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**TNO report**

**TM-04-D009**

# Roadside Infrastructure for Safer European Roads: Road-scene analyses of ten accident sites

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# Samenvatting

**Vraagstelling**
De hier gepresenteerde wegbeeldanalyses zijn uitgevoerd binnen het werkpakket 1 van het EU-RISER project. Binnen dit werkpakket bestond taak 1.2 uit het creëren van een gedetailleerde database met ongevalsreconstructies. Voor die database verzamelde TNO Automotive 10 ongelukken en TNO Human Factors voegde een wegbeeldanalyse toe voor elke ongevalslocatie om specifieker informatie te verschaffen over de interactie tussen weggebruiker, wegontwerp en wegkantmeubiliar. Deze database dient als uitgangspunt om binnen de context van wegkantontwerp Human Factors principes op te nemen. Dit gebeurt d.m.v. het ontwikkelen van richtlijnen en analyseprocedures nodig om een veilige, efficiënte en betaalbare wegkantinfrastructuur te selecteren, implementeren en handhaven in de EU.

**Werkwijze**
Twee experts hebben de tien ongevalslocaties overdag bezocht. Als het ongeluk had plaatsgevonden in het donker werd de locatie ook ‘s nachts bezocht.
Voor elk van de tien locaties werd een video gemaakt van het aanrijdtraject om een goede impressie te hebben van het traject dat het slachtoffer had afgelegd voor het ongeluk. Nadat een video van het aanrijdtraject was gemaakt, keerden de wegbeelddeskundigen terug naar de locatie om ter plekke foto’s te maken. Daarna vulden beide deskundigen, onafhankelijk van elkaar, de wegbeeldanalyselijst in (Bijlage A). Nadat de lijst was ingevuld werd de locatie nog een keer bezocht. Deze procedure was dezelfde voor zowel dag als nacht observaties. Na de observatie op locatie werden de analyses met behulp van het videomateriaal en de foto’s afgerond en de deskundigen bediscussieerden elkaars conclusies om tot een eenduidig eindoordeel te kunnen komen voor elke situatie.

**Resultaten**
Elke wegbeeldanalyse is als volgt gerapporteerd:
1 Korte beschrijving en achtergrond van het ongeluk
2 Beschrijving van het wegbeeld
3 Resultaten van de wegbeeldanalyse.

**Conclusies**
Van de 10 situaties zijn er 5 waarbij het lastig is vanuit het wegbeeld een oorzaak te vinden voor de crash met het wegmeubilair of boom.
Er zijn twee situaties waar het wegbeeld niet past bij de wegcategorie en de snelheid die gevraagd wordt van de weggebruiker. In beide gevallen nodigt het wegbeeld uit tot harder rijden dan de plaatselijke maximale snelheidslimiet, zeker voor frequente weggebruikers. Voor een derde situatie geldt dat het wegbeeld een zogenaamd ‘Macho-effect’ heeft door het bochtige karakter wat aantrekkelijk kan zijn voor de snelle weggebruiker. In dit geval komen het wegbeeld en de wegcategorie wel met elkaar overeen, maar het nodigt desondanks uit tot racen voor de “macho” weggebruiker.
Twee situaties waren in werk-in-uitvoering zones. Hier geldt dat het algemene principe dat gele markering voorrang heeft over witte markering voor de weggebruiker omgedraaid geldt voor werkverkeer. Het werkverkeer wordt een werkverkeeruitrit ingeleid dmv gele markering die op dat moment dus NIET geldt voor de gewone weggebruiker. In beide situaties lijkt deze dubbele betekenis van de gele markering verwarrend te zijn geweest.

Voor twee situaties geldt dat hoewel het wegbeeld geen verklaring biedt waarom weggebruikers van de weg afraken er wel iets te vermelden is met betrekking tot de bescherming van de obstakels die men, bij van de weg afraken, tegenkomt. Vermeldenswaardig is de situatie waarbij een busbaan afgescheiden wordt met een betonnen barrier waar de gewone weggebruiker makkelijk per ongeluk achterlangs kan rijden. Als dat het geval is zou het ontwerp van de busbaan er rekening mee moeten houden dat weggebruikers met over het algemeen hogere snelheden dan de bus de busbaan zouden kunnen oprijden.
Een andere situatie maakt het gevaar duidelijk dat ontstaat wanneer men obstakels lokaal afschermt en ruimte laat tussen de vangrails die de opeenvolgende obstakels beschermen. Als een bestuurder zo onfortuinlijk is om tussen de twee obstakels van de weg af te raken kan hij/zij achter de vangrail geraken en toch tegen het obstakel botsen.

# Summary

**Purpose**
The road scene analyses presented here were conducted within Work-Package 1 of the EU-RISER project. Within this workpackage, Task 1.2 consisted of constructing a detailed-reconstruction-database. For that purpose TNO Automotive collected 10 new accidents and TNO Human Factors added a road-scene analysis to each accident to provide more in depth information specifically in relation to the interaction of the driver with the road design and roadside furniture. This database serves as a starting point to include Human Factors principles within the roam of roadside infrastructure design by means of developing guidelines and analysis procedures necessary to select, implement, and operate a safe, efficient and affordable roadside infrastructure in the EU.
This report describes the road scene analyses performed by TNO Human Factors of the ten accidents.

