Accidents involving lorries manoeuvring in the dark

Safety Study

The Hague, 2003

Transport Safety Board

The Transport Safety Board is an independent institution with its own legal personality, established under Dutch law. Its objective is to investigate and determine the causes and possible causes of accidents in various categories across the entire transport industry: shipping, rail, air, road, and pipelines. The sole aim of its investigations is the prevention of similar accidents and incidents in the future, and to bring out recommendations if the findings so dictate. The organizational structure is a coordinating Transport Safety Board with a subdivision of Chambers and a Commission per transport sector. A staff of researchers and a secretariat provides the necessary support.

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FOREWORD

The Transport Safety Board not only investigates specific accidents, but also conducts thematic studies to closely examine particular types of accidents and safety issues. This report is of a thematic study of accidents involving lorries manoeuvring in the dark, on unlit roads.

In more ways than one, such accidents appear to involve structural safety issues. For example, a number of industrial sites have only a single driveway, and are laid out in such a way that lorries are unable to turn around. This means that the lorries have to reverse either onto or off the site. Furthermore, in the dark, it appears that under certain conditions, the sides of lorries are insufficiently visible/recognisable, even when equipped with the required lighting and reflectors.

The problems uncovered have existed for a long time. In the course of time, measures have been taken (such as requirements for side reflectors and side markings for lorries), but, relatively speaking, a large number of accidents still occur in which the poor visibility and/or recognisability of lorries plays a role. Moreover, it should be noted that not all the opportunities for improving the situation are being utilised. For instance, sections of industrial sites could be made better accessible by constructing an extra driveway and /or changing the layout of the site; and the visibility/recognisability of lorries could be improved by the introduction retro-reflective contour markings (RRCM).

A recent SWOV [Institute for Road Safety Research] report showed that the transport sector in question is aware that introducing RRCM would contribute to further reducing the safety risks in respect of lorries. However, the report also showed that within the sector, no broad-based support exists for the voluntary introduction of RRCM on a large scale. The major argument put forward is that the direct ‘benefits’ for the sector are outweighed by the amount of investment needed.

The introduction of RRCM, however, could result in a substantial reduction of the number of accidents and injuries, and, in addition, socially speaking it would be profitable. The Transport Safety Board therefore believes that this improvement option should be taken up and – if broad-based support is lacking for voluntary introduction – a statutory obligation should be set down. It is worth noting that the Board – by extension of the slogan “the polluter pays” – does not find it unreasonable for the sector to be held financially accountable for measures for reducing safety risks that are introduced by the sector itself.

The Board realises that a statutory RRCM obligation entails European legislation and that the poor visibility and recognisability of lorries in the dark is not simply a Dutch problem. The European Union recently decided to include RRCM in the European Type Approval for lorries. However, this legislation will take some time to go into effect, and for that reason the Board believes the RRCM obligation should be included in national legislation as soon as possible and prior to the EU legislation going into force. Introduction at a national level will probably have an immediate positive effect given that the large majority of accidents do not involve foreign lorries.

Pieter van Vollenhoven
Chair of the Board

J.H. Pongers
Acting Secretary Director

SUMMARY

The traffic accident on which this study is based, involved the collision of a passenger car with the side of a lorry. The lorry was reversing into a driveway, in the dark. It is worth noting that the lorry met the legal requirements in terms of lighting and reflectors and there is no reason to assume the driver of the car was driving significantly too fast, was under the influence of alcohol, or distracted.

In the Netherlands, over 100 such accidents happen every year. On average, each year 2 people lose their lives and over 20 people are injured badly enough to be admitted to hospital.

In general outline, such accidents involve the following three structural safety issues:
- The layout of and access to the company site concerned is such that lorries have to reverse onto the site.
- Despite meeting the legal requirements for lighting and reflectors, in the dark, the sides of the lorry were not sufficiently visible/recognisable at a distance.
- Both drivers appear to have lacked traffic awareness in that they both only realised the danger of the imminent accident at a considerably late stage.

Furthermore, the study showed that the visibility and recognisability of lorries in the dark could be considerably improved by using retro-reflective contour markings (RRCM). Needless to say, the improved visibility and recognisability of lorries is important in more traffic situations than simply those related to driving into and out of driveways. On an annual basis, the total number of accidents in which this issue plays a possible role, is around 1800. Each year, over 80 people have to be admitted to hospital and some 9 deaths occur. The introduction of RRCM would not prevent all of these accidents/injuries, but could reduce the annual number of lorry accidents by several hundred, the number of hospital injuries by 20 to 30, and the number of death by 2 or 3.

Four recommendations were drawn up based on the findings:
- When issuing/extending permits for driveways at industrial sites that are regularly visited by lorries, the road authority concerned is recommended to take into account whether or not the layout of and access to the site allows lorries to enter and leave the site by driving forwards.
- The minister of Transport, Public Works and Water Management is recommended, as far as possible, to exert pressure for the swift introduction of European legislation on the compulsory use of retro-reflective contour markings for lorries. In addition, prior to the introduction at a European level, the RRCM obligation should be included in national legislation as soon as possible.
- The sector organisations of shippers, receivers and transporters, as well as agriculture and horticulture companies, are recommended to urgently advise their members, that in the dark in particular, the manoeuvring of lorries on public roads should be restricted as far as possible, and when it does occur, adequate safety measures should be in place.
- The problem of poor visibility and recognisability of lorries in the dark must be included in the theory section of the various driving tests as well as in the lorry-drivers' licence exam.

1. MOTIVATION

1.1 Accident in Marknesse

The direct motivation for this theme study was a serious traffic accident that took place on 22 November 2000, in Marknesse. The accident involved a collision between a passenger car and the side of a lorry, in the dark, while the lorry driver was attempting to reverse into a driveway. One of the passengers in the car died as a result of the accident and the other two passengers sustained severe injuries.

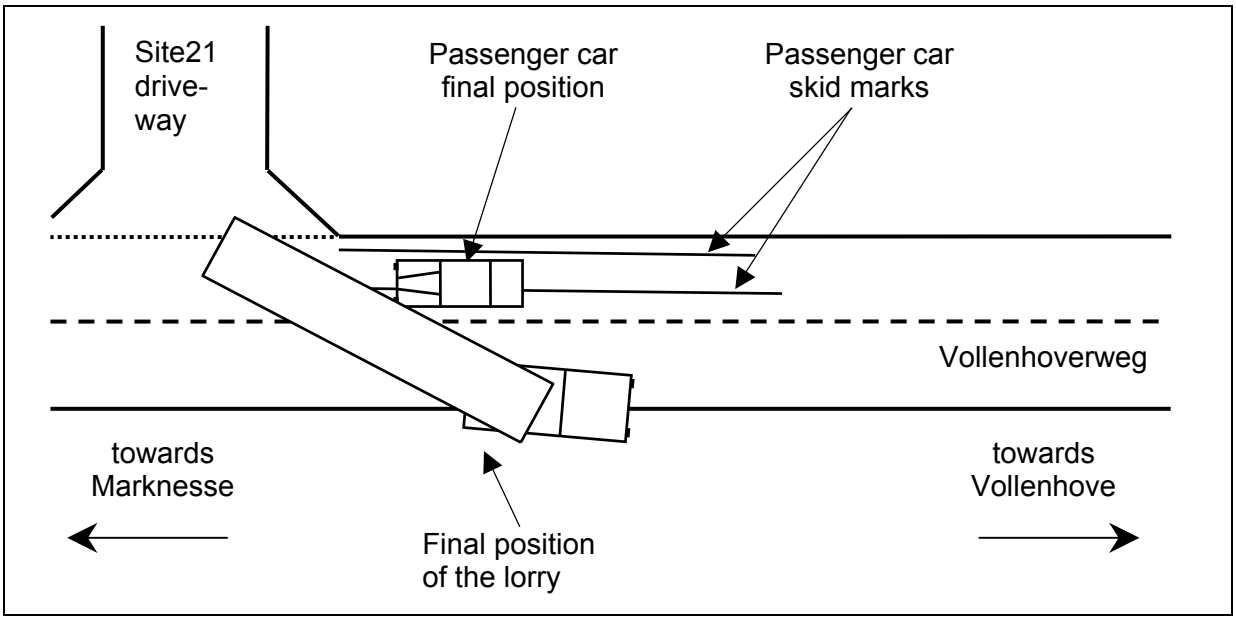

Illustration 1: Situation and final positions of the vehicles involved in the accident.

This photo does not show that most of the serious damage to the passenger car was on the right front side. This was caused by the right corner of the car hitting the foremost left wheel of the trailer. For the same reason, after the crash, the car was thrown back to the left rear, and came to a halt next to the skid marks. (See illustration 1).

Illustration 2: Vehicles damaged in the accident in Marknesse. (Source: Flevoland Region Police)

The circumstances surrounding the accident can be outlined as follows:

- The accident occurred on Wednesday, the 22nd of November 2000, on the Vollenhoverweg (between Marknesse and Vollenhove) in the Noordoostpolder. The access road concerned is surfaced with impervious asphalt concrete and the roadway is about 6.5 m wide, divided by a broken centre line into two lanes, allowing for traffic in both directions. A separate cycle path lies next to the roadway, with a soft shoulder of about 5.5 m wide in between. The road is signposted as a priority road and the legal speed limit is 80 km/h. The accident took place at about 7.15 p.m. It was already dark at that time, and the weather was dry and clear.
- The lorry involved in the accident (a semi-trailer combination), driven by a 53-year-old man, approached the accident site from the direction of Marknesse. The lorry was carrying empty crates to be unloaded at section 21. The company site concerned was laid out in such a way that articulated lorries like the one concerned, are unable to turn around. On arriving at the site, the driver first brought the lorry to a stop on the right lane. The lorry was standing a short distance past the driveway, which was situated on the left side of the road (viewed from the direction in which the lorry was driving). In addition to the usual (dipped) headlights, the lorry's hazard lights were also on. While in this position, the driver of the lorry allowed several cars (from both directions) to pass by. He stated to the police that he waited until a car behind him stopped, and in the other direction, the headlights were at a far distance. He then began to reverse and turn left into the driveway concerned.
- While the lorry was performing this manoeuvre, a passenger car approached from the opposite direction. A 25-year-old man was driving the car, with his 65-year-old mother in the right-front passenger seat and his 18-year-old girlfriend in the back. According to the driver, he approached the site of the accident at a speed of about 80 km/h and saw the headlights of the lorry on the side of the road of the oncoming traffic, and at a great distance away. He assumed the lorry was stopped, and decided to pass it in the usual way. However, once he was closer to the lorry, he saw something glittering on his half of the road, and slammed on the brakes in response.
- According to the lorry driver's statement, while reversing, he saw the headlights of the passenger car approaching from the opposite direction. Initially, he expected the motorist would see that the trailer was blocking his side of the road, and in response would bring his vehicle to a stop. At a certain moment, however, it became clear to the lorry driver that the passenger car was not slowing down in time and at the last instant the lorry driver attempted to drive forward to clear the other lane.

