Sétra
Service d'études sur les transports, les routes et leurs aménagements

May 2002
Translate June 2009

Understand and Act

Improving the safety of bends

on major rural roads

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire

Technical Department of the Ministry of Ecology, Energy Sustainable Development and the Sea, Sétra, is an engineering and expertise reference in the fields of transport, road infrastructure and engineering structures.

The Sétra supports the public owner

The Sétra supplies State agencies and local communities (counties, large cities and urban communities) with informations, methodologies and tools suited to the specificities of the networks in order to:

- improve the projects quality;
- help with the asset management;
- define, apply and evaluate the public policies;
- guarantee the coherence of the road network and state of the art;
- put forward the public interests, in particular within the framework of European standardization;
- bring an expertise on complex projects.

The Sétra, producer of the state of the art

Within a very large scale, beyond the road and engineering structures, in the field of transport, intermodality, sustainable development, the Sétra:

- takes into account the needs of project owners and prime contractors, managers and operators;
- fosters the exchanges of experience;
- evaluates technical progress and the scientific results;
- develops knowledge and good practices through technical guides, softwares;
- contributes to the training and information of the technical community.

The Sétra, a work in partnership

- The Sétra associates all the players of the French road community to its action: operational services; research organizations; Scientific and Technical Network (Réseau Scientifique et Technique de l'Équipement – RST), in particular the **Public Works Regional Engineering Offices (Centres d'Études Techniques de l'Équipement – CETE),** companies and professional organizations; motorway concessionary operators; other organizations such as French Rail Network Company (Réseau Ferré de France – RFF) and French Waterways Network (Voies Navigables de France - VNF); Departments like the department for Ecology and Sustainable Development…
- The Sétra regularly exchanges its experience and projects with its foreign counterparts, through bilateral co-operations, presentations in conferences and congresses, by welcoming delegations, through missions and expertises in other countries. It takes part in the European standardization commissions and many authorities and international working groups. The Sétra is an organization for technical approval, as an EOTA member (European Organisation for Technical Approvals).

Understand and Act

Improving the safety of bends

on major rural roads

This document is the translation of the work
"*Amélioration de la sécurité des virages des routes principales en rase campagne - Savoir et Agir*" published in may 2002
under the reference E0214.

This document has been prepared by:

- Guy DUPRÉ, *CETE Normandie – Centre*
  (Regional public Works Engineering Agency – Normandie-Centre)
- Olivier FLORIS, CETE Normandie - Centre
- Lionel PATTE, *Sétra*

Photographs: *CETE Normandie - Centre*

Contents

1 - Bends = risk area 9
2 - The characteristics of bends that lead to accidents 10
3 - Radius of curvature 11
4 - Uniformity of the radius of curvature 12
5 - Surface characteristics 13
6 - Legibility 14
7 - Visibility 15
8 - Length of the bend 16
9 - Crossfall 17
10 - Obstacles on the verges 18
11 - Verges 19
12 - Signing bends 20
13 - Safety when overtaking 21
14 - Further information 22

Introduction

Accidents on bends in open country result in around 2000 deaths every year, a quarter of all deaths due to road accidents. They are a major safety stake.

While driver error is usually the underlying reason for the accident, the characteristics of the road infrastructure also play a significant role in the events leading up to the accident. Conversely, a consistent road geometry and appropriate signalling ease the task of the driver and dramatically reduce the risk of driver error. Treating side obstacles can also reduce the severity of injuries when a vehicle leaves the carriageway on a bend.

Applying these considerations makes it possible to improve the safety of existing road network significantly and new roads can be made as safe as possible if suitable design rules are followed.

This document provides design engineers and planners with all the knowledge they need in a condensed form to improve the safety of bends on major roads in open country. More detailed information may be found in the documents listed in the references.

However, the actions recommended in the remainder of this document should not be followed blindly. In the case of existing roads, a safety diagnosis should always be carried out before any modifications are made to the road infrastructure. It should also be noted that the technical information presented in this document does not take precedence over the technical recommendations currently in force.

1 - Bends = risk area

- 40 % of fatal accidents occur on bends on rural roads.
- The risk of an accident is five to ten times greater on a bend than on a straight section of road.