**Method**
Two experts visited all ten locations during daytime circumstances. If the accident had taken place during the dark hours of the day the site was also visited at night. For each of the ten accident sites, a video was made of the approach to the accident site to have a clear impression of the road the victim travelled prior to the accident. After an approach-video was made, the road scene analysts returned to the sight to take pictures. Both road scene analysts then filled in a road-scene analysis checklist, independent of each other. The checklist can be found in Appendix A. After filling in the checklist the site was visited once more. The same procedure was followed during day- and night-time observations. After the on-site analysis as described above, both experts finalised their observations using the video and picture material off-site and discussed each-others conclusion to come to a clear final analysis of each case.

**Results**
Each analysis of each accident site is reported as follows:
1 Short description and background of the accident
2 Description of the road scene
3 Road-scene analysis results.

**Conclusions**
For five of the ten locations, the road-scene analysis did not reveal a specific reason based on the road layout why the crash with a tree or road side furniture had occurred.
Two locations showed a mismatch of the road design and the road category and the speed limit posted. In both cases the road design invites the road user to drive faster than the local maximum speed limit. This is specifically the case for frequent users who know the road very well. For a third location the road design introduced a specific risk factor: machismo. The road has a multitude of curves that could be appealing to the frequent user with a racing mind. The road layout is congruent with the road category in this case but invites nevertheless to race.
Two accidents occurred in a work zone. In this work zone the general principle that yellow markings go before white markings for the general public is reversed for work traffic. Work traffic is directed toward a work-traffic exit by yellow markings that are NOT to be used by the general public. In both cases it seemed that the double meaning of the yellow markings depending on the context was very confusing.

For two situations the conclusion is that the road scene itself does not provide an explanation for why the driver left the road. In those cases worth mentioning is the shielding of the obstacles the driver encountered while running off the road. One is a situation with a bus lane that is being separated by a poorly visible barrier. This barrier can easily be passed on the wrong side by the road user. This means that the driver can enter the bus lane by accident very easily. If this is the case the design of the bus lane should take into account that drivers with, in general, higher speeds than the busses, accidentally enter the bus lane. In that case the design should be accordingly. Another situation reveals the hazard that is introduced when one shields specific obstacles locally but leaves space between the guardrails that consecutively shield them. When a driver is so unfortunate to leave the road between the two obstacles he/she can then get behind the guardrail of an obstacle and crash into it anyway.

# Contents

# 1 Introduction

Injuries and fatalities due to single vehicle collisions are a significant component of annual road casualties. According to Eurostat (Collin, 2000) 33.8 percent of all fatalities in the European Union in 1998 were the result of single vehicle collisions. This represents over 14,000 lives lost each year of which many can likely be saved through better roadside infrastructure design. The chance of road safety professionals is to find methods and design strategies to reduce these casualties.

The challenge today in roadside design is a lack of direction in the implementation maintenance and operation of these devices. Guard rails, crash cushions, breakaway posts, roadside embankments, and signposts are common human -made structures beside the road. There is no clear consensus within the international community about how these should be designed positioned, dimensioned, and operated.

This RISER project is part of the European Union's Common Transport Policy Sustainable Mobility: Perspectives for the Future: Action Program 2000-2004; more specifically: the June 2001 GROWTH calls for proposals Task 2.2.3/16: Lifecycle safety impact assessment for road planning, design, construction, operation, and maintenance. The project addresses the current omissions in the current state-of-the-art, and the vision of the project is to develop a knowledge base that can provide better roadside design tools and strategies as current resources are conspicuously incomplete.

The main project outputs of RISER are:

1 A collision database containing information on single vehicle collisions exploiting existing and new data sources,
2 Technical performance data for roadside infrastructure describing the physical interaction of vehicle and roadside in addition to the human factors influencing the collision events,
3 Best practice guidelines for designing roadside environments including road safety audit approaches,
4 Best practice maintenance guidelines identifying the operation and maintenance necessary to ensure adequate safety levels.

This report contributes to point 1 described above: A collision database containing information on single vehicle collisions exploiting existing and new data sources.

TNO Automotive has performed 10 in-depth analyses of accidents involving roadside furniture in the context of the RISER EU-Project. These in-depth analyses are performed to investigate the collision sequence for vehicles and their occupants. TNO Human Factors (TNO-HF) has performed road scene analyses on these same 10 locations to determine whether elements or structures on or near-by the location could have induced or enhanced the impact with the roadside furniture from a driving behaviour and human factors' perspective. The idea of a road-scene analysis is to analyse the possible problems with that specific location under normal circumstances (not the exact same situation of the accident). The outcome of a road-scene analysis may therefore be that there was no specific reason for the accident happening at that location, or that there were indeed some elements that explain the accident occurring, for instance misleading lights or a limited preview.

This document describes the road scene analyses performed by TNO-Human Factors as part of the RISER project.