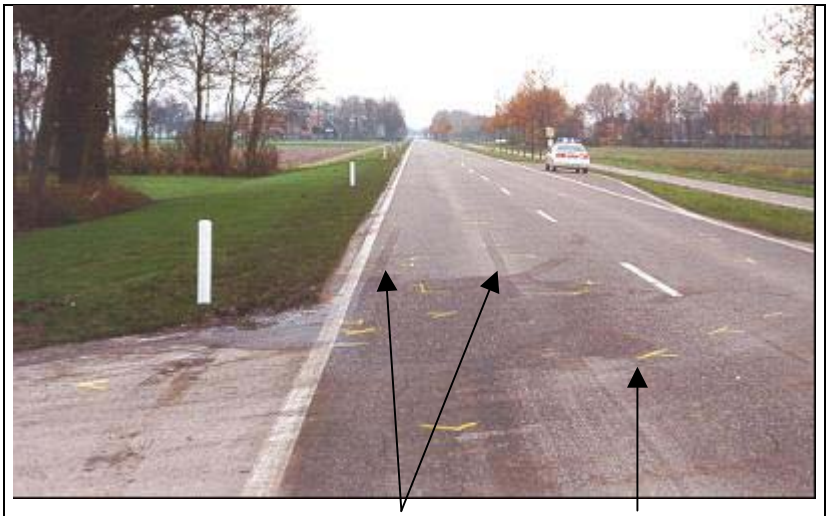

Illustration 3: The section of road on which the passenger car was travelling towards the site of the accident, seen from the site of the accident. (Source: Flevoland Region Police)

- Despite the fact that the driver of the passenger car slammed on the brakes, and the last minute attempt of the lorry driver to drive forwards, a collision occurred. The passenger car collided with the foremost left wheel of the trailer. The passenger in the right front seat, sustained such severe injuries that as a result, one and a half weeks later, she died in hospital. The driver and the backseat passenger had to be admitted to hospital for their injuries. Both vehicles were severely damaged.

The following comments apply to the situation and circumstances ofthe accident:
- The section of road on which the passenger car was travelling towards the site of the accident, is, (as can be seen in illustration 3), straight for a long section.
- The lorry had side markings and lights and these were in use and functioning.
- At the time of the accident, the weather was dry and clear. The road surface was also dry. No street lights or other lighting was present at the site of the accident.
- The lorry had to reverse into the driveway, because the company site concerned had only a single driveway, and was laid out in such a way that it was impossible for lorries of this type to turn around.

The police conducted a thorough investigation of the events leading up to the accident and the circumstances concerned. The question of why the driver of the passenger car did not have the opportunity to bring his vehicle to a stop was examined. There was no indication that he had not been paying attention, nor was he speeding, or under the influence of alcohol, and the like. The passenger car driver's statement makes clear that when approaching the site of the accident, he did see the headlights of the lorry on the other side of the road. However, he did not see that the trailer was standing diagonally across his side of the road until it was too late. This reading of the facts is in line with the results of the police inquiry. The police report shows that the marking lights on the side of the trailer would only have been reasonably visible to the driver of the passenger car once the distance between the vehicles were too small for him to avoid a collision. It is worth noting that the lighting of the lorry, on the side too, was in accordance with the statutory provisions.

Furthermore, the statement made by the lorry driver to the police shows that he had misjudged the amount of time it would take to reverse into the driveway. He thought he would be able to free up the road without hindering any oncoming traffic. His statement also shows that he was not fully aware that the side of his vehicle (due in part to the obscuring effect of the lorry's headlights) was poorly visible for oncoming traffic.

1.2 Similar accidents

Interviews conducted within several police forces show that accidents with similar circumstances to the one described above, occur more frequently. The two accidents below are typical examples:

Accident of 21 October 1998 (municipality of Noordoostpolder)

This accident between a passenger car and a lorry with a trailer occurred at around 6.45 a.m. on the Westerringweg, at the T-intersection with the Onderduikerspad, between Creil and Espel in the municipality of Noordoostpolder. The section of the Westerringweg concerned, lies outside the built-up area and is signposted as a priority road. The road surface is asphalt and the roadway is about 6.0 m wide, with a broken line dividing the road into two lanes. The speed limit is 80 km/h. At the time of the accident, it was dark and the weather was dry and clear.
The accident occurred while the driver of the lorry was attempting to turn the vehicle around. To this end, he first drove ahead across the T-intersection, in order to subsequently reverse into the side street on the left. The passenger car approached the T-intersection from the opposite direction.
At the time of the collision, the front section of the articulated lorry was situated parallel to the road axis in the right lane, while the trailer was situated in the other lane. The left front side of the passenger car collided with the left front wheel of the trailer. This resulted in both occupants of the passenger car sustaining serious injuries, and both vehicles were severely damaged.
Apart from the usual dipped lights, the lorry was using its hazard lights, and the sides of both the lorry and the trailer had side markings. The passenger car was driving with dipped lights.

Accident of 24 November 1998 in Sellingen (municipality of Vlagtwedde)

This accident too, involved a passenger car and an articulated lorry. The accident happened at around 10.55 p.m. in the vicinity of section 9 on the Lammerweg, in Vlagtwedde (Groningen). The section of road concerned lies outside the built-up area and is signposted as a priority road. The speed limit is 80 km/h.

The lorry driver was attempting to turn the combination left while reversing into the driveway adjacent to his home. At the time of the accident, the cab was roughly parallel to the road axis and was in the right lane, while the trailer was situated diagonally across the lane. The lorry was using both dipped lights and hazard lights; both the sides of both the cab and trailer had side reflectors.

The passenger car approached the lorry from the front. The passenger car driver's statement comes down to the following: he saw the headlights on the opposite side of the road, but he did not see that the trailer was standing diagonally across his own side of the road. He thought that the lorry driver – whom he knew lived here – would allow him to pass before turning into the driveway next to his home.

The passenger car collided with the trailer at about the mid-point of the left side. The crash resulted in the driver of the car (there were no passengers) sustaining serious injuries and the car and trailer were severely damaged.

2 STUDY

2.1 General

The three accidents described in chapter 1 have the following in common: they were all caused by articulated lorries manoeuvring in the dark outside built-up areas and occurred on roads with no street lighting. Furthermore, none of the motorists involved noticed the lorries in time. It is worth noting that the lorries concerned had all complied with the statutory provisions on lights and reflectors, and that there was no indication that any of the passenger car drivers were under the influence of alcohol, were driving (significantly) too fast, or were distracted at the time. This leads us to surmise that lorries, and particularly their sides, are not visible enough in the dark.

In themselves, lorries are not any less visible (including their rear and sides) in the dark than passenger cars. However, they are considerably larger, less manoeuvrable and significantly slower when accelerating and during manoeuvres. These characteristics have a number of consequences:

- Due to their large size, lorries frequently have to use both sides of the road when driving into and out of driveways.
- For large lorries in particular, it may be the case that they have to reverse into a driveway on a public road. The reason for this may be, for example, that the site concerned does not have sufficient space for lorries to turn around. The same applies when large lorries have to be loaded and unloaded on unpaved roads (something that often happens in the potato and beetroot season). Heavy vehicles cannot manoeuvre on unpaved surfaces. In such instances, the choice is given to reversing into the site in question rather than reversing out of it.
  Due to the limited right-rear field of vision of lorry drivers from the driver's seat, such manoeuvres are actually only possible when turning left. If the driveway concerned is relatively small, such manoeuvres must begin on the right side of the road.
- Due to limited acceleration capacity, lorries need considerably more time than passenger cars for manoeuvres like crossing roads and accelerating to cruising speed.
- For articulated lorries[1], it may be that the cab (where the headlights are situated) is standing approximately parallel to the road axis, while the back section is diagonally across the road. In such instances, for approaching traffic at least, the poor visibility of the back section is related to the obscuring effect of the lorry's headlights. It may be that the situation of a lorry occupying the (entire) opposite side of the road only becomes clear to oncoming traffic at a relatively late stage.

