures proposed require a more extensive follow-up study before they can be developed into final form and implemented.

The measures proposed are typically low-cost measures that can be implemented on short notice and do not require the acquisition of more land or extensive planning. Most of the items covered by the inspection are known to be traffic hazards. This applies, for example, to sight restrictions (Elvik and Vaa 2004), curve radius on entry ramps (Erke 2006) speed (Elvik, Christensen and Amundsen 2004), rain, snow or ice (Elvik and Vaa 2004) and fog.

Items that were rated as unimportant refer to traffic hazards that are not present on this particular road, like roadside development, or to potential traffic hazards that were found to be in good conditions, like road markings. Similar tables were prepared for other sections of the inspected motorway, but are not shown here, as they are identical to Table 1 (in terms of the items included and the way these were assessed).

Table 1: Check list used in road safety inspection of motorway in Austria

A 8 - Innkreisautobahn	**Relevance for safety**			**Road safety analysis**	**Measures**
	High	**Mid**	**Low**		
Highway design parameters	**x**				
Design in general			x		
Alignment		x		Radius of transition curve too small	
Cross section, including shoulders	x			Narrow shoulders as a result of maintenance work, drainage problems, etc.	Broader shoulders and transverse grooves to improve drainage
Sight conditions	x			Restricted sight, in particular in curves to the right	Provision of adequate sight distances
Service areas	x			Unsafe exit from parking space at km 21	Upgrading the exit area
Entry ramps		x		Small curve radius and too short sight distances	
Pavement condition		**x**		Km 19,0 - km 19,5: poor road surface condition	
Analysis of traffic operations	**x**				
Speed	x			Not measured	More enforcement and variable speed limits
Traffic volume		x		AADT: 23.600	
Heavy vehicle volume	x			AADT: 7.200 (31%)	
Light conditions		**x**			
Dazzle from sun			x	Not a problem	
Dazzle at night		x		Possibly a problem	Anti dazzle screen on median guard rail
Surrounding lights			x	Not relevant	
Road lighting				Not relevant	
Traffic control devices			**x**		
Traffic signs			x	Not a problem	
Destination signs		x		Parking space not properly signed	Upgrade signing
Road markings			x	Unimportant	
Plants			x	Unimportant	
Elements in the dark			x	Unimportant	
Directional devices			x	Unimportant	
Weather management		**x**			
Rain		x		46% of accidents on wet road surface	Speed is reduced during rain
Snow/ice			x	Unimportant	
Fog		x		Does not occur frequently	Attention to spots where fog may form
Surroundings of road			**x**		
Houses			x	Unimportant	
Information facilities			x	Unimportant	
Trees, bushes			x	Unimportant	

2.2 Germany

A draft set of guidelines for road safety inspections in Germany was published in 2006 (German road and transportation research association 2006). Road safety inspections have been performed for a long time in Germany. The guidelines now proposed formalise and standardise current practice.

There are three types of road safety inspections in Germany: (1) Regular, periodic inspections, (2) Special purpose inspections, and (3) Ad-hoc inspections. The regular inspections are performed on all roads – every second year on major roads and every fourth year on secondary and local roads. Special purpose inspections include night-time road safety inspections, railway crossing inspections, tunnel inspections, destination-sign inspections and inspections of other signs and traffic control devices. Ad-hoc road safety inspections are performed as the need arises and comprise signs and traffic control devices.

Table 2 represents an attempt to summarise the scope and contents of regular road safety inspections in Germany. It should be pointed out that no formal check list are in use for these inspections. Table 2 is not intended as a check list, but shows what inspections include.

Table 2: Items covered in road safety inspections in Germany and criteria for assessing each item

Main elements	Detailed elements	Criteria for assessment
Junctions	Field of vision in approaches	Adequate to see traffic signs and other road users
	Regulatory traffic signs	Necessity, location, condition, discernibility and consistency
	Traffic signals	Necessity, location, condition, discernibility and consistency
	Signs and marking indicating direction of travel	Necessity, location, condition, discernibility and consistency
	Other road markings	Necessity, location, condition, discernibility and consistency
	Destination and road-name signs	Necessity, location, condition, discernibility and consistency
Road sections	Hazardous areas	The observability of such areas for road users
	Unofficial signs and advertisement signs	If such signs are detrimental to road safety
	Speed limit signs	Necessity, location, condition, discernibility and consistency
	Signs prohibiting overtaking and corresponding road markings	Necessity, location, condition, discernibility and consistency
	Other road markings	Necessity, location, condition, discernibility and consistency
Edge of road and roadside environment	Parked vehicles or other obstacles in the field of vision in urban areas	Whether parked vehicles block road users' view
	Roadside area	Remove or protect any hazardous obstacles
	Passive safety installations and reflector posts	If they have a rational purpose, are in good condition and are correctly located

Road safety inspections in Germany are carried out by teams consisting of 5 to 8 people, often with different professional backgrounds. Each inspection is documented by means of a written report. Three months after an inspection, there is a progress review, designed to check progress in implementing safety measures proposed in inspections.