**Method**

A road-scene analysis has been executed at each of the ten accident sites. As part of the method the road scene analyses are always performed by 2 experts. This way it is certain that as much knowledge as necessary to be able to come to a valid conclusion is included as input of a thorough discussion based on independent observations by each expert.

For each site, a video has been made of the approach to the accident site to have a clear impression of the road the victim travelled prior to the accident. If the accident occurred during nighttime, observations were done during daytime and nighttime. When the accident occurred during daylight only daytime observations were done. After an approach-video was made, the road scene analysts returned to the sight to take pictures. Both road scene analysts then filled in a road-scene analysis checklist, independent of each other. The checklist can be found in Appendix A. the checklist is not a checklist as such, it is rather a topics list to make sure that all topics of relevance in a road-scene analysis are reviewed and later discussed.
After an on-site analysis both experts finalised their observations using the video and picture material off-site and discussed each-others conclusion to come to a clear final analysis of each case.

Each analysis is reported as follows:

1 Short description and background of the accident.
2 Description of the road scene
   This section provides the background for each accident describing the location and the occurrences before during and after the accident. The time frame of this description will vary among accidents. The pictures of the location are such that the exact location of the accidents is not recognised to protect victims' rights in this. This information has to remain confidential and the reader of this document has to realise this.
3 Road-scene analysis results
   This section gives the final road-scene analysis per location. The results describe specifically whether there are elements in the environment that can be identified as factors due to which the driver may choose consciously or unconsciously to enhance the risk-level of driving. In some cases this final analysis includes recommendations to improve the site in order to prevent similar accidents in the future. Only elements that were of importance due to either the cause of the accident or because in general they would introduce complexity or confusion for the driver are included in this section.

# 2 Road-scene analysis of ten accidents

## 2.1 Short description of the accident at location 1

The accident described was a motorcycle accident. The motorist entered the entry of a motorway during daylight circumstances. Before actually entering the parallel main carriageway of the motorway the motorist started sliding, lost control of the motorcycle and crashed into the left side barrier on the left side of the main motorway carriageway.

## 2.2 Road-scene description location 1

Before getting to the parallel carriageway, the motorist encountered two curves: first a curve to the left with a maximum speed limit of 50 km/h (Figs 1, 2 and 3, show this situation) and secondly a curve to the right (Figs 4 and 5) before entering the main parallel motorway.


Figure 1 – Curve 1 at location 1 at entrance.

Figure 2 – Curve 1 at location 1 continued 1.


Figure 3 – Curve 1 at location 1 continued 2.

About halfway the first curve the maximum speed limit changes from 50 to 100 in accordance with the fact that at this point the entry officially changes into to a motorway. On the right side a direction sign is positioned (see Figs 3 and 4). After the curve to the left, a transition followed between the left and the right curve (see Fig. 4).

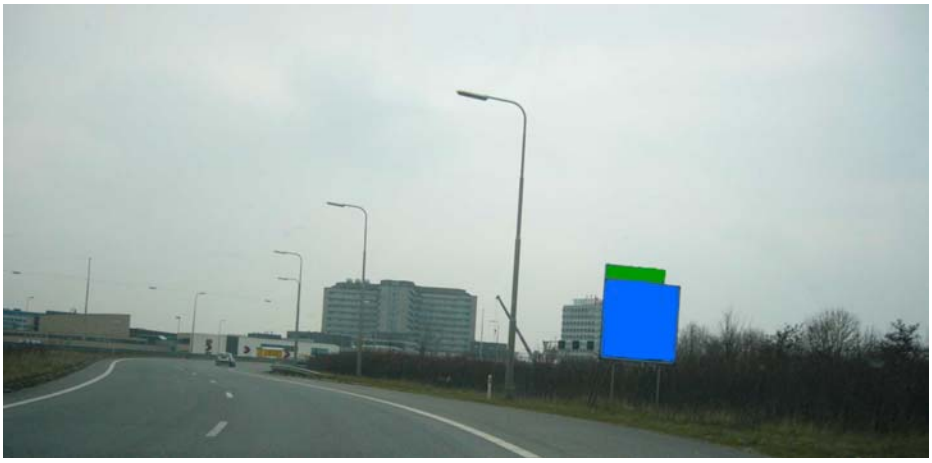

Figure 4 – Transition between the left and the right curve at location 1.

After the transition, the second curve (to the right) is encountered (see Fig. 5).

Figure 5 – Curve 2 location 1.

Essentially, while negotiating this second curve the motorist was preparing to enter the main motorway, as can be seen in Figures 5 and 6. In Figure 6, the location of the green and white truck is about the location where the parallel main motorway lane is located that the motorist most probably wanted to enter.
Figure 7 shows the entrance on the main motorway with on the left side the crash location of the motorist with the left side barrier.

Figure 6 – Curve 2 continued, location 1: preparation position to enter motorway parallel lane.

Figure 7 – Entrance of motorway with crash location (yellow star), location 1.