Furthermore, three types of major compatibility issues play a role in crashes involving lorries and other vehicles:

- In general, the total weight of lorries is many times more than that of other vehicles. Broadly speaking, passenger cars usually weigh between 1 to 1½ tonnes, while lorries weigh anywhere from 5 tonnes to over 40 tonnes. This difference in mass is important because when two objects collide, the changes in momentum are reciprocally proportionate to the mass of the object concerned. In other words, a vehicle involved in a collision with a lorry, experiences a significantly greater change in momentum than if it were to collide with a passenger car or other similarly light object.
- In general, lorries are constructed in such a way that their deformation resistance[2] is considerably greater than that of passenger cars and vans. This not only applies to the front and back of the vehicles, but also to their sides. As a result, in a collision with a lorry,

[1] Articulated lorries consist of more than one part. In Europe, this is usually a cab with a trailer (a semi trailer combination).
[2] The *deformation resistance* indicates the force necessary in order to deform/impress the vehicle concerned. This is expressed in kN/cm.

the greater part of the force that is translated into deformation during a collision has to be absorbed by the other vehicle.
- Moreover, the greater part of lorry fleets are not yet equipped with effective underride-prevention systems. Consequently, to some degree or another, passenger cars frequently end up underneath lorries, which means that instead of the relatively strong bumper zone absorbing the impact, only the considerably weaker upper sections of the passenger car are involved in the collision. It even regularly happens (especially if the side or rear of a lorry is involved) that the crash impact is chiefly absorbed by the roof construction of the other vehicle. The result is that the passive safety systems in passenger cars ("crumple zones", seatbelts, and airbags) hardly function or do not function at all when a collision with a lorry is concerned.

The aforementioned means that the sides of lorries should be more clearly visible at night than passenger cars and vans, given that the examples listed above show that arguably this is currently not the case.

2.2 Breakdown of the study

Further to the accidents described above and the considerations mentioned, the study was broken down into the following parts:
a) First, the statutory provisions for lorries concerning vehicle side lighting were inventoried. (See 2.3).
b) Subsequently, the accident statistics were further analysed and the frequency of accidents involving poorly visible lorries was charted. (See 2.4).
c) Following on, the visibility and recognisability of lorries at night was further investigated, first using a theoretical approach and later empirically. (See 2.5).
d) Finally, an inventory and evaluation was conducted concerning retro-reflective contour markings on lorries. (See 2.6).

2.3 Statutory provisions

The statutory provisions for road vehicles are set down in chapter 5 (permanent requirements) of the regulations for road vehicles[3]. For commercial vehicles, the category to which lorries belong, the requirements are summarised in section 3. In this respect, paragraph 10 is of particular relevance, given that it contains the requirements concerning lights, light signals and retro-reflective material.

Normal lorries
Concerning the sides of lorries, the requirements can be outlined as follows: lorries that are over 6.00 m in length must be equipped with reflectors4 on both sides and, if the vehicle was brought into use after 31 December 1995, side-marking lights5 must be present. In broad terms, the relevant provisions are as follows:
- both sides of the lorry must be equipped with approved side reflectors and/or side marking lights must be present;
- the reflectors/lights must be between 0.35 and 1.50 from the road surface[6];
- the distance between the reflectors/lights must not exceed 3.00 m[7].

In addition to the obligations outlined above, lorries "may"[8] be equipped with retro-reflective contour markings on the sides and/or rear (RRCM and/or RRLM)[9]. This marking must meet

[3] The regulations for road vehicles are an administrative order of the 1994 Dutch Road Traffic Act.
[4] Side reflectors are non-triangular amber-yellow retro-reflectors.
[5] Side marking lights must always emit amber yellow light.
[6] In special cases, the maximum height may be 2.10 m.
[7] In special cases, the maximum distance between the reflectors may be 4.00 m.
[8] See the further explanation under 2.6.3.

the terms and conditions of UN/ECE-Regulation 104. The provisions concerning the sides of lorries, basically state that this marking must consist of a white strip with amber retro-reflective material[10], and be 50 to 60 mm wide.

Special transport

Lorries with a total transport and/or vehicle length of over 22.00 m[11] must be equipped with conspicuity markings[12]. The provision states that:

- both sides of the vehicle and/or load must be marked with striping; for at least 80% of the length[13] (in so far as possible, horizontally)
- the markings must consist of a white strip with amber retro reflective material[14] and have a minimum width of 50 mm and a maximum width of 60 mm;
- the striping must be between 0.25 and 2.10 from the road surface.

For the sake of completeness, it should be noted that conspicuity marking is only compulsory for long vehicles in circumstances in which the statutory requirements for lights actually apply (i.e. in the dark or during the day if visibility is extremely poor)[15].

2.4 Accident Statistics

Driveway related accidents

The frequency of accidents in the Netherlands with circumstances like those in Marknesse, was first investigated. Accidents from 1999 and 2000 were selected from the AVV (Traffic & Transport Advisory Service) database of accidents, if they occurred in darkness or twilight and if:

- the accidents involved side-imp-act collisions;
- at least 2 vehicles were involved and at least 1 was a lorry;
- one of the vehicles was turning across or crossing a line of traffic;
- the site of the accident expressly showed that a driveway was concerned.

151 accidents fitted the above criteria. It should, however, be noted that the actual number of driveway-related accidents involving lorries is probably higher. We suspect that the police do not consistently specify the location of "driveway" in the relevant reports. For that reason, the figures listed here should be regarded as lower limits.

We requested the police reports of the 151 accidents referred to above, and used these to assess the extent to which the circumstances were relevant to this study.

The latter proved to be the case for 76 accidents over the two-year period. This figure implies that in the Netherlands, 35 to 40 accidents are recorded each year involving lorries in the dark or at twilight, driving into or out of driveways. The records also showed that each year 16-17 persons were admitted to hospital and two deaths resulted from these accidents.

Bearing in mind the degree to which this type of accident is not officially recorded[16], it can be assumed that the actual figures of relevant accidents amount to around 110 to 125 per year, and that an average of 2 deaths occur and about 20 to 22 people are admitted to hospital for their injuries.

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[9] For RRLM/RRCM, the shape and dimensions of vehicles are made more conspicuous through the application of strips of retro-reflective material on the sides and/or rear.

[10] The material must be approved in accordance with class C of UN/ECE Regulation 104.

[11] Exemptions for such long vehicles can be requested from the RDW Centre for Vehicle Technology and Information (formerly the government Road Traffic Service).

[12] A horizontal strip of retro-reflective material is used for conspicuity marking.

[13] If necessary, conspicuity marking along the length of a vehicle can be broken into sections of no longer than 1.00 m.

[14] The material must be approved in accordance with class C of UN/ECE Regulation 104.

[15] Special transports are forbidden to drive in weather conditions whereby visibility is less than 200 m (if it is misty, for example).

[16] The SWOV publication referred under [6] showed that the percentage of accidents registered as involving at least 2 motor vehicles was about 32%, while the percentage for accidents resulting in hospital admittance about 77%. Based on this same SWOV publication it was assumed that the percentage of registered vehicle occupant deaths was roughly 100%.

The 76 selected accidents involving lorries in 1999 and 2000, were further analysed using the police registration form[17]:
- was the lorry entering or leaving the driveway?
- was the lorry reversing or driving forwards?
- was the lorry turning left or right?
- did the other vehicle approach the lorry from the front or the rear?

Table 1: DRIVEWAY-RELATED ACCIDENTS INVOLVING LORRIES IN THE DARK																
1999 and 2000 total	76 accidents															
Lorries entering or leaving driveways	entering 52								leaving 24							
Lorries driving forwards or reversing	driving forwards 5				reversing 47				driving forwards 20				reversing 4			
Lorry turning left or right	left 4		right 1		left 46		right 1		left 17		right 3		left 3		right 1	
Other vehicle approaching from the front (F) or the rear (R)	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R
	4	0	1	0	38	8	0	1	11	6	0	3	3	0	0	1

In respect of table 1 above, the following should be noted:
- In almost 70% of all the selected accidents the lorries were *entering* driveways. The explanation for this is that, almost certainly, it takes more time to enter a driveway than to drive out of it.
- Of the 52 accidents in which lorries were leaving driveways, almost 90% occurred while the lorries were *reversing* (just like in the accident in Marknesse). The explanation for this – as was indicated earlier – is undoubtedly that the dangerous situation lasts longer when the lorries are reversing. Of the 47 accidents in which lorries were reversing into driveways, with one exception, all the lorries were *turning left*. This is unsurprising given that lorry drivers only have sufficient field of vision to reverse left into driveways (this is why the figures for such manoeuvres are so high).
- Furthermore, it is significant that, in 80% of the 70 accidents in which lorries were turning left while entering or leaving driveways, the other vehicle approached from the *front*. The reason for this is almost certainly that other vehicles only have a problem with the obscuring effect of lorries' headlights when approaching from this direction.

It should also be noted that this type of accident (driveway-related accidents involving lorries in the dark) occur significantly more frequently where the road surface is wet[18]. This is probably due to poor visibility and/or the increased braking distances required in such conditions.

Other darkness-related accidents involving lorries

Alongside the specific situation described for the accident in Marknesse, other situations can be envisaged in which the lack of conspicuity of lorries plays a role to some degree in accidents that occur. For example, accidents involving lorries parked on an unlighted section of road, or turning into traffic from a side street (as opposed to a driveway) or crossing an intersection.

[17] The registration forms are filled in by the police for significant traffic accident and are used for updating the AVV Traffic Accident Database AVV.
[18] In over 55% of the 76 accidents that were investigated further, the road surface was either wet or damp, while this applied to only 32% of all other traffic accidents involving more than one motor vehicle.

A study recently completed by the SWOV [see 6], showed that in the Netherlands, an average of probably[19] around 1800 accidents involving lorries in the dark or at twilight occur yearly in which the circumstances are such that the lack of conspicuity of lorries plays a possible role[20]. These accidents result in a total of about 9 deaths per year and 80 to 85 people are injured seriously enough to need hospital treatment.

2.5 Conspicuity and recognisability

2.5.1 Study

Based on the accidents described in chapter 1 and the information derived from the accident statistics in chapter 2.4, it appears the suspicion that the sides of lorries in the dark are not sufficiently conspicuous and/or are not recognised in time (even when the legal requirements for side reflectors and side marking have been met) is justified. In order to evaluate the extent to which this suspicion is indeed correct, at the request of the Board, the Technische Menskunde [Technical Human Studies] Department of the Netherlands Organisation for applied Scientific Research (TNO) conducted further research into this issue. This research and the findings are set out in detail in the reports mentioned under [4] and [5]. The following general points should be noted in respect of this research and the findings:

a) The primary objective of the research was to discover the extent to which drivers of approaching passenger cars are able to recognise, in good time, an articulated lorry standing diagonally across the road, in the dark. This situation matches the conditions of the accident in Marknesse, and can be regarded (in more ways than one) as a worst-case scenario. One reason for this is that the position of the lorry means that the side of the trailer is in the area adjacent to the relatively strong beam of the cab's headlights. In addition, passenger cars generally travel considerably faster than bicycles or mopeds and therefore require a longer braking distance.