2.3 Norway

Norway has had road safety inspections since 1999. A revised set of guidelines for such inspections was recently published (Statens vegvesen 2005). Table 3 lists items that are surveyed in Norway, and indicates for each of them whether it is known to be a risk factor for accident occurrence or injury severity.

Not all items will be covered in all road safety inspections. Besides, not all items are described in sufficient detail to evaluate whether, based on general knowledge, they represent a risk factor or not. Most items addressed by road safety inspections do, however, appear to be known risk factors for accident occurrence or injury severity.

With respect to roadside obstacles, for example, trees, rock cuttings, rigid poles and unprotected bridge supports are all known to be associated with more serious injuries than guardrails when struck (Elvik 2001). The probability of fatal or serious injury would therefore normally be reduced by removing these fixed obstacles from the safety zone or by protecting them by means of guardrails if removing the obstacles is too costly or impractical. A poor design of guardrail endings may, however, be a significant risk factor on its own. Turned down ends, which have been common until recently, may act as a “rocket launching pad” when struck by a car – if the car rides up the slope and is thrown into the air. Hence, it is now recommended to flare out guardrail ends and attach them to the back slope, or to design guardrail ends as crash cushions (Elvik and Vaa 2004).

As far as the road itself is concerned, poor alignment increases the accident rate (Elvik and Vaa 2004). Darkness is known to be a risk factor; yet it may be too expensive to provide lighting of all roads. Ordinary road markings do not appear to be very important for road safety; however, rumble strips have been found to improve safety (Erke 2006).

With respect to junctions, sight distances, in particular the size of the sight triangle, does not appear to influence safety very much. The reason for this is probably that drivers compensate for limited sight distance by slowing down and observing traffic more carefully. Ordinary marked pedestrian crossings have not been found to improve road safety (Elvik and Vaa 2004). Upgraded pedestrian crossings may improve road safety. Upgrading usually takes the form of a raised pedestrian crossing or a crossing with refuges or safety fences.

As far as bridges and tunnels are concerned, less is known about how various design elements influence safety. High speed in tunnels may, however, be a problem, which can be treated by means of speed cameras.

Table 3: Items covered by road safety inspections in Norway. Source: Statens vegvesen, håndbok 222, 2005

Item checked	**Item known to be a risk factor?**
Roadside area	
• Profile of ditch	Steep slopes known to be a hazard
• Drainage facilities (as a hazard)	Not very well known
• Poles	Rigid poles known to be a hazard
• Trees	Striking trees is associated with injury severity
• Edges of walls or noise barriers	Sharp and rigid edges can be a hazard
• Bridge supports (as a hazard)	Unprotected bridge supports can be a hazard
• Guard rails	Missing or faulty guard rails can be a hazard
Traffic lanes, road markings, etc	
• Sight distances for overtaking	Short sight distances may increase accident rate
• Stop sight distances	Short sight distances may increase accident rate
• Traffic signs	Poor state of traffic signs may be a hazard
• Road markings – use of rumble strips	Ordinary road markings have small safety effects
• Road lighting – poor or missing	Darkness is known to be risk factor
Junctions, access points, pedestrian crossings	
• Sight triangles in junctions	Sight triangles have small safety effects
• Junction design and location	Item is too vague to assess its importance
• Traffic signs	Poor state of traffic signs may be a hazard
• Road markings	Ordinary road markings have small safety effects
• Marked pedestrian crossing	Ordinary marked pedestrian crossings do not improve safety; upgrading them may do so
Bridges	
• Road alignment near bridge	Sharp curves known to increase accident rate
• Sight distance at crest curves	Sharp vertical curves may be a hazard
• Junctions near bridge – sight distances	Short sight distances may increase accident rate
• Bridge rails	Importance for road safety not known
• Facilities for pedestrians or cyclists	Importance on bridges not known
Tunnels	
• Road alignment near tunnel	Sharp curves known to increase accident rate
• Tunnel opening, edges	Unprotected edges can be a hazard
• Need for speed cameras	High speed is known to be a risk factor
• Road markings – use of rumble strips	Ordinary road markings have small safety effects
• Other equipment	Item too vague to assess its importance

Based on current knowledge, it is concluded that road safety inspections in Norway are to a large extent targeted at known risk factors for accident occurrence or injury severity.

2.4 Portugal

In Portugal, road safety inspections are still at the development stage. Check lists are being tested. There will be different check lists for junctions and road sections. The items that are covered in the check lists currently used are listed below.

For road sections:

- Minor accesses to the road
- Potential conflicts with game (wild animals)
- Drainage facilities
- Road lighting
- Road markings
- Pavement surface characteristics
- Signing
- Pedestrian and cyclists
- Cross section characteristics
- Longitudinal profile characteristics
- Horizontal alignment characteristics
- Heavy vehicle traffic characteristics
- Roadside hazards

For junctions:

- Access from roadside
- Drainage facilities
- Road lighting
- Road markings
- Pavement surface characteristics
- Signing
- Pedestrians and cyclists
- Longitudinal profile characteristics
- Intersection type
- Horizontal alignment characteristics
- Roadside hazards

These lists are quite comprehensive and include not just the condition of the road surface or the roadside, but also a number of highway design elements. In general, however, road safety inspections do not consider road design.