## 2.3 Road-scene analysis results location 1

Although the reason why the motorist lost control of his motorcycle was caused by a reason other than the road situation, the road-scene analysis only concentrated on the road layout and design elements of the environment. The results indicate that there are indeed some aspects that may be of concern in terms of general road safety, independent from this specific accident.
The design of the entry (motorway entry) can be described as “marginally safe”. Although the two curves (left and right) that follow each other each have an adequate speed limit according to the Dutch Design Guidelines for Motorways: Alignment (ROA, 1991), they do introduce a complex situation. The curves by themselves are no problem, but following each other at a location where the motorist needs not only negotiate both curves, but in the mean time accelerate to 100 km/h, anticipate and join the traffic on the main motorway while making route choices. This al together does not make for a “standard” driving situation. All the aspects together implicate a high workload for the motorist.

A perceptual narrowing of the road due to the curves causes a limited sight distance while the speed limit is changing from 50 to 100 km/h; therefore it is hard to oversee the complete situation beforehand. The advance direction sign as can be seen in Figure 4 indicates that drivers should move to the left while they are negotiating the transition between the curves (entering a right hand curve) to enter the main motorway. The motorist is negotiating a right-hand curve while having to look to the left at the same time; this is counterintuitive.
While the situation may be hard to negotiate for the unfamiliar driver on this stretch of road, the familiar driver might see the design of the road as a challenge when the motorist is receptive for this, because the entry itself has an element of “machismo”: the curves can be seen by a risk-seeking motorist as a perfect race-track. This can be confirmed by the fact that the road markings are very worn down at the typical places where motorists would break out of the curve: the middle marking in the left-hand curve and the right sided marking in the right-hand curve (see Figs 3 and 6).

## 2.4 Short description of the accident location 2

The accident that occurred on location 2 involved a person car colliding with an iron wall positioned next to a pillar of an overpass under construction during night time.
The situation was temporary. At the time of the road-scene analysis the situation had changed such that the overpass was completed and the barrier positioned in parallel of the pillar on the shoulder was changed in position and angle (see Figs 12 and 13).
The driver of the vehicle wandered onto the shoulder approximately 300 meters before the collision with the iron wall occurred. Almost in a straight line the driver kept wandering and eventually collided with the iron wall. The path the driver took included a work zone exit, which led eventually to the iron wall construction.

## 2.5 Road-scene description location 2

The road described is a three-lane motorway (one-directional) with a hard shoulder. Before the position that the driver 'wanders' of the road an entrance lane is added to the motorway on the right side (see Fig. 8). The block markings indicate the entrance lane.

Figure 8 – Three-lane motorway with an entrance/acceleration lane on the right driving toward location 2.

Figure 9 – Three-lane motorway toward location 2: change in horizontal alignment.

Figure 9 shows the lay out of the road just after the entrance lane where the road makes a shift to the right as can be seen: a change in horizontal alignment. Just after this shift the driver gets on the shoulder and eventually off the road.

Figure 10 – Temporary exit lane for work-zone traffic indicated with yellow marking, location 2.

Figure 10 shows the lay out of the hard shoulder where the driver has driven before getting off the road. The yellow block markings indicate that there is an exit for work traffic. A yellow traffic sign positioned before that had indicated this already: a mirror image of sign WIU100.1 with an extra arrow added for the third lane (NVV, 2001).
Figure 11 shows the exit itself.

Figure 11 – Temporary exit for work-zone traffic on shoulder location 2.

Figure 12 – Accident location 2 with new barrier at time of road-scene analysis.


Figure 13 – Accident location 2 with old barrier at time of accident.

Figures 12 and 13 show a picture of the two different barriers that were located alongside the pillar at two points in time. Figure 12 shows the situation as encountered during the road-scene analysis. Figure 13 shows a picture of the barrier that was located at this position at the time of the accident.

Figure 14 – Accident location 2.

Figure 14 shows a picture of the exact accident location at the time of the accident (with the old barrier). The yellow star indicates the position of the iron wall in between the pillar and the barrier that he driver hit eventually.

## 2.6 Road-scene analysis results location 2

It is impossible to reconstruct exactly what happened to this particular driver but after the road-scene analysis two general comments can be made.
The fact that the work zone markings indicating an exit for work-zone traffic are yellow might have been confusing. Normal regulations state that yellow markings in work zone areas on the main road always have precedence over the normal white markings. All traffic has to follow the yellow markings. In this case the opposite situation is true: the yellow markings are only for work-zone traffic, all other traffic should follow the white markings.
The original barrier (see Fig. 13) did not protect the area enough to prevent a vehicle to drive toward the pillar and iron wall in an almost straight line. The new situation, after the accident (see Fig. 12) shows a barrier at an angle, which prevents traffic from colliding with the pillar in a straight line. Also the position of the barrier is changed. The old barrier was positioned on the shoulder leaving space between the pillar and the barrier where the iron wall was positioned. The new barrier is positioned closer to the pillar leaving no space between the pillar and the barrier to pass through and collide with the iron wall.

## 2.7 Short description of the accident at location 3

A vehicle leaves the road for unknown reasons and after hitting two trees ends up in a water-filled ditch. The accident occurred during the early (dark) morning hours.