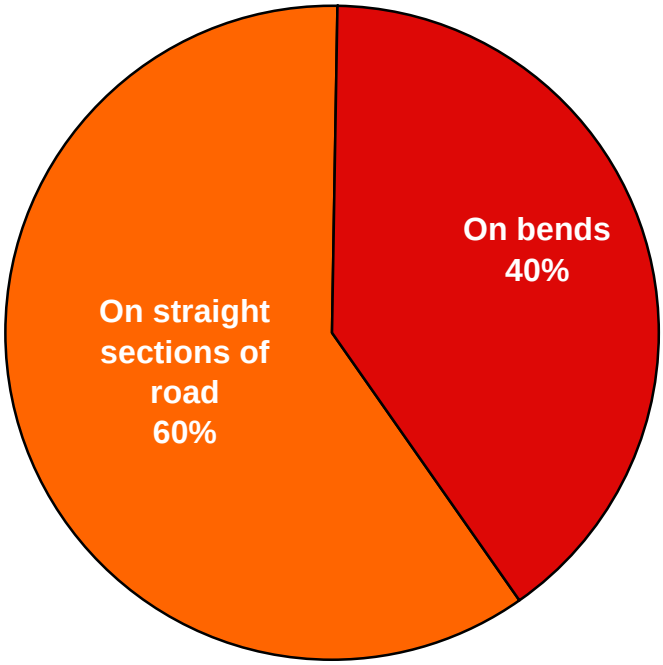
especially if the carriageway is wet

- 40 % of all accidents on bends occur when the carriageway is wet.
- The risk of an accident is doubled.

or at night

- 42 % of all accidents occur at night.
- The risk of an accident is doubled.

Distribution of fatal accidents in the open country



Source: Accidents on bends LAB, CEESAR, INRETS, April 1999

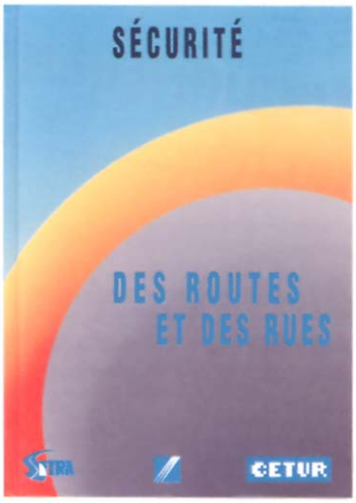
2 - The characteristics of bends that lead to accidents

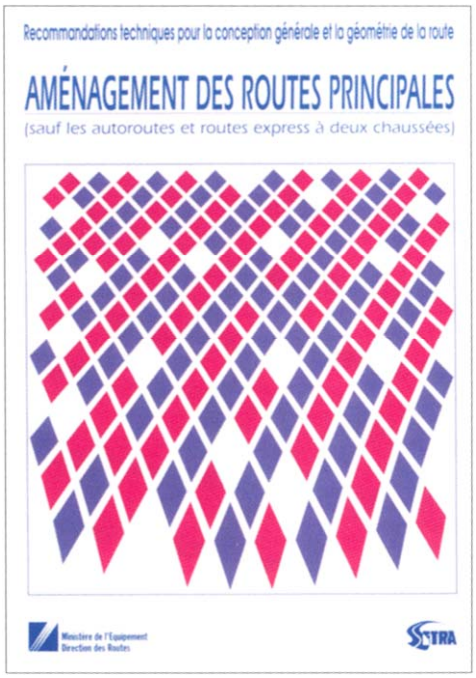
The bends with the worse accident records on major roads in open country are those that present the driver with a problem that was not present on the preceding section of road. Examples include:

- Single bends with a small radius of curvature (less than around 150 metres).
- Bends with a radius of curvature significantly less than that of the preceding bend.

Bends with a poor accident record may have a mid-range radius of curvature (less than around 250 metres) associated with some other difficulty, such as:

- A progressively reducing radius of curvature.
- A long introductory bend.
- A road surface with poor skid resistance.
- unevenness.
- Poor visibility.
- Poor road legibility.
- A long bend.
- Poor crossfall.
- Obstacles on the verges.





Technical recommendations for the design of major roads. (See Chapter 3 in particular)

3 - Radius of curvature

Understand

Studies in France and in other countries have shown that accidents tend to occur on bends with a small radius of curvature if they are preceded by an easy section of road.