3 Defects identified in road safety inspections

3.1 Austria

In road safety inspections of four motorways in Austria (A8 Innkreisautobahn, A7 Mühlkreisautobahn, A2 Südautobahn and A36 Murtal Schnellstrasse) a total of 125 items were checked. The category "high importance for road safety" was used 29 times. The category "intermediate importance for road safety" was used 41 times. The category "little importance for road safety" was used 55 times. Speed was noted as being of high importance on all the four inspected motorways. Other problems that were rated as important for at least three of the four motorways were weather management, in particular a high proportion of accidents on a wet road surface, and defects of cross section design.

3.2 Norway

A Norwegian study (Haldorsen and Hvoslef 2003) summarised the findings of 56 reports from road safety inspections. 41 reports dealt with roads outside urban areas, 15 reports dealt with roads inside urban areas. A total of 365 remarks about traffic hazards were made in the 41 reports for roads in rural areas. Figure 2 summarises the number of remarks made by main category.

The mean number of hazards identified was 8.9 per report. Nearly half of the hazards that were mentioned were roadside hazards, such as rock cuttings close to the road, large trees close to the road and high and steep embankments. Various deficiencies related to guardrails were also mentioned quite often. The most frequently mentioned deficiency of guardrails was that guardrail ends were not protected and represented a preventable traffic hazard.

15 reports for urban roads identified a total of 79 defects. Figure 3 shows the main categories of defects pointed out in the reports dealing with urban roads. The mean number of hazards identified per report was 5.3.

It is seen that the hazards identified for urban roads are quite different from those identified for rural roads. Characteristics of junction design and of the facilities provided for pedestrians and cyclists are mentioned quite often.

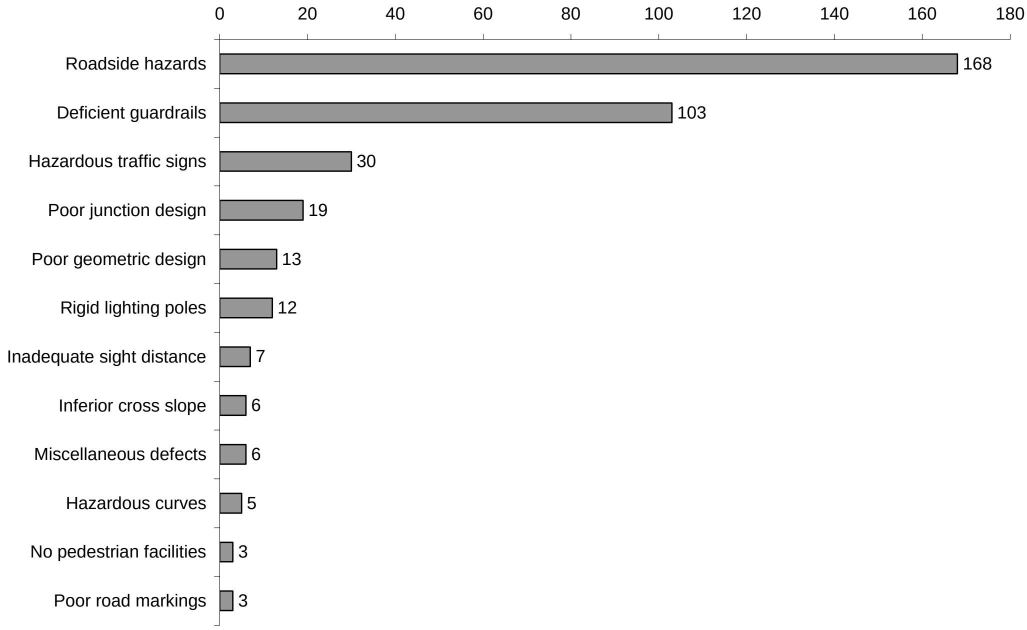

Figure 2: Number of hazards mentioned in reports from road safety inspections of rural roads in Norway. Source: Haldorsen and Hvoslef 2003