## 2.8 Road scene description location 3

The road on this location is a secondary road. This road connects the motorway with the build up area beyond and is essentially an off ramp transitioning into a secondary road. A bus lane is added to the right side of the two lanes of the secondary road (see Fig. 15). The vehicle left the road just before the bus lane starts approximately at the location of the 50km/h sign (see Fig. 15) that he just misses.


Figure 15 – Approach location 3 during daytime.

Figure 16 – Approach location 3 during nighttime.

Figure 17 – Location 3 illustration of drop-off of roadside (a) looking back (not according to driver perspective).

Figure 18 – Location 3 illustration of drop-off of roadside (b).


Figure 19 – Collision location with tree, location 3.

## 2.9 Road-scene analysis results location 3

Although the road design at this location is not particularly dangerous there are some elements that make it more understandable why drivers may leave the road more easily here.

1 Traffic at the location is speeding.
2 It is a transitionally situation between a motorway with a 100 km/h speed limit and a built-up area with a 50 km/h speed limit (slowing down) via a 70 km/h speed limit
3 including an added bus lane on the right side (see Figs 15 and 16)
4 and a curve to the right,
5 and an absence of an emergency lane.
6 Public lighting is continued on the left-hand side while discontinued on the right hand side where the bus lane appears.

The nighttime picture (Fig. 16) shows that the bus-lane markings in combination with the public lighting on the left side seem to indicate that the road goes more to the right than it actually does.
More important however is the fact that when vehicles leave the road the steep drop-off of the road (see Figs 17 and 18) and the soft shoulder makes it difficult to recover.

## 2.10 Short description of the accident at location 4

A motor vehicle collided with a pillar that was situated on the roadside as an element of a horizontal crossover.

## 2.11 Road-scene description of location 4

The motorway is a three-lane motorway with a shoulder. The speed limit is 120 km/h.
The motorway passes a noise barrier and after that a crossover passes the motorway. Prior to the crossover the shoulder is designated as bus lane for about 100 metres. At about 25 metres after the shoulder changes into a bus lane, it passes the noise barrier. The wall is shielded with a guardrail (see Fig. 20).


Figure 20 – Location 4 noise barrier (wall) and pillars of the crossover.

Just after this wall the bus lane changes direction in a curve to the right, leaving the shoulder. The shoulder and bus lanes are semi-separated by a concrete barrier.
Right after the noise barrier ends, a breakdown emergency area is constructed on the right side of the bus lane with an emergency pole (Fig. 21).
This emergency area can be reached from the main motorway.

Figure 21 – Bus lane semi-separated by concrete barrier, location 4.

Figure 22 – View from motorway at barrier and pillar, location 4.

After about 10 metres the motorway and the bus lane pass under the cross over. The bus lane is here situated on the left side of two pillars. The barrier for the motorway shields the pillar at this point. (See Fig. 22 for the location of bus lane and motorway.) For the traffic on the bus lane, however, the pillar is not shielded (see Fig. 23).

Figure 23 – Bus lane passing under crossover with unshielded pillar on right side, location 4.

## 2.12 Road-scene analysis at location 4

Problems encountered were:
1 Unshielded pillar for bus lane traffic
2 Unnecessary emergency/break down area
3 Semi-separation of bus lane with unmarked/invisible concrete barrier.

The road-scene analysis showed that two other elements other than the unshielded pillar for the traffic on the bus lane were problematic (2 and 3).
Although a barrier between the bus lane and motorway shielded the pillar somewhat for the general traffic on the main motorway this barrier itself was not visible enough. Changing the concrete barrier to a crash cushion with a red and white striping pattern, a RIMOB (as can be seen in Fig. 13) could enhance the visibility of the barrier. However if the pillar remains unshielded for the bus traffic and the bus lane and motorway remain only semi-separated the pillar remains a dangerous obstacle for both the general traffic as well as the busses.
We recommend extending the barrier such that the general traffic can not easily travel onto the bus lane as well as shielding the pillar itself. We can imagine that the emergency/break-down area can be used by busses as a ‘waiting’ area during busy hours. We recommend, however, that the design of the area be then changed into a design that fits this function and does not resemble a break down area with an emergency pole.

## 2.13 Short description of the accident at location 5

In a work-zone area a motor vehicle entered a work zone exit. While doing so he crashed with the concrete barrier situated there and was launched back onto the motorway in a corkscrew manner. It is likely that this situation occurred because the driver realised his mistake and tried to move back onto the road encountering the barrier. This is however not clear from the analysis of the accident itself and purely speculative.

## 2.14 Road-scene description location 5

The road scene that we encountered at the time of the road-scene analysis was a totally different one than the road scene at the time of the accident. Both were temporary situations in a work zone area.
We therefore analysed the situation from the available pictures made right after the accident while taking the situation as it was during our analysis in account.
The road as it was during the accident was a two-lane entrance of one motorway onto the next. The road the driver was driving on had a 70 km/h speed limit because of the work-zone situation.
Figure 24 shows the location as it was during the accident. The yellow markings indicate the work zone exit. The exit is made more conspicuous with the red and white poles. A yellow traffic sign positioned before that had announced the exit for the driver already: a mirror image of sign WIU100.1 (NVV, 2001).