Act

New roads

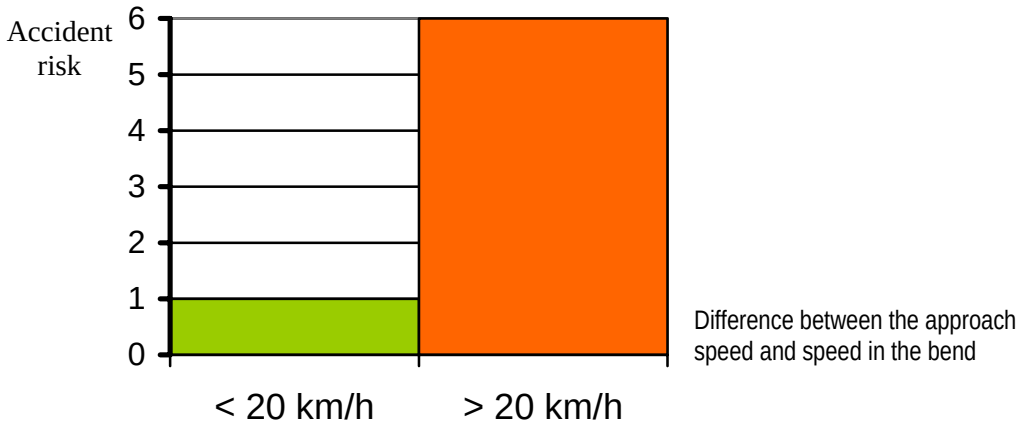
Preceding straight section (metres)	Radius of curvature should be greater than
> 5 km	400 m
> 1 km	300 m
> 0.5 km	200 m

- Rule for two successive bends: R1/R2 < 1.5

Existing roads

- Realign single bends with a radius of curvature below 150 metres. (bends preceded by a straight section or gentle curves for at least 500 metres)
- If a realignment of the bend is not possible:

– Ensure that the road surface has the best possible grip characteristics by resurfacing at regular intervals.
– Remove or shield any fixed obstacles.
– Install adequate signalling.
– Remove any other defects leading to accidents.



The risk of an accident rises sharply when the deceleration needed to enter a bend reaches 20 km/h.

Source: Sétra, 1998

4 - Uniformity of the radius of curvature

Understand

The following road layouts make it impossible to assess the difficulty of the bend and constitute a dangerous trap for drivers:

- Reducing radius of curvature.
- A long introductory bend.

Act

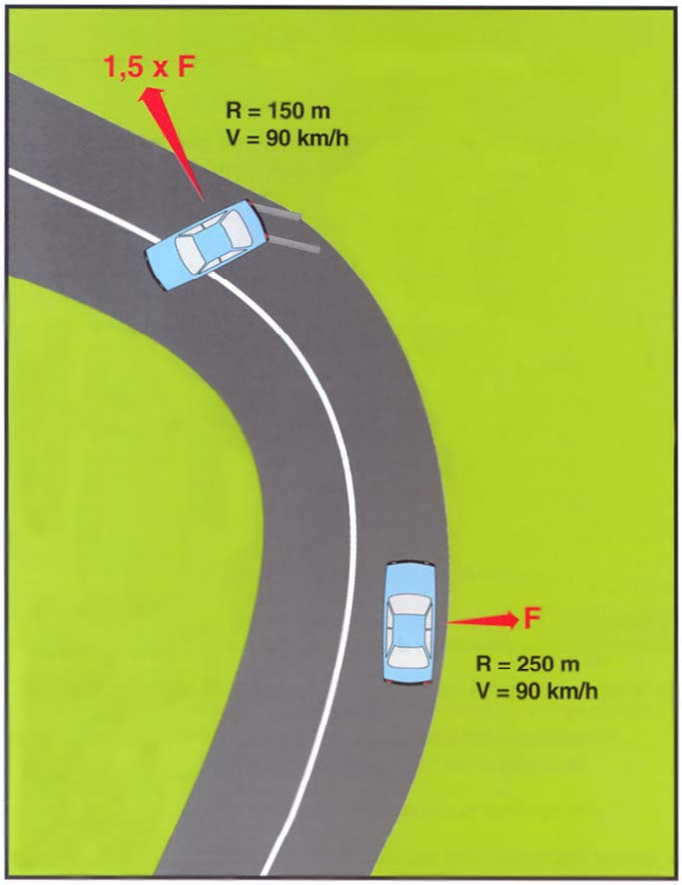
New roads:

- Limit the length of progressive transition curves.