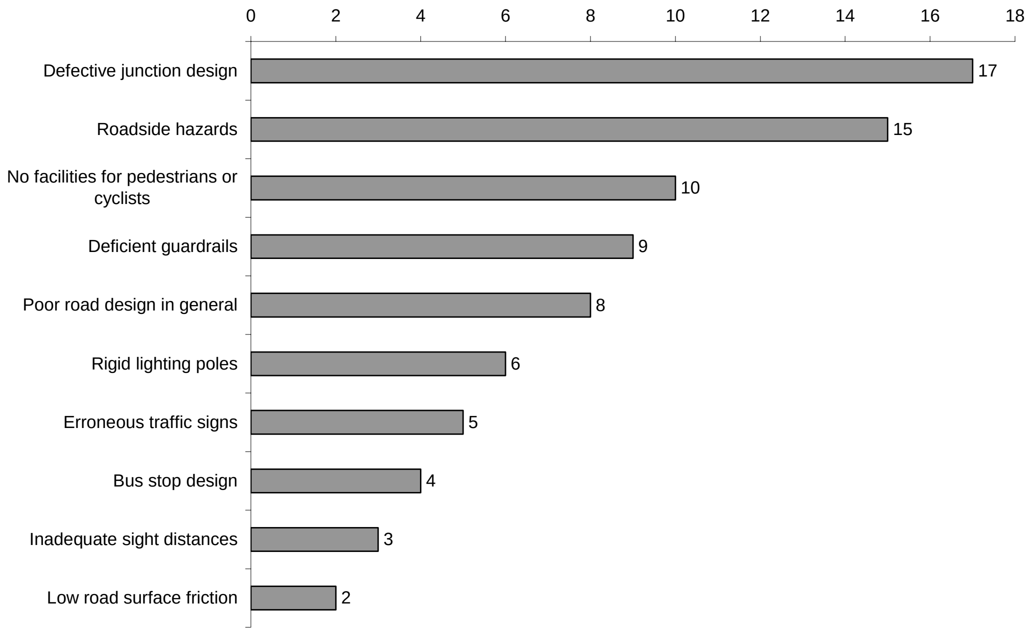

Figure 3: Number of hazards mentioned in reports from road safety inspections of urban roads in Norway. Source: Haldorsen and Hvoslef 2003

An earlier study (Ragnøy, Vaa and Nilsen 1990) found that erroneous traffic signs are quite common. The study examined 731 signs on eight road sections. The following errors were pointed out:

1. Location error: sign is placed so that it is not easily visible, at the wrong height or too close to other road signs (30%).

2. Design fault: sign was of the wrong size, wrong text or the wrong colour (27%).
3. Repetition error: sign was wrongly placed in relation to crossroads or other signs which must be repeated (4%).
4. Lack of correspondence with road markings: there is no correspondence between the sign and the road marking (2%).
5. Wrong use of sign: an individual sign has been used wrongly, or there is a poor combination of signs (9%).
6. Too many signs: according to the guidelines for signing, the sign is not necessary, or is repeated too many times (19%).
7. Lack of road sign: the guidelines for signing state that there should be a sign but there is not (9%).

In total, errors were found for 60% of the signs in Norway. Corresponding studies in the other Nordic countries (Vaa et al 1990, Muskaug 1995) found error rates of 45% for traffic signs in Finland, 15% in Denmark and 14% in Sweden.

4 Corrective measures proposed in road safety inspections

4.1 Austria

The measures proposed in the Austrian road safety inspections of four motorways included: speed enforcement by means of section control, lowered speed limits during rain, anti-dazzle screen on median guard rail, widening of shoulders, upgrading of road lighting. These are measures that can be implemented within the existing road area and that do not require extensive planning.

4.2 Norway

The report based on 56 road safety inspections in Norway referred to in Chapter 3 (Haldorsen and Hvoslef 2003) also contained a summary of the measures proposed to remove or mitigate the traffic hazards that were identified. Figure 4 summarises the measures that were proposed for rural roads.

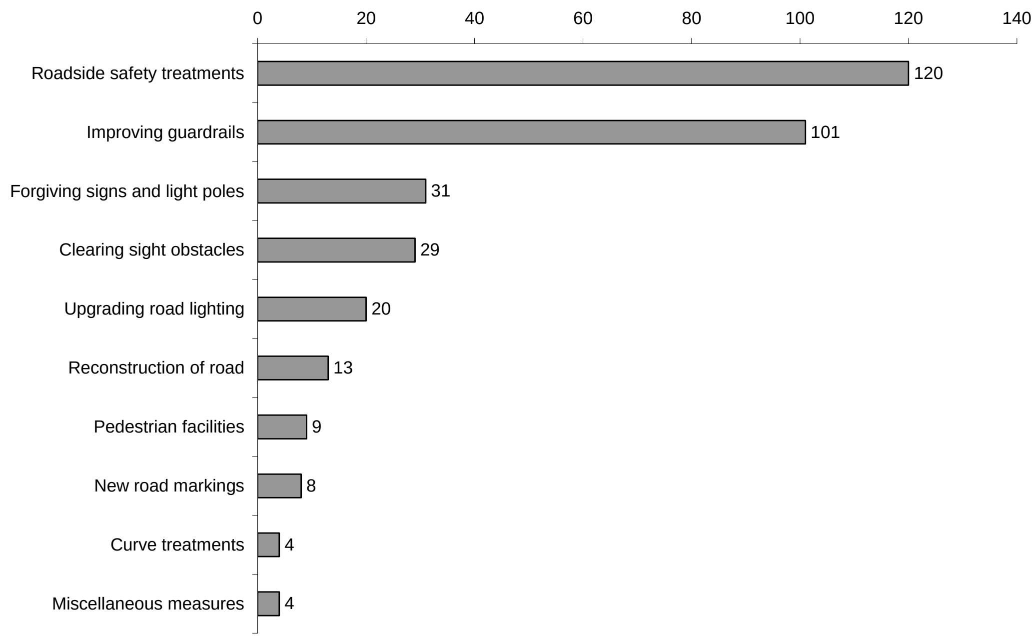

Figure 4: Measures proposed in road safety inspections of rural roads in Norway. Source: Haldorsen and Hvoslef 2003