Figure 24 – Work traffic exit location 5.

Figure 25 – Work traffic exit and barrier (behind last red/white pole), location 5.

Figure 25 shows the barrier at the end of the yellow marking that the driver encountered eventually. The driver hit the barrier from the right side and was launched back onto the road.

## 2.15 Road-scene analysis results location 5

- Work-zone situation that can cause confusion
- Barrier is discontinuous to let work-zone traffic through. This opening is not very visible.

The fact that this is a work zone exit where temporary and permanent markings are both at place makes the situation somewhat unclear. In combination with the fact that the barrier that is discontinued to let work traffic through could have led to a situation where the driver might have been led astray by the markings and exit to think that this is a 'normal' exit instead of a temporary work-zone exit. The situation is similar to the accident at location 2. However this situation is maybe even more confusing because there are other yellow lane markings that are not only valid for work zone traffic but are valid and to be followed by the public. In location 2 the only yellow markings there were for the exit. Here the exit is preceded by a situation where the yellow markings had a different meaning.
The main problem thus is that the meaning of yellow markings depends on its context.

## 2.16 Short description of the accident at location 6

At this location a driver left the road on the right hand side due to fatigue. The road has two lanes for each direction one, not physically separated (see Fig. 26). The driver hits a light pole and swerves to the left side of the road where he hits the guardrail. He is able to re-enter the road on the left side briefly but then leaves the road again on the left side crossing a bike lane and hitting a tree eventually.

## 2.17 Road-scene description location 6

The road described is a secondary road with a speed limit of 80 km/h with a sustained road safety design. The road has a widened median and discontinuous markings on the right and left side (see Fig. 26). Bushes are positioned on the side of the road as well as light poles on almost the complete stretch of road. The vertical alignment of the road is slightly elevated at the place where a secondary road crosses under the road. This position is marked with a guardrail and green lamellas/panels positioned on top of the guardrail on the right side (see Fig. 28). At this point however the vehicle had already left the road. A parallel road is positioned to the right side of the road, most of the time invisible to the driver, except for small sections such as can be seen in Figure 27.

Figure 26 – Road scene 300 metres before accident location 6.

Figure 27 – Location 6, 150 metres before vehicle leaves the road.

Figure 28 – Location where a vehicle starts swerving off the road to the right (location 6).

## 2.18 Road-scene analysis results location 6

The road-scene analysis on this location did not reveal any road design elements or roadside furniture elements that could have contributed to the accident or should be taken into account at this location in general.
There were no discontinuities in alignment other than the fact that after the vehicle got off the road the driver entered the site of the viaduct where the road was slightly elevated. Once off the road on the right side and trying to recover this could have enhanced the difficulties of recovery. No other elements of discontinuity during night or day have been encountered. No other elements in terms of light arrangements, traffic signalling, sight distance or stop distance, misleading elements or any other element have been found. The driver said to have fallen asleep and although we have not driven the complete route the driver drove before falling asleep the conclusion should be that it was not because the road was inducing boredom or inattention as such.
During the night time observations we specifically looked at the possible misleading influence of the light poles on the parallel road, but we found them not misleading in any way.

## 2.19 Short description of the accident at location 7

On a secondary road exiting the build up area with a maximum speed of 70 km/h, a driver lost control of the vehicle in a curve to the right. The driver was speeding (around 150 km/h). The car broke out of the curve on the right side and exited the road. After leaving the road the vehicle collided with two trees.

## 2.20 Road-scene description location 7

The road described is a secondary one-way two-lane road (the other direction is separated from the other with a median with bushes and trees) with a speed limit of 70 km/h from a build-up area to the main motorway network. The road has a number of curves and has bushes and trees alongside the whole stretch (see Fig. 29). The accident occurred after the last curve to the right before an intersection with traffic lights signalling the end of the stretch before entering the main motorway network (see Fig. 32). Light poles are positioned on either the right or left side or both. Parallel to the road on the right side is a bike lane that can not be seen form the road itself. The light poles alongside this road can be seen but are not misleading as to where the main road is leading.

Figure 29 – Approach trajectory 600 metres before accident location 7.

Figure 30 – Start of curve to the right of accident location 7: the red and white low plastic barrier is added after the accident.

Figure 31 – Halfway curve, the accident (location 7) occurred at the end of this trajectory.


Figure 32 – Last part of curve, location 7.

Figure 33 – The accident location at time of road-scene analysis (yellow star indicates end position of vehicle).

Figures 30, 31 32 and 33 show the whole curve where at the end the accident occurred. As can be seen from these pictures, this is not a particular dangerous curve when one keeps the maximum speed limit. It is rather shallow. The red and white barrier that is visible in the pictures is added after the accident had occurred. Apparently the local police had known the location, as a location where frequently people would crash. We assume, however, that this is solely the result of speeding and not because the curve itself is a problem.

Figure 34 – Looking back from location 7 at tracks of vehicle exiting the road (at day of accident).