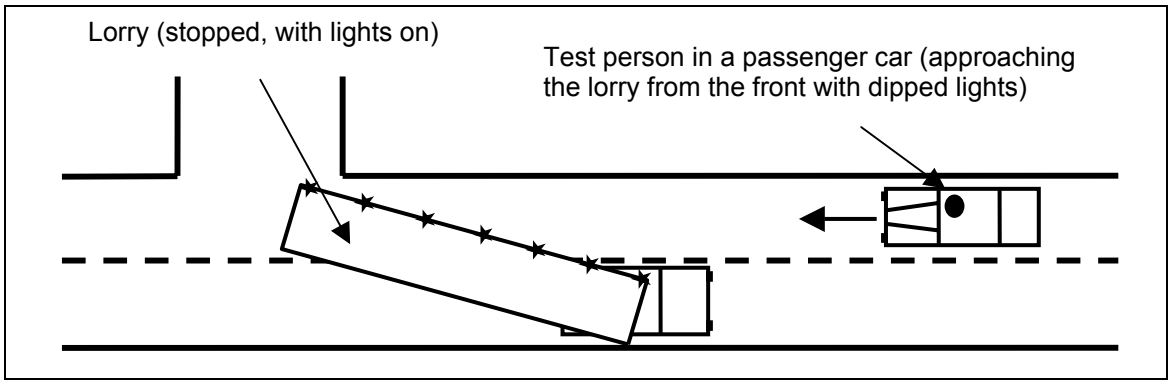


Illustration 4: The situation investigated (as a diagram)

b) Initially, a theoretical approach was adopted, as described under [4] in the aforementioned TNO report. However, it appeared that the information available on a number of aspects was insufficient for accurately determining their degree of influence in a theoretical model. This applied in particular to the effect of the diffused light from the lorries' headlights on the passenger cars' windshields and on the eyes of the passenger cars' drivers.

[19] The figures mentioned are the "most accurate estimates possible" for the actual numbers, based on the recorded figures.
[20] This concerns all traffic accidents that occurred in the dark or at twilight in which at least 1 lorry and one other motor vehicle driving forwards was involved, and in which the lorry was hit on the side or the rear by the front of the other vehicle.

Moreover, the following issue arose: in situations like that in Marknesse, whether or not the reflectors/marking lights on the side of the trailer are sufficiently visible for oncoming motorists was not the only matter of importance; in order to take preventative action in such a dangerous situation, the motorist also has to realise in good time that his half of the road is blocked. Therefore, not only do the reflectors/marking lights on the side of the trailer have to be sufficiently visible at a distance, but also, it must be clear that these are not the lights of reflector posts or the like, and they actually belong to the same vehicle as the headlights on the cab. In this respect too, the theoretical model was not the means for proper evaluation (given that psychological elements also play a role).

c) In light of the reasoning stated under b) above, empirical research was also conducted. This section of the research was also performed out by the TNO-TM (see [5] and the summary in annex C) at the request of the Board. A test situation was set up to determine the conspicuity of a trailer standing diagonally across the road, using both measurements and the observations of test subjects. In respect of the lighting on the trailer, all three relevant situations were examined: side reflectors, side marking lights and retro-reflective contour marking.
The lorry was operating with dipped lights. The test subject whose observations were recorded was in a passenger car. The passenger car approached the test situation from the front, driving with dipped lights.
The observations and measurements for were recorded with both wet and dry windshields. The angle of the trailer in relation to the road axis was either 16 degrees or 37 degrees)[21].

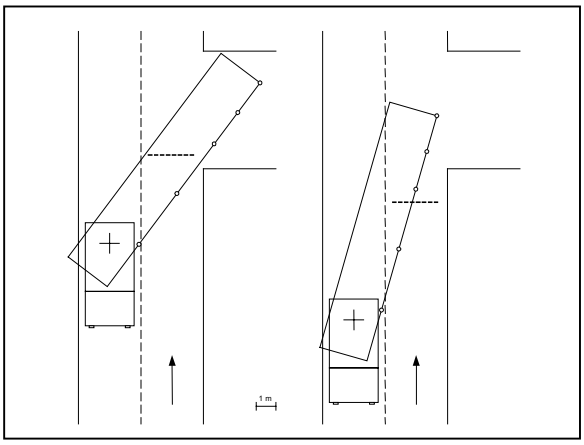


Illustration 5: The two positions in which the trailer was placed during the tests at an angle of 37 degrees and 16 degrees between the road axis and the trailer.

d) The test situations concerned the following 3 observation criteria:
- the distance at which the reflectors/marking lights/contour marking on the side of the trailer became visible to the test subject;
- the distance at which the test subject could reasonably deduce that the reflectors/marking lights/contour marking belonged to a lorry (and not to posts on the shoulder or other types of lighting in the area) and therefore it was likely that something was situated alongside the cab on the lane being used by the passenger car;
- the distance at which the test subject actually became aware that his lane was blocked by a trailer.

The tests should be regarded as exploratory research, given that they only involved a small number of test subjects (4), the observations/ measurements were not repeated, and only a portion of the possible relevant combinations of vehicle positions and weather conditions were investigated.

[21] These angles were chosen because at an angle less than about 16 degrees, the trailer did not completely block the right driving lane, while if the angle were greater than 37 degrees, the cab was no longer parallel to the road axis on the right driving lane.

2.5.2 Findings

The most important results of the TNO research are summarised in table 2.

Table 2: OBSERVATION DISTANCES
(The angle between the trailer and the road axis is 37°)

Observation criterion	Side reflectors		Side marking lights		Retro-reflective contour marking	
	windshield dry	windshield wet	windshield dry	windshield wet	windshield dry	windshield wet
Detection of the reflectors/markings	< 40 m	< 25 m	over 500 m	approx. 300 m	over 500 m	over 300 m
Awareness of threat of accident	< 40 m	< 25 m	approx. 120 m	approx. 60 m	over 300 m	over 200 m
Recognition of the trailer	< 40 m	< 25 m	approx. 40 m	approx. 25 m	approx. 220 m	over 200 m

In order tot evaluate the observation distances set, they had to be compared with the stopping distances (i.e. the distance needed to bring a vehicle to a halt). The method of determining stopping distances for particular combinations of approach speed, response time and brake delay, is set out in annex B (under 3).
An alert driver in a passenger car travelling on a road with the usual grip, the brake delay[22] is around 3.5 m/s^2 and the response time[23] is about 1 second. Based on these assumptions[24], the stopping distance at a speed of 80 km/h is about 90-95 m and at a speed of 100 km/h, about 130-150 m. To allow motorists a reasonable chance to take appropriate action to avoid manoeuvring lorries, the sides of the lorries would have to be equipped in such a way as to be conspicuous and recognisable at a distance whereby the second conspicuity criterion (not being confused with reflector posts or lights on the horizon) is met is greater than the aforementioned stopping distance.

Side reflectors

The tests showed that the standard side reflectors on lorries could be seen well, if they were at an angle of at least 70 degrees in relation to the direction from which they were being seen. This means that for a lorry standing almost perpendicular to the road, the reflectors are clearly visible at a distance of over 200 m for a motorist approaching (using dipped lights). However, when the observation angle was smaller, the detection distance decreased significantly. The calculations showed that at an angle of 50 degrees, the detection distance – even under such favourable conditions as dry windshields – was only sufficient for a motorist with an approach speed of 80 km/h to come to a halt by braking relatively hard. It should be noted in this respect, that manoeuvres such as entering and leaving driveways or side streets involve considerably smaller observation angles than the limiting value of approximately 50 degrees mentioned above. The tests showed that the lorry already blocked the road totally when the angle between the trailer and the road axis was only 15 degrees. In this position, the detection distance was less than 40 m; the reflectors were visible at the moment that the other, non-reflective, parts of the vehicle could be seen.

[22] It may be true that passenger cars, even on wet roads, usually have a higher brake delay than 3.5 m/s^2. However, with even a brake delay of 3.5 m/s^2, the braking force concerned here is stronger than what is usual in day-to-day traffic situations. Furthermore, when the delay is longer, the pedal has to be operated with such force that the chances are high that braking is no longer controlled, but rather excessive. The exertion of too-great force on the brake pedal can cause the wheels to block, which in turn can lead to the need for a longer braking distance and/or loss of control of the vehicle.
[23] Here, response time is meant as the time between the moment at which the danger is recognised and the moment at which the car begins to slow down.
[24] See annex B (under 3) for the calculation methods.

Illustration 6: photograph of a test situation using side reflectors. (Source: TNO-TM)

Therefore, if the lorry's position is not approximately perpendicular, but rather diagonal to the road, the reflectors do not make an actual contribution to its level of conspicuity for approaching traffic. Put in a different way, if a lorry is standing diagonally across a road, its reflectors are not able – at least in the usual conditions existing outside built-up areas – to make it visible to motorists in good time.

Side marking lights

The tests showed that the detection distance for side marking lights was considerable greater than that of side reflectors. This applied to relatively narrow observation angles as well. When the angle between the trailer and the road axis was about 37 degrees, the detection distance appeared to be around 500 m, and when the observation angle was narrowed to around 16 degrees, the detection distance was still about 300 m. The reason the detection distance decreases with a narrower observation angle, is that the strength of the light of the usual side marking lights (just like the reflection level of side reflectors) is highly dependent on direction.