	Length of clothoid
Two lanes	$L = 6R^{0.4}$ limited to 67 metres
Three lanes	$L = 9R^{0.4}$ limited to 100 metres

Existing roads:

- Ensure that the radius of curvature is constant for all bends with a radius of curvature of less than 250 metres.



5 - Surface characteristics

Understand

- There are two types of surface defect that can result in accidents or aggravate other defects associated with the geometry of the bend:

– evenness (especially if the wavelength is relatively short - between 0.8 and 2.8 metres).

– Poor skid resistance. This is a major stake as 40 % of all accidents occur when the carriageway is wet.

- Skid resistance reduces dramatically when the carriageway is wet, but drivers tend to reduce speed only slightly under these conditions.

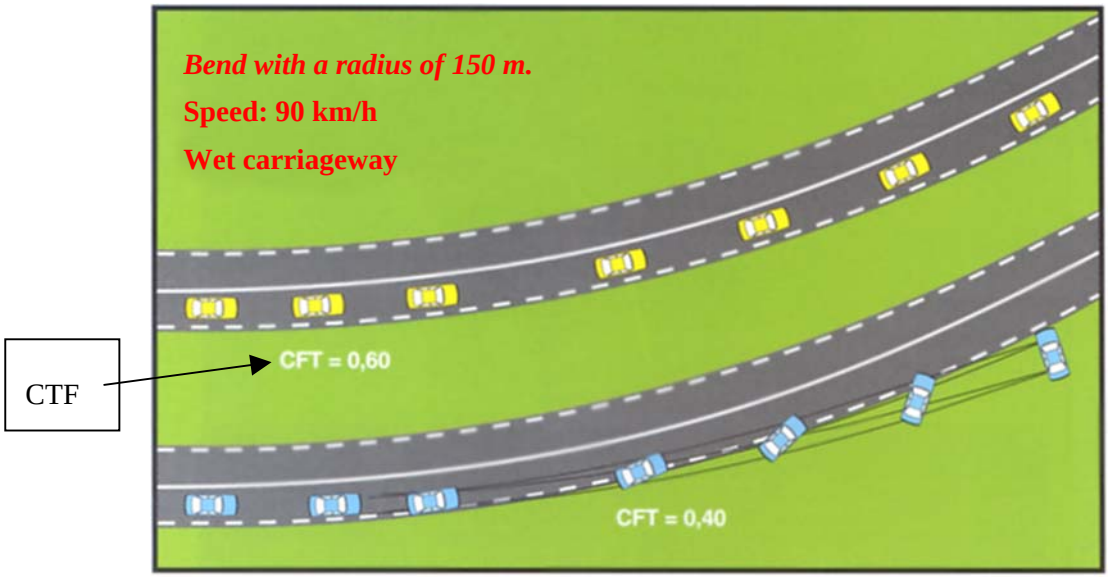
Act

- Curative action:

– Examine the values of the evenness and the coefficient of transverse friction (CTF) on bends with a small radius of curvature, or those with other hazardous characteristics, in order to determine the measures to be taken.

- Preventive action:

– Establish a specific resurfacing programme for bends.



Bend with a radius of curvature of 150 metres - Speed 90 km/h – Wet carriageway

Simulation: PC CRASH software

6 - Legibility

Understand

- A bend with poor legibility is less safe than other bends with similar characteristics.
- The main legibility defects are:

– The presence of a road junction on the bend. The risk of an accident is doubled.
– The presence of a row of trees giving the impression that the road continues in a straight line.
– An environment that gives no clues as to the presence of the bend.
– The perception of a section of road ahead.

Act

- Mask the view past the outside edge of the bend by planting shrubs that will yield on impact.
- Install additional posting.
- Move the intersection to a straight section or modify the alignment of the minor road.

Where does the road go?

Bend at the top of a hill ...

Danger at night!

Be careful! There's a bend ahead!

7 - Visibility

Understand

- The bend must be clearly visible when it is approached so that drivers have sufficient time to prepare for it:

– As a general rule, the recommended distance is equivalent to three seconds at V85[1] speed.

– If there is a significant difference between the speed of approach and the speed in the bend, the required visibility distance may be estimated using the following formula:

$$d = \frac{V_{approach}^{2} - V_{bend}^{2}}{2}$$

where: d is in metres and V is in metres per second.