Figure 34 shows the tracks of the vehicle leaving the road looking onto the road in the opposite direction the driver was driving. The brick road visible on the right hand corner is the start of an entrance to a gas station just beyond the accident location. We have specifically looked at the influence of the location of this gas station in relation to the accident location.

## 2.21 Road-scene analysis results location 7

- Main problem : speed in combination with curves

The road scene as analysed was different from the one at the time of the accident in that the red and white barrier on the left and right side was not in place during the time of the accident.
The main result of this analysis is that this road invites the driver to drive faster than the 70km/h speed limit, especially for the frequent user. The road has a layout including trees on the side of the road that give enough guidance to speed. The road design of the curves allows a higher speed limit as well. Once a driver has decided to show willingly unsafe behaviour by speeding there are no places where he is forced to lower the speed limit in a safe manner. The curve where the accident occurred has been known to have more accidents and is located at the end of the road connecting a build up area with a motorway system. The barrier that is placed now does induce a lower speed limit and as such will probably be beneficial to prevent high speeds at this location. It is advised that in order to keep the speed down on this road more measures like this should be put in place.

## 2.22 Short description of the accident at location 8

A vehicle driving on the left lane of a two-lane highway (one-directional) leaves the road briefly on the left side, entering the soft shoulder. The driver is able to recover and returns to the lane, but then enters into a skid and side-ways leaves the road on the right side. Entering a ditch stops the vehicle. It is unclear whether the vehicle touched the guardrail on the left side. There is no guardrail or barrier on the right side.

## 2.23 Road-scene description location 8

The road described is a two-lane motorway one-directional with the other direction separated by a median. The speed limit is 120 km/h. Guardrails are positioned on the left side in the median at some distance from the recovery area (about a meter). No guardrail is positioned on the right side. There is an emergency lane on the right side with a wide recovery zone. A ditch is located at about 4 meters from the end of the emergency lane.

Figure 35 – Approach trajectory location 8.

Figure 35 shows the approach trajectory before the vehicle leaves the road just beyond the blue route navigation sign in the picture (see Fig. 36). This approach trajectory is representative for the whole road in fact the road looks pretty much the same for about 3 kilometres up until this point.

Figure 36 – Location 8: position where vehicle leaves road on left side.

Figure 37 – Tracks of vehicle leaving road on right side, location 8.

Figure 36 shows the approximate location where the vehicle ran off the road on the left side. Eventually the driver could not fully recover and ran off the road on the right side (see Fig. 37).

## 2.24 Road-scene analysis results location 8

No elements that were of importance either to the cause of the accident or for safety in general could be located. Some general comments are:

- The road itself has some bumps along the way. When keeping the speed limit these should not cause a problem. With high speeds they might.

- On the right side no guardrail was placed. It might be the case, however, that because a ditch was located on this same side about four metres from the shoulder a guardrail could have prevented the driver from entering the ditch. The downside of placing a guardrail to prevent this would, however, be that cars could re-enter the road and be a danger to the traffic there.

## 2.25 Short description of the accident at location 9

A vehicle leaves the three-lane motorway on the right side, just after two viaducts. A guardrail on the right shields the walls of the viaducts. After the viaduct there is a stretch of about 50 metres where no guardrail is placed. At about 40 metres from the end of that guardrail a pole is placed with a route information sign. A guardrail is shielding this pole. Because of the discontinuity of the guardrail between the viaduct and the pole, the vehicle is able to end up behind the barrier colliding with the pole for the route information sign.

## 2.26 Road scene description location 9

The road described is a three-lane motorway. The motorway passes under two viaducts (see Fig. 38). After the viaduct an entrance lane on the right that is higher located than the main motorway merges with the three-lane motorway. Just before the merge zone a route information sign is located positioned on a pole to note the direction of the entrance and exit zone following. This pole is located behind a guardrail that starts at about 10 metres before the position of the pole. The motorway has a continuous shoulder. The entrance lane has a sound barrier (see Fig. 39).

Figure 38 – Approach trajectory, location 9, before two viaducts (600 metres).

Figure 39 – Approach trajectory, location 9, under second viaduct, pole for route information sign is visible on the right.

Figure 40 – Approach trajectory, location 9, halfway viaduct and end position vehicle.

Figures 39 and 40 show the position where the vehicle ran off the road and ended behind the guardrail against the pole.

Figure 41 – Location 9, tracks behind guardrail.

## 2.27 Road-scene analysis results location 9

The main elements that were important in this situation were:

- A discontinued guardrail from the viaduct to the route information sign pole.
- A downward slope to the right in the recovery area.
- The downward slope meets an upward slope caused by the elevated entrance lane coming in from the right.
- The two slopes together make a V-shaped ditch in the recovery area.

It is unclear why the vehicle got off the road at the location it did. However, when it did it almost had no chance of recovery and re-entering the motorway because the vehicle passed behind the guardrail located to shield the pole it eventually hit. Because of the fact that the entrance lane coming from the right is located at a higher position the recovery zone between the main motorway and the entrance lane where the pole has a slant as can be seen in Figure 40. The vehicle thus enters a V-shaped ditch as described before. This is the reason the vehicle was not able to recover and had no chance to miss the route information sign pole.
It is recommended to either position the route information sign at a location where no pole is needed or, to continue the guardrail between the viaduct and the pole.