However, the above information on the detection distance concerning side marking lights, should not be read as meaning that the use of side marking lights makes the sides of lorries recognisable in good time under all the relevant conditions. The test subjects stated in fact, that initially, the side marking lights could easily be regarded as reflectors on shoulder posts or lights on the horizon – at least by 'careless' observers. It was only at a distance of about 120 m, according to the test subjects, sufficient reason for concern, was it possible to discern that the lights might belong to a lorry and that there was a danger of an accident occurring. The trailer itself, only became recognisable as such, just like with the reflectors, a distance of about 40 m.

Illustration 7: photograph of a test situation using side marking lights. (Source: TNO-TM)

The reason side markings are not immediately recognisable as such, is largely due to the fact that they are placed at approximately the eye-level of the drivers of passenger cars. For motorists, this means that the lights are always on about the same level as the horizon. This, combined with the relatively weak light they emit, means the markings can easily be mistaken for lights at a much greater distance away.

In addition, the test subjects indicated that the side marking lights – due to their height above the ground and regular spacing – were easily mistaken for reflectors on shoulder posts. Motorists are used to seeing such regular rows of lights on what seems to be the horizon as indicating an approaching bend in the road. It is well known that motorists in such situations attempt to match the evidence of their eyes for as long as possible to the internal visual image they have acquired over time of a road winding in the dark. It is only when the observed scene differs too strongly from the internal image that concern grows and the motorist seeks a different image (for example a trailer standing diagonally across the road) that fits in with the evidence of his eyes.

The tests showed the distance at which it becomes clear to a motorist approaching from the front, that the side marking lights were not shoulder post reflectors (or distant lights) is strongly influenced by the angle between the trailer and the road axis, and, on the other hand, whether the windshield is dry or wet. The distance mentioned above of around 120 m applies in relatively good conditions with an observation angle of 37 degrees and a dry windshield. When the windshield was wet[25], the imminent accident was only detected at a

[25] The reason that with a wet windshield, side marking lights are only detected and recognised as such at smaller distances, is because the water drops on the wet windshield light up and look very much like side marking lights. When the windshield is dry, on the other hand, the background is uniform and this makes the side marking lights stand out more clearly.

distance of around 60 m. the effect of a narrower observation angle[26], in this respect, appeared to be similar. For an angle of 16 degrees (and a dry windshield) the realisation that an accident was imminent only came at a distance of 50 m.
The above indicates that side marking lights are not capable of making the sides of lorries properly recognisable under all relevant conditions. For narrow observation angles in particular, as well as wet windshields, side marking lights only become recognisable as such when the distance to the trailer is too small – at least for the usual speed limit outside built-up areas - for motorists to be able to stop in time.

Retro-reflective contour marking

The tests show that trailers with contour marking can be recognised as such at a sufficiently safe distance, even under unfavourable conditions. The distance at which contour marking becomes visible appears to be about the same as that for side marking lights (namely over 500 m at an observation angle 37 degrees with a dry windshield, and about 300 m with a wet windshield). The distance at which the danger of an accident was realised, on the other hand, appeared to be considerably longer than is the case for side marking lights. Even with a wet windshield, the distance at which the test subjects became aware that a trailer was blocking the road was still over 220 m.

Illustration 8: photograph of the test situation with contour marking. (Source: TNO-TM)

Apparently, being able to see the contours was sufficient for the motorists to deduce that a trailer was diagonally blocking the road behind the cab. This is probably due to the fact that the upper section of the contours – at least when seen from the position of an approaching

[26] The effect of the observation angle is caused by the fact that the strength of the light seen from side marking lights at narrow observation angles is only 40% of that seen when the angle is greater. It is worth noting that in the statutory provisions concerned, minimum requirements for the strength of light for side marking lights are only set down for an observation angle between 45 degrees and 135 degrees.

motorist – are clearly above the horizon. This makes confusion with reflector posts or distant lights all but impossible. And, of no less importance, the contour marking traces the shape of the vehicle so that confusion with other light sources almost never occurs.

For the sake of completeness, in respect of the conspicuity of retro-reflective contour marking, the following should be noted. The practical tests only investigated the conspicuity of retro-reflective contour marking when the angle between the trailer and the road axis was about 37 degrees. Given that roads are already blocked at a considerably narrower angle, it is relevant to find out the extent to which retro-reflective contour marking is conspicuous at narrower angles. It is worth noting that the provisions of UN/ECE Regulation 104 regarding the degree of reflection for materials used for contour marking, only mention a minimum retro-reflection value for observation angles between 60 and 120 degrees. In order to assess whether the degree of reflection is sufficient outside these parameters, additional tests and measurements are required.

2.6 Retro-reflective contour marking

2.6.1 General

A study of the literature (described in the publications listed under [4], [5] and [6]) showed that the conspicuity problem of lorries in the dark has been thoroughly investigated. It can be noted that retro-reflective contour marking (RRCM) is largely viewed as the solution for the lack of conspicuity. This consists of the application of narrow strips of retro-reflective material along the contours and sides of lorries. The most important argument is that by applying RRCM recognisability is significantly increased (see also the results of the practical tests). Needless to say, marking lights can also be used to accent the contours of vehicles. The advantage of marking lights is that they are conspicuous at greater distances (because they do not need to be hit by light from oncoming traffic but rather generate light themselves). The use of retro-reflective material, on the other hand, appears to have major advantages: due to the linear form, strips of reflective material cannot be confused with other sources of light; secondly, retro-reflective contour marking also functions as when the lorry's lights are switched off or malfunctioning. Furthermore, retro-reflective material, unlike side marking lights, is not malfunction-sensitive.

Illustration 9: photograph of lorries with and without contour marking. (Source: 3M)

2.6.2 Safety impact

General

In mid-2002, the SWOV published the results of a literature study [6] concerning the expected safety impact of the introduction of RRCM. The study included several laboratory experiments and the evaluation of three field investigations.

The laboratory experiments, see [6.1], [6.2] and [6.3], were mainly concerned with investigating what the preferred form of the markings should be in terms of optimum conspicuity and recognisability. Of the 3 field investigations, 2 were conducted in the US (by the NHTSA and the Vector research agency [6.4]), and 1 in Germany (by the TH in Darmstadt [6.5]). Two of the cases involved were case-control studies, in which the accident involvement level of 1 group of lorries with and 1 group without marking was compared over a longer time period. The third study (NHTSA), analysed a large number (over 1500) side-impact and rear collisions involving lorries in the dark or at twilight.

The findings of all three foreign field investigations showed that contour marking on lories has a positive effect. The extent of the impact on safety differed from investigation to investigation:

- the HTSA investigation [6.4], the biggest and best-documented of the three, demonstrated a reduction of 29% in side-impact and rear collisions involving articulated lorries in the dark;
- the Vector investigation [6.4] showed a reduction of 15% for side-impact collisions and 25% for rear collision involving articulated lorries in the dark;
- the TH Darmstadt investigation [6.5] recorded a reduction of 97% in side-impact and rear collisions that solely involved the conspicuity of lorries.

The SWOV, however, believes the last-mentioned reduction percentage (97%) should be regarded cautiously. The investigation concerned only examined accidents that were in all probability largely caused by the problem of lorries' conspicuity; accidents involving other factors (that could interact with conspicuity problems) were excluded from the investigation, and therefore, the recorded reduction percentage can be termed flattering.

Based on the figures cited above, the SWOV made as accurate an estimate as possible of the accident reduction that could be expected in the Netherlands on the overall introduction of retro-reflective contour marking. The findings are summarised below:

- A further analysis of the AVV traffic accident database showed that in the Netherlands, on average over 2400 accidents each year involving at least one lorry and another motor vehicle moving forwards, are registered as occurring in the dark or at twilight. In about one-quarter of these accidents, (almost 600) the lorry is hit on the side or at the rear, and the impact point is the front of the other vehicle. The SWOV believes that this last group can be regarded as the most useful estimate of the number of registered accidents in which the conspicuity of lorries in the dark plays a role. The registration shows that the accidents concerned result in an average of 9 deaths and 64 injuries requiring hospital treatment every year. Given that not all accidents and victims are recorded in the AVV database, the actual figures are higher. Based on what is known about the registration level (which is influenced, by the severity of the accident, among other things) as accurate an estimate as possible was made of the actual numbers. The figures arrived at were around 1800 relevant accidents, 9 deaths and over 80 injuries needing hospital treatment each year.
- Based on the data from the three foreign field investigation referred to above, it was calculated that in the Netherlands, the large-scale introduction of contour marking for lorries would roughly translate into the following safety benefits on a yearly basis: a reduction of several hundred accidents, 2 to 3 fewer deaths and 20 to 30 fewer injuries requiring hospital treatment. In financial terms, these reductions would result in a total costs saving of between 15 to 20 million euro per year[27].

[27] The SWOV publication concerned calculates the total costs of lack of traffic safety in the Netherlands at over 8 billion euro per year (roughly 7 million euro per traffic fatality).

- In respect of the values mentioned above, the SWOV report [6] notes that it can be argued that the calculation of the effect is “optimistic”, and it can also be argued that the calculated effect can justifiably be termed “conservative”[28]. All things considered, the suspicion is that the estimate gives *a relatively positive view* of the expected reduction in the number of victims.

Sustainable safety

The SWOV also investigated the relationship between the introduction of retro-reflective contour marking and the principles of sustainable safety[29] (SS). To this end, an evaluation was made of the extent to which contour marking meets and is in harmony with the three basic principles of sustainable safety: *functionality, homogeneity and predictability*.

The findings can be summarised as follows:

- The application of contour marking is in line with the SS requirement that the recognisability level of different types of vehicles must be as high as possible, under all kinds of conditions. By having marked contours, lorries are not only more conspicuous, but they are more easily recognisable as lorries. This is pertinent to the expectations of other road users because, in relation to other vehicles, lorries are very different in terms of speed, weight and manoeuvrability.
- However, two cautionary points are worth mentioning: first, it is possible that partial introduction could have a negative impact on predictability. In the event that only some lorries start to use contour marking, it will be possible that even when no contours are visible, the vehicle concerned could still be a lorry.
  The second point concerns the possibility that a stopped lorry with retro-reflective contour marking may be thought to be an advertising billboard, if retro-reflective material is also used in roadside advertising.