In total, 339 safety treatments were proposed. This means that treatments were proposed to address virtually all the hazards (365 in total) that were identified. The types of treatment proposed closely matched the types of hazards identified. Unsurprisingly, various roadside safety treatments were most frequently proposed for rural roads. The most frequently proposed treatments included putting up a new guardrail (23 times), prolonging existing guard rails (22 times), making rock cuttings less hazardous by cutting edges etc (18 times), and flattening embankments by using closed drainage systems (drainage by means of pipes; 18 times).

For urban roads, a total of 74 treatments were proposed to address 79 hazards. Figure 5 shows the proposed treatments by main category. It is seen that various junction treatments are proposed most frequently.

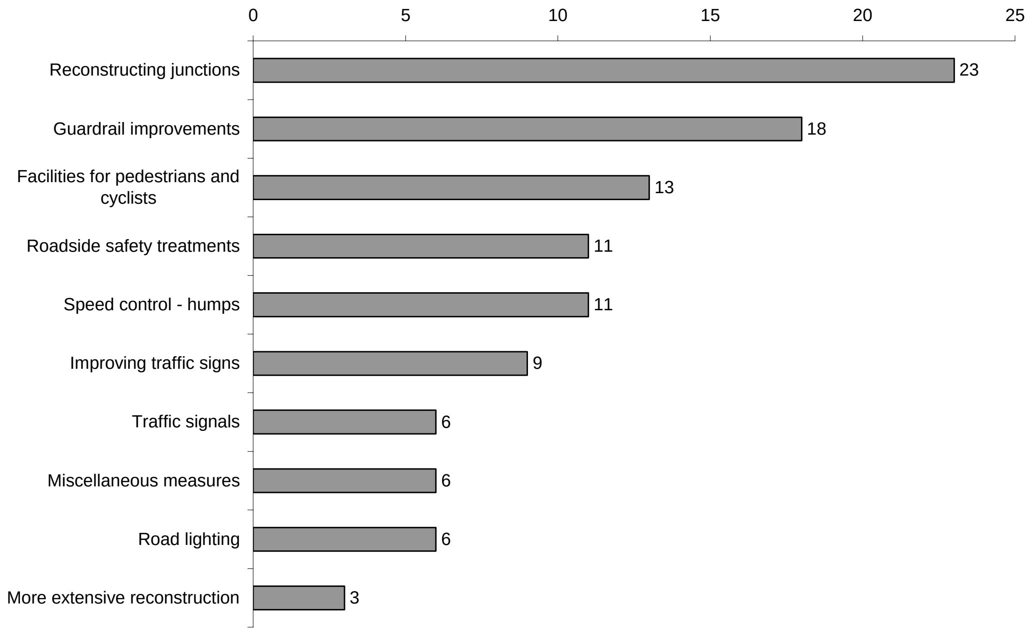

Figure 5: Measures proposed in road safety inspections of urban roads in Norway. Source: Haldorsen and Hvoslef 2003

The treatments proposed closely match the nature of the hazards uncovered.

Cost estimates were provided in 22 of the 56 road safety inspection reports. On the average, the cost of the treatments proposed was estimated to about 46,000 Euro per kilometre of road.

In conclusion, the following observations can be made:

1. Numerous safety treatments are proposed as a result of road safety inspections.
2. The treatments proposed tend to closely match the traffic hazards identified.
3. Treatments are proposed to address most of the traffic hazards identified, i.e. most of these hazards are regarded as to some extent preventable.
4. Most treatments proposed are not very costly.

5 Road safety effects of treatments implemented as a result of road safety inspections

There are very few studies of the effects of road safety of measures that are known to have been implemented as a result of road safety inspections. In fact, only two studies, both of them dealing with the correction of erroneous traffic signs, have been found (Lyles et al 1986, Ford and Calvert 2003). Both of these studies are from the United States. Their findings will be discussed below.

While few studies evaluating road safety treatments explicitly state that they were initiated as a result of road safety inspections, there are very many studies of road safety measures that are identical to the measures that tend to be proposed in reports from road safety inspections, see chapter 4. It therefore seems reasonable to assume that the effects of measures that are introduced following road safety inspections will be the same as the effects of these measures as reported in general in evaluation studies. Based on this assumption, this chapter will give a brief overview of current knowledge regarding the effects of the following road safety measures:

- Removing sight obstacles located close to the road
- Roadside safety treatments
- Installing guard rails along embankments
- Guard rail end treatments
- Using frangible or break-away poles
- Low cost treatments of horizontal curves
- Correcting erroneous traffic signs

The overview is based mainly on the Handbook of Road Safety Measures (Elvik and Vaa 2004), but some studies are discussed in more detail.