## 2.28 Short description of the accident at location 10

In a 60 km/h zone on a secondary road (two way-two lanes) a vehicle leaves the road in a curve to the right colliding with a tree on the right side. The road was slippery due to early-morning frost.

## 2.29 Road-scene description location 10

The road described is a rural road that originally had an 80 km/h speed limit. Due to new regulations the road has been given a new speed limit of 60km/h enforced by signs at the beginning of the road describing that this is a 60 km/h zone (see Fig. 42). It is a common rural road with curves to both left and right in a sparsely build-up area. The

road has trees and bushes on the left and right side in a discontinuous manner (see Figs 43 and 44).


Figure 42 – Start of 60 km/h zone location 10 (about 2 kilometres before accident location).

Figure 43 – Curve to the left before accident location 10.

Figure 44 – Road scene 100 metres before accident location 10.

Figure 45 – Accident location 10 at time of road-scene analysis.

Figure 45 shows the location where the driver ran off the road and hit a tree on the right side. The yellow star shows the location of impact.

## 2.30 Road-scene analysis results location 10

Although the road was slippery on the morning of the accident which likely has caused the vehicle to leave the road, the main element of importance in respect of the human factors involved in this case, is that the road described has a speed limit of 60 km/h that is only endorsed by a speed limit sign at the entrance of the zone about 2–3 kilometres ahead from the accident location. The layout of the road is not different from any traditional 80 km/h road in that the driver is not reminded throughout the journey by road design elements that the speed limit is 60 km/h.

# 3 General conclusions

For five of the ten total locations, the road-scene analysis did not reveal a specific reason based on the road layout why the crash with a tree or roadside furniture had occurred.
Two locations showed a mismatch of the road design and the road category and the speed limit posted. In both cases the road design invites the road user to drive faster than the local maximum speed limit. This is specifically the case for frequent users. For a third location the road design introduced a specific risk factor: machismo. The road has a multitude of curves that could be appealing to the frequent user with a racing mind. The road layout is congruent with the road category in this case but invites nevertheless to race.
Two accidents occurred in a work zone. In this work zone the general principle that yellow markings go before white markings for the general public is reversed for work traffic. Work traffic is directed toward a work-traffic exit by yellow markings that are NOT to be used by the general public. In both cases it seemed that the double meaning of the yellow markings depending on the context was very confusing.
For two situations the conclusion is that although the road scene itself does not provide an explanation for why the driver left the road it is worth mentioning something about the shielding of the obstacles the driver encountered while running of the road. Worth mentioning is the bus lane that is being separated by a barrier that is poorly visible and is easily passed on the wrong side by the road user. This means the driver by accident enters the bus lane very easily. If this is the case the design of the bus lane should take into account that drivers with in general higher speeds by accident enter the bus lane and the design should be accordingly.
Another situation reveals the hazard that is introduced when one shields specific obstacles locally but leaves space between the guardrails that consecutively shield them. When a driver is then so unfortunate to leave the road between the two obstacles he/she can than get behind the guardrail of an obstacle and crash into it anyway.

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# 5 Signature

Soesterberg, August 31, 2004 TNO Human Factors

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First author, Project leader

# A Road-scene analysis topics list

Discontinuity road design (horizontal alignment)

Vertical alignment

Discontinuity road markings or guardrail/barrier

Discontinuity buildings/built up area/trees/bushes

Perceptual narrowing

Actual narrowing (due to, Fe. entrance of tunnel, end of shoulder etc.)

Transition to other speed limit zone

Transition to area with traffic signalling

Public lighting transition (misleading?)

Limited field of view

Limited stop or anticipatory distance

Unclear route information

Elements with unclear functions

Abnormal or unknown elements

Too many information carriers

Attention drawing road elements

Presence of sound barriers or light reflecting screens (dazzling)

Presence of entrances/intersections/exits

Uncommon layout of entrances/exits/intersections

Traffic signs?

Possibility to park (for emergency breakdown, Fe. hard shoulder)

One or two directional?

Old markings or milled away markings

Traffic intensity

Road environment (trees, forest. buildings, advertisement, meadows)

Are dangerous areas marked? (Fe. Railroad crossing?)

Is there a dynamic use of the road (Fe. hard shoulder becomes extra lane during peak hours)?

Is it easy or understandable because of the design to find yourself driving against traffic?

What is the right-of-way situation?

Is there a situation where different sources of information or safety are conflicting or incongruent?

Is there a situation of apparent safety?

Traffic lights in the distance that draw attention when green (so the driver does not see the close-by lights that are red)

Are road design and road categories congruent?

Was it a temporary situation?

Intersections of roads with different types of traffic/ different road categories?

Risk factor: Design of specific equipment and tools alongside the road?

Risk factor: Accident enhancing factors like high temperature, noise and psychological factors like boredom or machismo?

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