Costs

The SWOV report mentioned above [6] also includes an estimate of the expected costs connected with the large-scale introduction of retro-reflective contour marking. Based on rough calculations, the expected costs of fitting retro-reflective contour marking to existing articulated lorries is given as around 500 euro, and about 350 euro for light commercail vans[30]. The lifespan of the marking is estimated at roughly 6 years.

The above means that, in combination with the number of lorries on Dutch roads, the large-scale introduction of contour marking amounts to a total investment of almost 10 million euro per year.

[28] Arguments that the estimate leads to an optimistic safety impact, are: any impact overlap with the introduction of compulsory side marking lights, lack of methodological clarity in the TH Darmstadt field investigation, the possibility that partial introduction could have negative side effects (incorrect expectations), and the possible negative influence of visual obscuring and/or distraction when retro-reflective advertising is also present. Arguments for a conservative estimate are: the positive effect of large-scale introduction as opposed to the partial introduction of the filed investigations and the fact that the field investigations used reflector material that was less conspicuous than that set down in
UN/ECE Regulation 104.

[29] According to the concept of sustainable safety (that forms the basis of the traffic safety policy in force in the Netherlands) the chance of accidents occurring increases in proportion to the degree of difference in the speeds of the vehicles concerned, the amount of oncoming traffic, the speed being driven and the degree of unpredictability of the traffic situation.

[30] The amounts stated would apply when contour marking is fitted retroactively, with the understanding that this would take place during a routine service. If the marking were to be fitted separately, the costs would be higher. The costs are expected to be lower when contour marking is fitted during manufacture.

2.6.3 Introduction

In its decision of 26 June 2001, the Council of the European Union adopted UN/ECE Regulation 104 and decided to include this regulation in the community legislation on motor vehicle type approval. That legislation comprises requirements for the retro-reflective material used in the line or contour marking that defines the shape and/or dimensions of large lorries aimed at improving conspicuity. Given that it is clear that implementation of the regulation concerned in the European type approval legislation will take quite some time, the Dutch Minister of Traffic, Public Works and Water Management recently decided to amend the existing national legislation, in anticipation of the European legislation, to allow for the application of retro-reflective marking on large lorries and trailers[31] in accordance with UN/ECE Regulation 104. The draft general administrative order is currently[32] before the Dutch Lower House.

The SWOV study referred to earlier [6] mentioned the opinions and views of the government, sector organisations, two large transport companies, a car manufacturer and a liability insurer[33], in respect of the introduction of RRCM. All the parties indicated they were convinced that RRCM has a positive safety effect, and that they supported its use. However, the study also showed that within the transport sector in particular, the support base for large-scale/compulsory introduction of RRCM is small. In this respect, the unfavourable cost efficiency (at an investment level[34]) appeared to be the most important criterion. Furthermore, it appeared that both the government and the liability insurer (that actually covers a number of lorries for liability) were reluctant about providing any financing (in the form of a subsidy or discounted premiums).

In terms of the introduction of RRCM, in addition to large-scale introduction (whereby all lorries would have to be equipped with RRCM before a particular date), two alternatives also exist: introduction in stages and partial introduction. For introduction in stages, at first only new lorries would have the marking, and after a transitional period, the rest of the lorries would be outfitted; for partial introduction, only large lorries or lorries used for certain types of transport (involving high risks) would have the marking.
From the point of view of road safety, due to the predictability criterion, it is not desirable (even temporarily) that only some lorries should have retro-reflective contour marking. In the situation that only some lorries are equipped with RRCM, the absence of visible contour marking would not necessarily mean that no lorries were present in the area. For these reasons, the preference is to have RRCM introduced not only for new lorries, but also for lorries already on the roads. In respect of the last point, it can be noted that the application of RRCM on older lorries[35] would result in improved conspicuity (because to date these vehicles only have to be equipped with side reflectors). In this respect, it can also be noted that the retroactive introduction of the retro-reflective strips concerned, is, technically speaking, very well possible.

[31] The limit has been placed at vehicles with a maximum weight of over 3500 kg.
[32] The draft, including memorandum and explanatory note was submitted to the clerk of the Upper and Lower Houses on 30 August, 2002.
[33] Interviews were conducted with representatives of V&W-DGG and RDW, TLN and EVO, BK-Gas and Van Gend & Loos, DAF and TVM.
[34] That costs efficiency is unfavourable at an investment level, result from the fact that a large part of the "revenues" connected with the introduction of RRCM, consist of savings at a societal level (like medical expenses, loss of production due to injury and/or traffic jams and claims for pain and suffering).
[35] It should be remembered that the economic lifespan of trailers is relatively long (about 15 years).

3. CONCLUSIONS

The accident at Marknesse does not appear to be at all unique. As explained earlier, it can be noted that:
- interviews of the traffic divisions of a number of police forces brought more accidents with almost identical circumstances to light;
- analysis of the AVV accident database showed that in the Netherlands an average of about 110 to 125 similar accidents occur each year, and that 20 to 22 people have to be treated in hospital, and 2 deaths occur as a result;
- a 2002 SWOV study showed that the total number of accidents in which the lack of conspicuity of lorries plays a possible role amounts to around 1800 every year, resulting in 9 deaths and some 80 to 85 people needing treatment in hospital.

It can also be noted that in the accidents concerned reckless driving did not play a role (no safety risks were expressly taken). Based on the investigations conducted, it appears that accidents of this kind involve the following structural safety problems:
a) the layout and/or access to the sites concerned is such that lorries have to enter the driveway by reversing;
b) the inadequate conspicuity and/or recognisability of the sides of lorries in the dark;
c) a lack of knowledge/awareness on the part of lorry drivers concerning both the limited conspicuity and recognisability of their vehicles, and the length of time needed to perform such manoeuvres;
d) a lack of awareness on the part of other drivers concerning timely awareness of a possibly dangerous situation.

re a) Site layout/access

When vehicles are reversing into driveways from a public road, apart from the conspicuity problem, a dangerous manoeuvre is also involved. If a lorry is concerned, given that such vehicles must usually perform the manoeuvre by turning to the left, a relatively long time is needed. Such manoeuvres are, however, unavoidable if the site concerned has only one driveway, and is laid out in such a way that lorries are unable to turn around. In this regard, it was noted that no legislation covering this aspect is currently in force.

re b) Conspicuity of lorries in the dark

In principle, lorries are not less conspicuous than vans or passenger cars in the dark. However, these vehicles are considerably larger and heavier, as well as less manoeuvrable. Moreover, lorries accelerate more slowly. In respect of loaded lorries, while manoeuvring the situation can arise whereby the front section occupies the right side of the road, roughly parallel to the road axis, while the rear section lies diagonally across the left half of the road. In this position, the conspicuity of the lorries for traffic approaching from the front is lessened by the obscuring effect of the lorries' headlights. The result of these aspects is that lorries must frequently perform manoeuvres that entail some hazard (like reversing into driveways) while such dangerous manoeuvres also last for a considerably long time. In addition, collisions involving lorries, due to their relatively large mass, strong construction and difficult shape, usually have serious consequences.

The study showed that the current legal provisions do not adequately ensure that in all relevant situations, lorries are conspicuous and recognisable to other traffic in the dark. This does, however, apply in particular to lorries that have been on the roads since before 1996, which only had to have side reflectors, but also applies to the current situation (whereby lorries also have to be equipped with side marking lights). In respect of the latter, it should be noted that side marking lights too, under certain conditions, are only visible at a distance too small to allow motorists the reasonable opportunity to respond accordingly. Furthermore, experiments showed that side marking lights can easily be misunderstood (because in terms

of light intensity and observation position, they closely resemble reflector posts or lights at some distance away).

The study also demonstrated that both the conspicuity and recognisability of lorries can be considerably improved through the use of retro-reflective contour marking. The SWOV calculated (by translating the results of three field investigations into the Dutch situation) that the overall introduction of RRCM could reduce the number of accidents by several hundred, injuries requiring hospital treatment by 20 to 30 and deaths by 2-3, each year.
The same SWOV study, however, also showed that within the transport sector, no support base exists for the voluntary introduction of RRCM. The sector has indicated that it is not justified in terms of the costs (350-500 euro per vehicle for a 6-year period) that transport companies would be expected to meet. The argument was put forward that the benefits would not be directly for the transport sector but rather for society at large. However, the counter-argument can be made that, in accordance with the slogan “the polluter pays”, it is justifiable for the costs to be met by the transport sector given that the accidents concerned are caused by the lack of conspicuity of lorries. It should be noted that this discussion is not new – it also took place regarding the introduction of DOBLI mirrors. In that instance, too, the transport sector appeared unwilling to make a relatively small investment in order to combat safety problems that were specifically related to accidents caused by lorries. In that case, even the reduction of the financial contribution required from the transport sector (through a substantial government subsidy) was not sufficient to lead to the large-scale voluntary introduction of the extra mirrors concerned.

With an eye to traffic safety, the overall introduction of RRCM is preferable to partial introduction or introduction in stages. Although introduction at an European level is the best alternative, considering the length of time the procedures concerned require, the advance introduction of RRCM – as was the case for DOBLI mirrors - (initially solely in the Netherlands) should be considered. It should be noted that introduction at a national level alone will in all likelihood have a considerable impact, given that foreign lorries for the most part use main roads and, moreover, are loaded and unloaded almost exclusively at large factories/industrial sites and that the large majority of problem situations in the Netherlands involve Dutch lorries[36].

re c) Knowledge/awareness of lorry drivers

The further analysis of the accidents (see chapter 1) showed that the lorry drivers concerned had made errors in judgement that could well be linked to a lack of awareness.