5.1 Removing sight obstacles

The Handbook of Road Safety Measures (Elvik and Vaa 2004) quotes two studies that have evaluated the effects of removing sight obstacles near the road – mostly by means of cutting down trees and bushes. One of the studies was Swedish, the other Norwegian. It is probably the treatments evaluated in the Norwegian study (Vaa 1991) that come closest to those one would typically expect to be implemented following a road safety inspection. Figure 6 shows a picture of one road section, before and after treatment.

Figur: Kurve på Rv 306. Før siktrydding.

Figur: Kurve på Rv 306. Etter siktrydding.

Figure 6: Sight distance before and after clearance of trees and bushes. Source: Vaa 1991

As can be seen from the picture, there was a remarkable improvement in sight distance. The study found that the frequency of overtaking increased. Mean speed also increased. Both these finding show that drivers tend to adapt their behaviour to changes in sight conditions, and will take the opportunity to drive faster when sight obstacles are removed.

The net effect on safety was small. Injury accident rate changed from 0.31 per million vehicle kilometres before to 0.30 per million vehicle kilometres after. This small change (a reduction of 3%) was not statistically significant.

5.2 Roadside safety treatments

There are two main types of roadside safety treatments: flattening of sideslopes and removing fixed obstacles from the safety zone. The safety zone is the area close to the road, up to about 10 metres from it. The Handbook of Road Safety Measures (Elvik and Vaa 2004) summarises evidence from studies that have evaluated the effects of roadside safety treatment. Possibly the best study was reported by Zegeer et al (1988). Table 4 summarises the findings of that study with respect to flattening of sideslopes.

Table 4: Expected reduction of single-vehicle-off-the-road accidents attributable to flatter sideslopes. Source: Zegeer et al 1988

	Sideslope after				
Sideslope before	3:1	4:1	5:1	6:1	7:1 or flatter
2:1	2%	10%	15%	21%	27%
3:1		8%	14%	19%	26%
4:1			6%	12%	19%
5:1				6%	14%
6:1					8%

These estimates are based on an accident prediction model that controls statistically for the effects of several other variables, including traffic volume, lane width, shoulder width and clear recovery distance (clear recovery distance is the width of the zone without any fixed obstacles).

Flattening steep sideslopes is not always feasible and can be very costly. Removing fixed obstacles near the road (providing a clear recovery zone) can be cheaper. According to Zegeer et al, the number of single-vehicle-off-the-road accidents can be reduced by up to 44% if the clear recovery distance is increased by 6 metres.

5.3 Guardrails and guardrail end treatments

A review of current knowledge regarding the effects of installing guard rails and providing safety treatment of guardrail ends is presented in the Handbook of Road Safety Measures (Elvik and Vaa 2004). The main points of the review are presented below. Table 5 presents summary estimates of the effects of installing guardrails along embankments.

Guardrails along embankments strongly reduce the number of fatal accidents and the number of injury accidents in the event of driving off the road. Guardrails also appear to reduce the total number of accidents, including property damage only accidents, but the effect is smaller and more uncertain. Changing to more yielding guardrails is also associated with a reduction of injury severity, but this is smaller than the effect of setting up guardrails in places where previously there were none.

Table 5: Effects on accidents of guardrails along the roadside. Percentage change in the number of accidents. Source: Elvik and Vaa 2004

	Percentage change in probability of injury		
Accident severity	Types of accident affected	Best estimate	95% confidence interval
	New guardrail along embankment		
Fatal injury	Running-off-the-road	-44	(-54, -32)
Any injury	Running-off-the-road	-47	(-52, -41)
Accident rate	Running-off-the-road	-7	(-35, +33)
	Changing to softer guardrails		
Fatal injury	Running-off-the-road	-41	(-66, +2)
Any injury	Running-off-the-road	-32	(-42, -20)

As far as guardrail end treatments are concerned, Elvik (2001) provides an overview of effects as presented in Table 6. While only 1.4% of drivers are killed when they strike a guardrail along the length of need, 2-5% of drivers are killed when striking a guardrail end. Turned down guardrail ends can act as “rocket launching pads”, literally lifting the car into the air and throwing it a considerable distance. The safest solution appears to be to attach the guardrail end to the back slope, i.e. not have any exposed guardrail end at all. If it needs to be exposed, designing the guardrail end as a crash cushion will reduce injury severity.