The speeds may be estimated using the nomograms on page 75 of Aménagement des Routes Principales.

Act

- Remove any crests on the road approaching the bend (costly and rarely cost-effective).
- Install additional signing and, above all, increase the height of the posts around the bend.

Late appearance of a bend immediately after a crest in the road

[1] Maximum speed attained by 85 % of drivers under freely traffic conditions

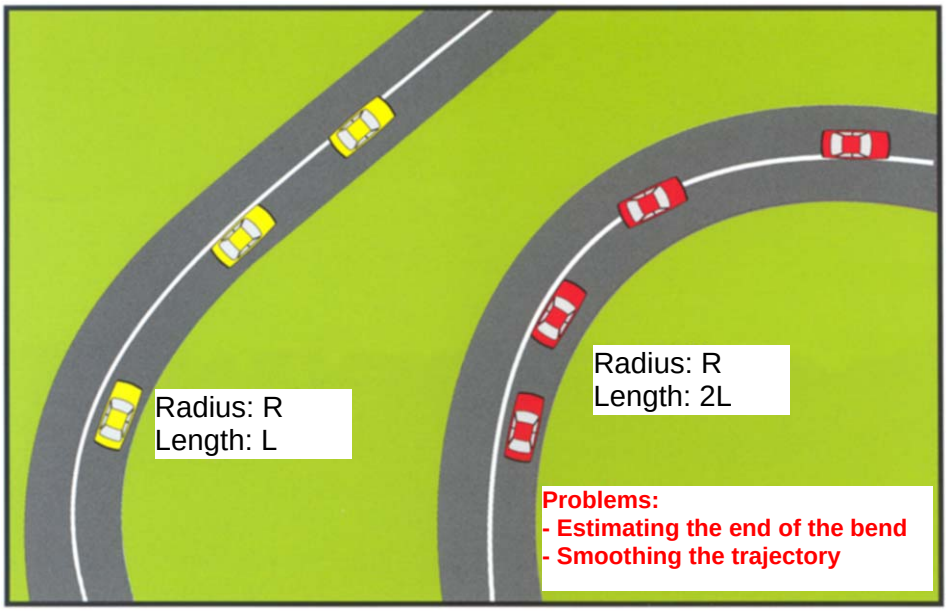
8 - Length of the bend

Understand

- The risk of an accident increases in proportion to the length of the bend. In a very long bend, a driver beginning to lose control does not have the opportunity to 'smooth out' the radius of curvature.

Act

- Improve the visibility within the bend.
- Install additional signing.



Approaching drivers cannot assess the length of the bend

9 - Crossfall

Understand

Studies have shown that an adverse crossfall can be a major contributor to accidents. Correcting the crossfall in these situations can have a major effect on the safety of the bend and change dramatically vehicle trajectories.

Any change of crossfall during the circular section of a bend can result in the following hazards:

- Poor vehicle trajectories.
- The accumulation of water on the carriageway in the bend.

Act

- Correct crossfall outside of the bend in accordance with the recommendations given in *Aménagement des Routes Principales – (Sétra, 1994)*. When scheduling this work, give priority to bends with a radius of curvature of less than 400 metres.
- Increase any insufficient crossfall on bends with accidents.

For the same level of safety

R = 150 metres
Inside crossfall = 7 %
V = 90 km/h

R = 150 metres
Outside crossfall = 2.5 %
V = 79 km/h

10 - Obstacles on the verges

Understand

The presence of obstacles alongside a bend is a determinant factor in increasing the severity of any accident. Fifty-six percent of all fatal accidents involving collision with an obstacle occur on bends.

A fatal impact on a bend may involve an obstacle on the outside edge (63 %) or on the inside edge (37 %).

Act

Deal with all obstacles on both the inside and outside edges of bends, giving priority to those with other hazardous configurations.