- It should first be noted that the lorry drivers were insufficiently aware of the fact that the sides of their vehicles might not become visible in time to motorists approaching from the front (in particular). Furthermore, in this connection, the drivers themselves could see the sides of their lorries particularly well (from the cab) because their view was not hindered by the obscuring effect of the lorry headlights.
- In addition, lorry drivers misjudged the length of time needed for the reversing manoeuvre, and on the other hand, the time needed by any approaching vehicles to cover the intervening stretch of road. This last point (overestimating the time needed for fast-moving traffic to cover a somewhat greater distance) can be regarded to some extent as a general problem. Only few people are aware that at a speed of 80 km/h, covering a distance of 100 m takes less than 5 seconds. It should be remembered in this regard, that the reversing manoeuvres under discussion usually take 30 seconds – and sometimes considerably longer – to be completed. The above means that lorry drivers seldom have a sufficient view of the road before commencing their manoeuvre to be able to assess whether or not any approaching traffic will have adequate time to respond properly.

[36] Of the 76 driveway-related accidents that were investigated further (see 2.4) only 2 involved foreign lorries.

re d) Knowledge/awareness of other drivers

The further analysis of the accidents (see chapter 1) showed that the drivers of the passenger cars concerned too, failed to properly assess the situation. They were insufficiently aware that a short distance behind the headlights of the lorry which they saw on the opposite side of the road, a trailer could be standing diagonally across the road. Due in part to the obscuring effect of the lorry headlights, this situation was recognised too late to allow time for an adequate response.

4. RECOMMENDATIONS

4.1 Harmonising site layout/access with traffic safety

The Board believes the primary goal should be to avoid wherever possible potentially dangerous manoeuvres of lorries on public roads (like reversing into driveways both in daylight and darkness). To this end, sites that lorries visit regularly should be laid out in such a way that such vehicles have access to the site without having to reverse (the same applies to exiting the sites).

Recommendation 1:
The umbrella organisations concerned (Interprovinciaal Overleg, the Vereniging van Nederlandse Gemeenten and the Unie van Waterschappen) are advised to initiate action whereby all relevant road authorities, when issuing/extending access permits, assess the layout and access of commercial sites regularly visited by lorries, in terms of lorries being able to enter and leave the sites without reversing.

4.2 Improving the conspicuity of lorries in the dark

The findings of this study have led the Board to conclude that all Dutch lorries should be equipped with RRCM as soon as possible. The Board is aware that this solution involves European Union legislation. Moreover, the lack of conspicuity and recognisability of lorries is not merely a Dutch problem[37]. Given that European union legislation will take some time to go into effect, the RRCM obligation should be included in national legislation beforehand.

Recommendation 2:
The Minister for Traffic, Public Works and Water Management is recommended to add as much impetus as possible to the introduction of European legislation on obligatory retro-reflective contour marking for lorries. In addition, the advance national obligation concerning RRCM – in anticipation of the European Union legislation – should be included in national legislation as soon as possible.

4.3 Extra measures for lorries manoeuvring in the dark

For incidental instances where it remains necessary for lorries to reverse into driveways, other traffic must be given adequate warning. If, for a certain period of time at a particular site, such manoeuvres will be taking place, (during the potato or beetroot season, for example) the temporary placement of street lights and/or warning signs should be considered.

Recommendation 3:
The sector organisation of loaders, receivers and transporters, as well as agriculture and horticulture companies, are recommended to advise their members that the manoeuvring of lorries in the dark on public roads should be avoided wherever possible, and when unavoidable, such manoeuvres must be performed in combination with adequate safety measures. This recommendation is specifically aimed at Transport en Logistiek Nederland (TLN), Ondernemersorganisatie voor logistiek en transport (EVO), Verenigde Eigen Rijders Nederland (VERN), Koninklijk Nederlands Vervoer (KNV) and Land- en Tuinbouw Organisatie Nederland (LTO).

[37] Given the European character of this problem, this report will also be sent to the European Commission (for the attention of the Commissioner for Transport and Energy).

4.4 Specific information/driver training

Motor vehicle drivers must be made well aware of the fact that in the dark, the sides of lorries, certainly when not equipped with retro-reflective contour marking, are not conspicuous and are poorly recognisable. Drivers should be particularly aware of the possibility of dangerous situations arising if such lorries perform manoeuvres in the dark on public roads. It is evident that lorry drivers in particular must be made aware of this problem. The Board believes that the problem of the lack of conspicuity and recognisability of lorries in the dark should become part of the requirements of the theory exam for all types of driving licences, including the exam for driving heavy vehicles.

In light of the fact that a similar recommendation is included in other ongoing Transport Safety Board studies (drowning accidents and emergency-lane accidents research, for example) in due course the relevant recommendations will be combined and presented to the Minister of Traffic, Public Works and Water Management.

5. LITERATURE

[1] Police report 200057448, drawn up by the Flevoland regional police, concerning the accident dated 22/11/2000 in Marknesse (Noordoostpolder).

[2] Police report 98044499-OD, drawn up by the Flevoland regional police, concerning the accident dated 21/10/1998 in Noordoostpolder.

[3] Police report PL0150/98-688411, drawn up by the Groningen regional police, concerning the accident dated 24/11/1998 in Vlagtwedde.

[4] R.F.T. Brouwer, J.W.A.M. Alferdinck & M. Hoedemaker (2001). *Zijmarkeringslichten en de opvallendheid van opleggers* (TNO report: TM-01-C025). Soesterberg: TNO Technische Menskunde[38].

[5] J.W.A.M. Alferdinck & M. Hoedemaker (2002). *Zichtbaarheid van opleggers, praktijkproef* (TNO report: TM-02-C012). Soesterberg: TNO Technische Menskunde[35].

[6] M. de Niet, Ch. Goldenbeld & P.M.M. Langeveld (2002). *Veiligheidseffecten van retro-reflecterende contourmarkering op vrachtauto's* (R-2002-16). Leidschendam, SWOV.

The relevant sections of the report referred to above [6] are based for the most part on the following publications:

[6.1] E.D. Hildebrandt & P.J. Fullarton (1997). *Effectiveness of heavy truck conspicuity treatments under different weather conditions*. In: Proceedings of the Canadian multidisciplinary road safety conference, 8 to 11 June 1997, Toronto, Canada.

[6.2] H.J. Schmidt-Claussen & K.M. Kurth (1987). *Rückwärtiges Signalbild von LKW. In: Deutsche Kraftfahrtforschung und Straßenverkehrstechnik*, Heft 303, VDI-Verlag, Düsseldorf.

[6.3] H.J. Schmidt-Claussen, U. Pawlak & J.E. Hartge (1987). *Seitenbeleuchtung von LKW. In: Deutsche Kraftfahrtforschung und*
e) *Straßenverkehrstechnik*, Heft 302, VDI-Verlag, Düsseldorf.

[6.4] Ch. Morgan (2001). *The effectiveness of retro-reflective tape on heavy trailers*. DOT HS 809 222. National Highway Traffic Safety Administration NHTSA, Springfield.

[6.5] H. Finsterer & H.J. Schmidt-Claussen (1992). *Kenntlichmachung von LKW Forschungsberichte des Bundesministers für Verkehr*, Bereich Fahrzeugtechnik, no. 10. Bundesanstalt für Straßenwesen, Bergisch Gladbach.

[38] The publications referred to under [4] and [5] relate to monographs (published by the *Technische Menskunde* Department of the TNO, commissioned by Transport Safety Board). The reports concerned form part of this study and are available on request.

Annex: A

Re: Justification of the study

This thematic study was conducted by staff members of the Transport Safety Board, under the supervision of the Road Traffic Chamber.

The data used was provided by:
- the regional police of Flevoland and Groningen;
- the *Adviesdienst Verkeer en Vervoer* [Traffic and Transport Advisory Service];
- the *Stichting Processen Verbaal* [Police Reports Foundation].

In addition, interviews were held with the staff of various institutions.

The *Technische Menskunde* Department of the TNO provided support research. The two reports in which this research is set out ([4] and [5]) form part of this report and are available on request.

This report (in draft form and without the recommendations set out in chapter 4) was submitted for comments to both the *Technische Menskunde* Department of the TNO and the *Stichting Wetenschappelijk Onderzoek Verkeersveiligheid* (SWOV). The commentaries have been processed.

Annex: B

Re: Explanation of the main photometric terms, observability and stopping distance

1) Photometry

The amount of light energy emitted by a light source or passing through or reflected by a surface per unit of time (t), is referred to as *luminous flux*, indicated by Φ and expressed in lumen or [lm]. The luminous flux radiated per unit from angle (ω), is referred to as *light intensity*, indicated by I and expressed in candela or [cd].

The luminous flux per unit that falls on a surface (A), is referred to as *luminous* intensity, indicated by E and expressed in lux or [lx].

The relationship between the light intensity (I) of the light that a surface projects in a given direction, and on the other hand, the apparent surface (A_s) of that surface for the relevant observation direction, is referred to as the *luminance*, indicated by L and expressed in cd/m^2. The luminance of a surface is an objective measure of the subjective characteristic *clarity* (which, alongside colour, is a determining factor in the visual observation of a surface).

The relationship between these variables can be expressed in the following equations:

Light intensity $I = \frac{\Phi}{\omega}$ in cd (or lm/sr)

with Φ = luminous flux[lm]
ω = angle [sr]

Luminous intensity $E = \frac{I \cdot e^{-3 \cdot \frac{d}{Z}}}{d^2}$ in lx (of lm/m^2)

with d = distance [m]
Z = meteorological visibility [m]

If Z is large in relation to d, then the term $e^{-3.d/z}$ is calculated up to the value 1, whereby the equation shifts to:

$$E \approx \frac{I}{d^2}$$

Luminance $L = \frac{I}{A_s}$ in cd/m^2

with A_s = apparent surface in observation direction [m^2]

2) Observability

In respect of light-emitting objects, a distinction can be made between objects producing light (light sources) and objects that allow light to pass through them or reflect light.