Table 6: Effects of guardrail end treatments. Source Elvik (2001)

	Car drivers by injury severity and treatment type			
Type of end treatment	**Not injured**	**Slight injury**	**Serious injury**	**Killed**
Results of Hunter, Stewart and Council 1993				
Guardrail (length of need)	294 (50.4%)	217 (37.3%)	63 (11.0%)	8 (1.4%)
Blunt end	60 (44.8%)	49 (36.5%)	22 (16.4%)	3 (2.2%)
Turned down end	51 (47.2%)	36 (33.4%)	16 (14.8%)	5 (4.6%)
Attached to back slope	11 (31.4%)	18 (51.4%)	6 (17.1%)	0 (0.0%)
Results of Gattis, Alguire and Natta 1996				
Exposed	99 (52.1%)	61 (32.1%)	21 (11.1%)	9 (4.7%)
Turned down end	177 (54.3%)	97 (29.8%)	42 (12.9%)	10 (3.1%)
Results of Ray 2000				
Parabolic flare	54 (60.7%)	22 (24.7%)	13 (14.6%)	
BCT simple curve	32 (48.5%)	17 (25.8%)	17 (25.8%)	

5.4 Frangible or break-away poles

The Handbook of Road Safety Measures (Elvik and Vaa 2004) presents the following information regarding break-away or frangible lighting poles.

The effect on injury severity of using deformable lighting poles has been studied in Great Britain (Walker 1974) and the United States (Ricker, Banks, Brenner, Brown and Hall 1977; Kurucz 1984). On the basis of these studies, frangible or break-away poles can be estimated to reduce the probability of personal injury in the event of a collision by about 50% (lower 95% confidence limit 72%, upper 95% confidence limit 25%).

5.5 Low cost treatment of horizontal curves

Sharp curves on otherwise straight roads have a high accident rate. An estimate of the accident rate in curves classified as unexpected using the Norwegian URF program (Elvik and Muskaug 1994) shows that the accident rate in such curves is highest when they are located on roads with few similar curves. The number of injury accidents per million vehicle kilometres with different numbers of curves was:

Number of unexpected curves (curves with an URF-value above around 4-5) per km road			
More than 0.75	0.51-0.75	0.26-0.50	Up to 0.25
0.19	0.24	0.59	0.66

The risk in unexpected curves is around 3 times as high when there are fewer than 0.5 such curves per kilometre road as when there are more than 0.75 curves per kilometre road. A study from New Zealand (Matthews and Barnes 1988) found a similar pattern. The longer the straight section before a sharp curve (radius less than 400 metres), the higher the accident rate in the curve.

It is not always possible to improve sharp curves by rebuilding the road. The accident rate in sharp and unexpected curves must therefore be reduced using other methods. In Norway a computer program has been developed in order to identify unexpected curves (Amundsen and Lie 1984). The program is known as the URF program (URF stands for UtforkjøringsRisikoFaktor – the driving off the road risk factor). The URF-value of a curve depends on the curve’s degree of unexpectedness, the width of the road and the gradient of the road. The degree of unexpectedness of a curve depends on how great the difference is in driving speed, curve radius and the super elevation of the road in the curve compared to average values of these quantities for a section of road.

The URF-program has been used in Norway to identify unexpected curves and to improve these (Eick and Vikane 1992, Eriksen 1993, Stigre 1993). The most common type of treatment is signs showing directional arrows that indicate the alignment of the curve. Background markings are sometimes also used.

The studies of Eick and Vikane (1992), Eriksen (1993) and Stigre (1993) have been re-analysed to control for regression-to-the-mean by relying on the study of Sakshaug (1998). That study provided a set of normal accident rates for horizontal curves that were not known at the time of the original studies. Based on the re-analysis, the effect on injury accidents of directional and background signing of hazardous curves is estimated to 16% reduction. This reduction is not statistically significant (lower 95% limit: 35% reduction, upper 95% limit 9% increase).

5.6 Correcting erroneous traffic signs

Two studies have evaluated the safety effects of correcting erroneous traffic signs. Both studies (Lyles et al 1986, Ford and Calvert 2003) were made in the United States. The first of these studies is discussed in the Handbook of Road Safety Measures (Elvik and Vaa 2004). The study found that improvements to make traffic signs conform to the MUTCD (Manual on Uniform Traffic Control Devices) led to a 15% decrease in the number of injury accidents (lower 95% limit 25% decrease, upper 95% limit 3% decrease). Property damage only accidents were reduced by 7% (lower 95% limit 14% decrease, upper 95% limit 0.3% decrease). The authors of the study incorrectly concluded that upgrading substandard signs did not reduce the number of accidents, on the basis of an inadequate statistical analysis of the data.

The second, more recent study (Ford and Calvert 2003) evaluated the effects of a low cost programme of upgrading signs and road markings based on road safety inspections. The study found a reduction of 55% in the number of fatal accidents, a reduction of 31% in the number of injury accidents and a reduction of 46% in the number of property damage only accidents. The study did not control for regression-to-the-mean, and the treatments were targeted to high-risk sites. It is therefore very likely that the true effects are considerably smaller than those reported.

5.7 Effects that can be expected as a result of road safety inspections

Table 7 summarises the effects that can be expected if the measures described above are introduced as a result of a road safety inspection. All estimates refer to injury accidents. All estimates are given as an interval only, as there is bound to be local variations and as there is a fairly large element of uncertainty in many of the estimates presented above.