Any error on the part of the driver could be fatal

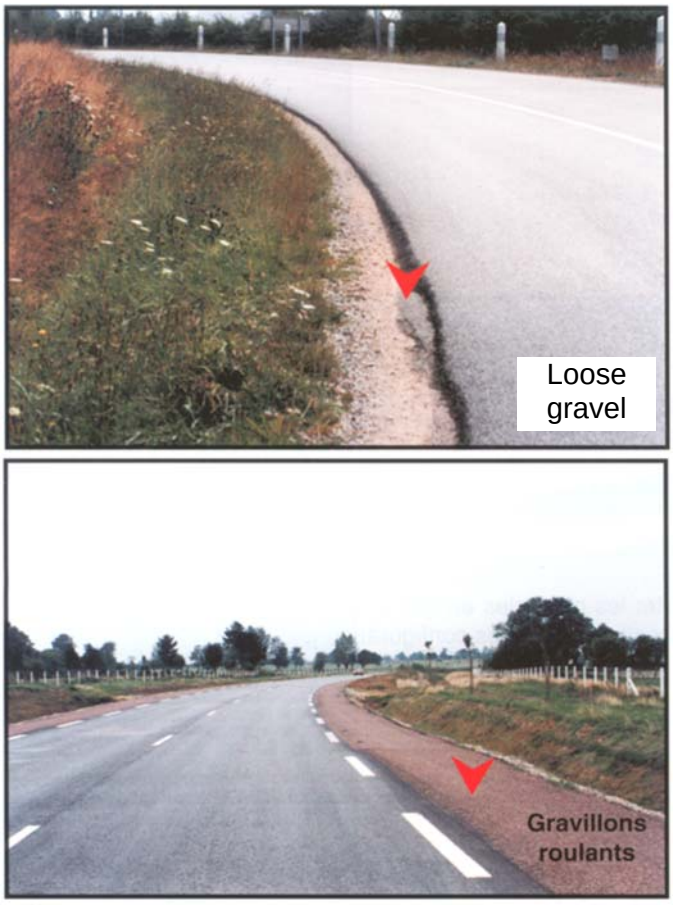
11 - Verges

Understand

- A verge covered in vegetation has zero skid resistance.
- Loose gravel on the verge or hard shoulder makes it very difficult to recover a vehicle that has left the road.
- The presence of a step at the side of the road is a hazard.
- Conversely, safety can be improved by the presence of a hard shoulder along the outside of a bend with similar characteristics to the main carriageway and delimited from it by a rumble strip.

Act

- Brush away any gravel on verges.
- Install a hard shoulder alongside the main carriageway, even if this is relatively narrow. Add an optional rumble strip at the edge of the main carriageway.



12 - Signing bends

Understand

The effectiveness of signing would be improved if all bends were signed uniformly.

With this in mind, Sétra has developed a methodology to determine:

- Which bends to sign.
- The level of signing to be installed.

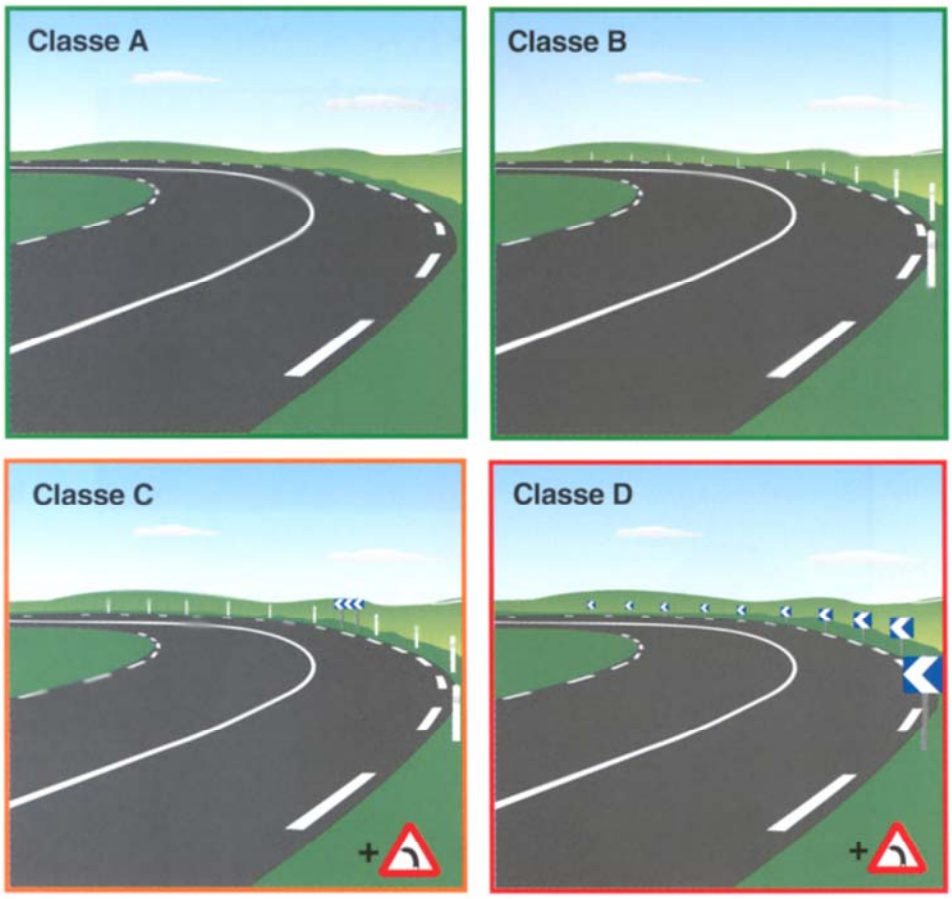
This method is described in the following document:

- Comment signaler les virages - signalisation verticale - Sétra 2002. (Signing bends – traffic signing)

Act

Install credible and uniform signing for all bends along a given route or in a given network.

Four degrees of danger: Four levels of signing



13 - Safety when overtaking

Understand

- Bends with a large radius of curvature (greater than around 1000 metres) present problems of visibility when overtaking, especially in the case of right-handed bends.
- The way in which lanes are allocated on three-lane roads can improve safety, especially on sections with many bends.

Act

- Prohibit overtaking on right-hand bends.
- On three-lane roads, alternate the central lane allocation between the two directions of travel.

An heavy goods vehicle may hide another vehicle

14 - Further information

Vitesses pratiquées et géométrie de la route. (Observed travel speeds and road geometry) Sétra, 1986.

Vitesses pratiquées et géométrie de la route. Information note *(in the Series: Traffic Safety Infrastructure Operating.)* No.10. Sétra, April 1986.

Caractéristiques routières et sécurité - Reconnaissance de la contribution des facteurs route dans la genèse des accidents. (Road features and road safety - Acknowledging the role of road factors in causing accidents) INRETS Summary No. 2, April 1986.

Sécurité des Routes et Rues. (Road and street safety) Sétra, CETUR, September 1992.

Aménagement des Routes Principales. (Technical guide on the design of main roads) Sétra, August 1994.

*Détection de configurations a priori accidentogènes de l'infrastructu*re. *(Identifying infrastructure configurations liable to cause accidents)* Sétra, LCPC, CETE Lyon, CETE Rouen, September 1997.

Accidents en virages sur routes bidirectionnelles interurbaines - Recherche des caractéristiques géométriques accidentogènes - Modélisation du nombre d'accidents. (Accidents at bends on two-way interurban roads interurbaines - Study on the geometric characteristics that lead to accidents - Modelling the number of accidents) Sétra, April 1998.

Comment signaler les virages - signalisation verticale (Signing bends - vertical signs) - Sétra 2002.

The purpose of the Itinerary Road Safety Inspection (RSI) is to identify events on roads, roadsides and their environment that may influence user behaviour or affect the user's passive safety, thus having an impact on road safety.

To this end, a method has been developed that allows road operators to request inspections with the main objective of taking a "fresh look" when visiting a given itinerary. Certified personnel will make these visits; since they are not familiar with the itinerary, they will be able to identify particularities of the road that are no longer seen by local road operators.

The objective of this approach is to provide the road operator with an additional tool for improving road safety on the local road network.

To achieve this objective, the approach is designed to be:

- preventive;
- simple, effective and practical;
- recurrent and systematic;
- done on the initiative and for the benefit of the road operator.

This guide describes the method in seven steps. It also includes nine tool files that will allow the inspectors and road operators to carry out inspection visits and utilise the results of these inspections.

Présent pour l'avenir

Service d'études sur les transports, les routes et leurs aménagements
46 avenue Aristide Briand – BP 100 – 92225 Bagneux Cedex – France
Phone: 33 (0)1 46 31 53 – Fax: 33 (0)1 46 11 33 55
This document is awailable and can be downloaded on Sétra website:
http://www.setra.developpement-durable.gouv.fr/

Reference: 0928A

The Sétra belongs to the scientific and technical network of the French Public Work Ministry (RST)

Le Sétra appartient au Réseau Scientifique et Technique du Mediddat