An object or part thereof can be visually observed when the emitted light can be distinguished from the surroundings in terms of colour and/or clarity. Clarity is a subjective notion, but the measurable amount of luminance can serve as an objective measure for clarity. This measure is the relationship between the light intensity in the direction of the observer and the apparent surface.

In order to assess the observability of objects (such as side marking lights and reflectors) the following can be assumed:

a) A light source or reflector is *observable* (visible) when its luminous intensity is greater than the detection threshold E_{dd} and *conspicuous* when the luminous intensity is greater than conspicuity threshold E_{do}
b) The values of the *detection threshold* E_{dd} and the *conspicuity threshold* E_{do} are determined by the *surroundings luminance* L_b which in turn is dependent on:
   - the background luminance (resulting from natural light) L_o
   - the blinding luminance of other light sources shining in the eyes L_{vo}
   - the diffused lighting luminance of other light sources either in the atmosphere L_{va} or the the windshield of the vehicle in which the observer is seated L_{vv}.

   Annex B of the TNO report [5] further explains the variables mentioned above (together with the factors that determine their values).
c) Given that the luminous intensity of a light source or reflector is dependent on the distance to the observer, the distance *d* up to which the object is visible (d_{dd}) or conspicuous (d_{do}) can also be indicated. When the meteorological visibility (Z) is relatively high, the following applies for calculating the *visibility distance and conspicuity distance* respectively:

$$d_{dd} = \sqrt{\frac{I}{E_{dd}}} \quad \text{c.q.} \quad d_{do} = \sqrt{\frac{I}{E_{do}}}$$

(whereby I is the light source/reflector light intensity in the direction of the observer).

3) Stopping distance

The visibility distance can in turn be equated with *the* sto*pping distance* (s_{stop}), the distance a vehicle needs to come to a halt. The following calculation applies for the stopping distance:

$$s_{stop} = \frac{v_o^{\,2}}{2 \cdot a_g} + v_o \cdot t_r \quad \text{in m}$$

Whereby: v_o = approach speed [in m/s]
a_g = average delay during the braking time [in m/s^2]
t_r = length of the response time [in s]

Annex: C

Re: Summary of the practical tests

1) General

At the request of the Board, the *Technische Menskunde* Department of the TNO conducted further research into the conspicuity of lorries from the side in darkness. To this end, practical tests were carried out. The tests were primarily aimed at learning the degree to which the application of side reflectors, side marking lights and retro-reflective contour marking improve the conspicuity of lorries (from the viewpoint of passenger car drivers). The evaluation was made using light measurements as well as test subjects. The practical tests are described in detail under [5] (which forms part of this report and is available on request). The tests should be regarded as exploratory research, in the sense that only a small number (4) of test subjects were involved, the observations/measurements were not repeated, and not all relevant combinations of vehicle positions and weather conditions were investigated.

2) Procedure

The tests were carried out using a lorry standing on an unlit road. The section of road in question lies outside the built-up area. The road surface is asphalt and the roadway width is around 6.5 m and is divided in the centre into two lanes by a broken line. During the tests, the section of road concerned was closed to all other traffic.

The lorry used was a usual articulated lorry: the trailer had a closed construction and was around 2.5 m wide, 13 m long and 3.8 m high. The sides of the trailer were equipped with the legally obligatory side reflectors and side marking lights. In the final stage of the tests, the sides of the trailer were fitted with retro-reflective contour marking. The white reflective tape was 5 cm wide (class C of UN/ECE Regulation 104).

The cab was parallel to the road axis on the right lane; the trailer was standing diagonally across the left lane. Measurements/evaluations were made in 2 different trailer positions: in one situation the angle between the axis along the length of the trailer and the road axis was 16 degrees; and in the other, the angle was 37 degrees.

The test subjects were seated in the right-front seat of a passenger car that approached the articulated lorry from the front. The test subjects were 1 woman and 3 men, all of whom could be regarded as experienced in the field of visual observation of traffic situations. All the test subjects wore glasses, had normal eyesight and were not colour blind.
For the trailer position of 37 degrees in relation to the road axis, observations were also made while the windshield of the passenger car was wet.
Both the lorry and the passenger car were using normal dipped headlights.

Beforehand, the test subjects were requested, when approaching the test situation, to indicate the point at which the following 3 observation criteria were met:

- The point at which the side reflectors, side marking lights or contour marking of the trailer actually became visible alongside the headlights of the cab;
- the point at which in all reasonableness the subjects became aware that the visible side reflectors, side marking lights or contour marking were not reflector posts or the like, but probably were part of the lorry (and that there was probably something also stationary on the lane in which the passenger car was driving);
- the point at which the trailer became conspicuous and recognisable as such.

If, while approaching the test situation, the test subjects indicated that one of the criteria listed above had been met, the distance between the vehicles was read (using a distance scale that had been fitted to the road surface).

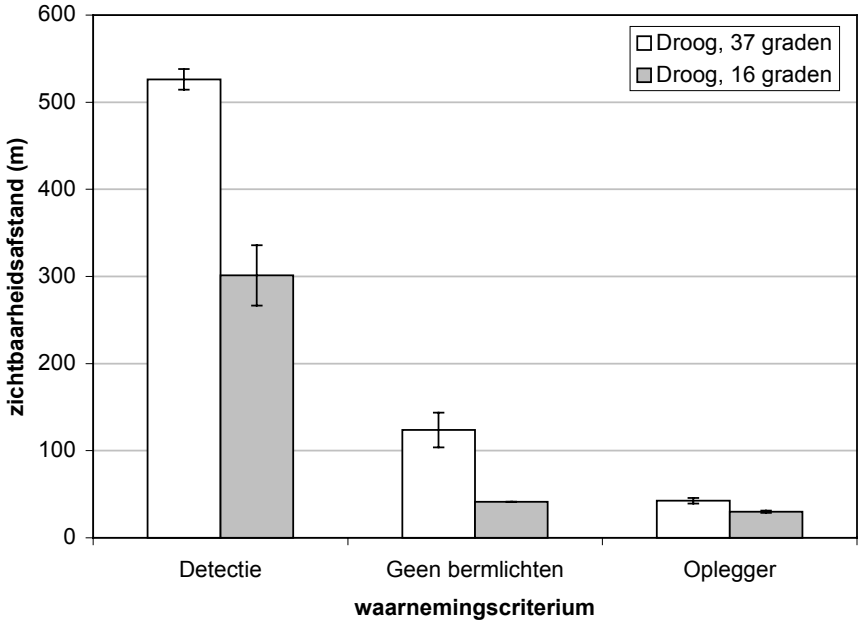
3) Results

3.1 Light measurements

Lamp	Light intensity (cd)	
	Trailer angle 37 degrees	Trailer angle 16 degrees
Headlight, left	242	242
Headlight, right	275	275
Side marking lights 1	0.192	0.108
Side marking lights 2	0.158	0.052
Side marking lights 3	0.211	0.067
Side marking lights 4	0.183	0.063
Rearmost position light (white)	0.457	~ 1

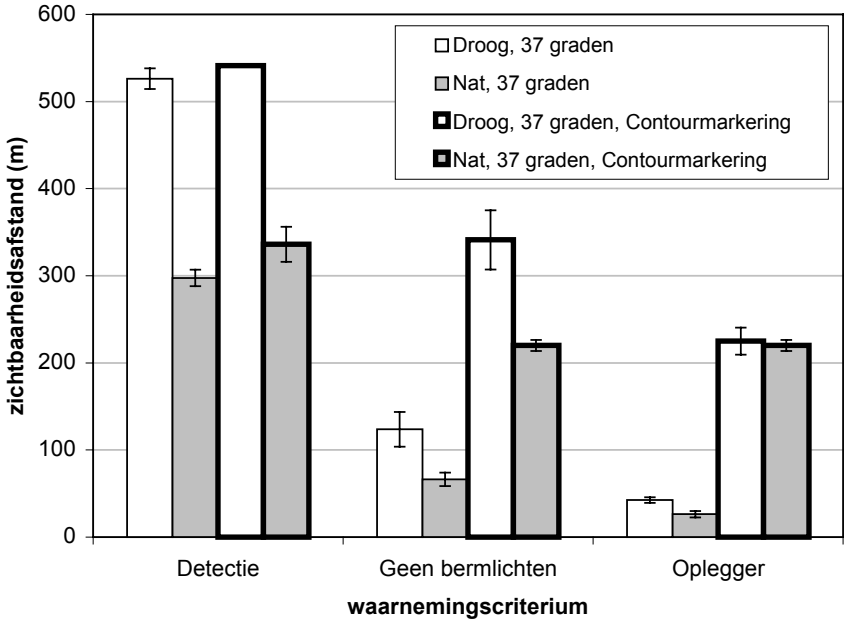
Light intensity of the lorry headlights/side marking lights. Source: [5]

3.2 Observations



The visibility distances for the three evaluation criteria for side marking lights with a dry windshield. Source: [5].

Translator's Note:
Zichtbaarheidsafstand = visibility distance, Waarnemimgscriterium = observation criterion, Detectie = Detection, Geen bermlichten = No roadside lighting, oplegger = trailer
Droog 37 graden = Dry 37 degrees, Droog 16 graden = Dry 16 degrees



The visibility distances for the three evaluation criteria for side marking lights, and retro-reflective contour marking with dry and wet windshields respectively. Source: [5].

Translator's Note:
Zichtbaarheidsafstand = visibility distance, Waarnemimgscriterium = observation criterion, Detectie = Detection, Geen bermlichten = No roadside lighting, oplegger = trailer
Droog 37 graden = Dry 37 degrees, Nat 37 graden = Wet 37 degrees, 16 graden = 16 degrees, Contourmarkering = contour marking