Based on these estimates of effect, it is reasonable to conclude that road safety inspections can lead to the implementation of measures that can improve road safety considerably.

Table 7: Summary of effects on injury accidents to be expected as a result of road safety inspections. Source: TØI report 850/2006.

Treatment	Accidents that are influenced	Expected accident reduction (%)
Removing sight obstacles	All accidents	0-5%
Flattening side slopes	Running-off-the-road	5-25%
Providing clear recovery zones	Running-off-the-road	10-40%
Guardrails along embankments	Running-off-the-road	40-50%
Guard rail end treatments	Vehicles striking guardrail ends	0-10%
Yielding lighting poles	Vehicles striking poles	25-75%
Signing of hazardous curves	Running-off-the-road in curves	0-35%
Correcting erroneous signs	All accidents	5-10%

6 Best practice guidelines for road safety inspections

The main findings of this study can be summarised as follows:

1. Road safety inspections are targeted at traffic hazards that may contribute to accidents and that are amenable to treatment.
2. Road safety inspections often point out numerous traffic hazards and propose measures to correct these defects.
3. Measures that correct the traffic hazards identified in road safety inspections have been found to be effective in reducing the number of accidents and the severity of injuries.

These findings suggest that road safety inspections can serve as a useful instrument of road safety management. Can anything be said about how best to conduct road safety inspections?

In the review of current practice, Nadler and Lutschounig (2006) identify several differences in the way road safety inspections are carried out in Europe. Some countries do not use road safety inspections at all. Others use road safety inspections selectively, while some countries routinely inspect all roads. More specifically, the following differences in current practice were found:

1. Some countries carry out road safety inspection of roads that have a bad safety record only. Other countries include all roads in their programme of inspections.
2. Some countries carry out road safety inspections regularly. Other countries carry out inspections only as a need is felt for them.
3. Some countries include all roads in inspections. Other countries inspect only a part of their road system.
4. Some countries require road safety inspection teams to be composed of formally trained and qualified inspectors. Other countries do not require any formal training of inspectors.
5. Some countries write reports describing the findings of inspections. Other countries do not summarise findings in reports.
6. Some countries use standard check lists for road safety inspections. Other countries do not use check lists. The precise contents of inspections made in different countries are not very well known.

The study presented in this report does not address all these points. Its main objective was to evaluate whether there is any reason for believing that road safety inspections will actually contribute to improving road safety. The conclusion is affirmative: there is reason to believe that road safety inspections will contribute to improving road safety – although there are very few studies that have evaluated the effects of road safety inspections.

In view of the findings of this report and the report of Nadler and Lutschounig, the following guidelines for best practice with respect to road safety inspections are proposed:

1. The elements to be included in road safety inspections should be known to be risk factors for accidents or injuries.
2. Inspections should be standardised and designed to ensure that all elements included are covered and are assessed in an objective manner. For this purpose, developing check lists may be of help.
3. The list of elements to be included in road safety inspections (check lists) should include those that are recognised as important. The following elements should be included in all road safety inspections:
    a. The quality of traffic signs, with respect to the need for them, whether they are correctly placed and whether they are legible in the dark.
    b. The quality of road markings, in particular whether the road markings are visible and are consistent with traffic signs.
    c. The quality of the road surface, in particular with respect to friction and evenness.
    d. Sight distances and the presence of permanent or temporary obstacles that prevent timely observation of the road or other road users.
    e. The presence of traffic hazards in the near surroundings of the road, such as trees, exposed rocks, drainage pipes, etc.
    f. Aspects of traffic operation, in particular if road users adapt their speed sufficiently to local conditions.
4. For each item included in an inspection, a standardised assessment should be made by applying the following categories:
    a. The item represents a traffic hazard that should be treated immediately. A specific treatment should then be proposed.
    b. The item is not in a perfectly good condition, but no short term action is needed to correct it. Further observation is recommended.
    c. The item is in good condition.
5. Inspections should report their findings and propose safety measures by means of standardised reports.
6. Inspectors should be formally qualified for their job. They should meet regularly to exchange experiences and to ensure a uniform application of safety standards in inspections.
7. There should be a follow-up of inspections after some time to check if the proposed measures have been implemented or not.

As far as the selection of roads for inspection is concerned, arguments can be given in favour of both the approaches that are currently used: (1) Inspecting roads known to have a safety problem only, or (2) Inspecting all roads. Both these approaches make sense, and the choice between them will often depend on whether highway agencies have sufficient resources to inspect and treat all roads or not.

During an initial stage, it may be appropriate to select roads with a bad safety record for inspection. However, as more experience is gained, road safety inspections may increasingly be used as a preventive tool and extend to roads that do not have a bad safety record. Today, road safety inspections are primarily used as a preventive tool in some countries, notably Germany, but still mainly as a corrective tool in other countries, notably Norway.

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