HAZARDS WITH FALLING LIGHTING COLUMNS

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Considerations regarding the positioning of lighting columns low-aggressive for private cars

SWOV

INSTITUTE FOR ROAD SAFETY RESEARCH SWOV

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More information is to be found in the booklet Aims and activities, available at request from the Information Department SWOV.

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Preface

The Roadside Obstacles Research was carried out in order that the Interdepartmental Project Group of the same name, set up by the Minister of Transport and Public Works, could formulate recommendations with the object of making the area alongside the carriageway as safe as possible thus reducing the risk of accidents or serious consequences to a minimum.

The basic assumption for creating the safest possible roadside area is that a vehicle runs off the road on to the shoulder. The aim should be to arrange the roadside area so that the risk of an accident involving injury in such cases is as slight as possible. Dangerous objects such as poles and trees, and also (steep) embankments, should be fitted into the roadside area in such a way that their presence entails as little risk as possible to road users running off the road. There are three distinct types of roadside area, each providing a certain measure of safety.

In the first type, regarded as the safest of all, there are no hazard areas or obstacles. Vehicles leaving the road can go on running freely or perhaps can be brought under control again. Such an area, however, must provide sufficient support so that a vehicle running on to it does not roll over, and it must be wide enough.

The second type, which is not quite as safe, is that on which obstacles such as lighting columns, roadside telephone pillars and signposts are located. Such obstacles then have to be designed so that if hit by a car or a heavier vehicle they do not endanger the occupants. This requirement takes private cars as the basis because such obstacles – in absolute terms – are hit mostly by this category of vehicle. The possibility of protecting such obstacles for private cars is, moreover, the most practicable.
It thus seems as if only car and truck occupants are offered a reasonable degree of safety. But the safety of two-wheeler riders (especially motor cyclists and moped riders) is also served in this way. These necessary obstacles, if they cause little danger to cars, can simply be placed on the shoulder without, for instance, having to be protected by a roadside safety structure. This greatly reduces the risk of hitting an object in the shoulder. This is an important aspect particularly for riders of two-wheeled vehicles, because an impact with a roadside safety structure may have very serious consequences for this category of comparatively vulnerable road users.
Besides these, there are also rigid obstacles that are comparatively uncommon and cannot be made safe, such as piers of bridges or overhead sign structures. If these are fitted into the second type of roadside area, they will have to be located outside the safety area. Should this be unfeasible for any reason, they will have to be protected separately, for example with an impact attenuator or roadside safety structure of a given length.

The least safe of the relatively safe roadside areas is that where there is a hazard area too close to the carriageway, such as a ditch, a steep embankment or a row of rigid lighting columns. This should then be protected, for instance with a roadside safety structure. Such a structure is safe enough for private car occupants (SWOV, 1970; Beukers et al., 1972; Flury et al., 1973; Paar, 1973). But there is a great risk of severe, if not fatal injury to two-wheeler riders.

In 1971, as part of the Roadside Safety Structures research project, the first ad hoc tests were made with lighting columns, signposts, traffic signs, roadside telephone pillars, obstacle-impact attenuators. Accidents with fixed objects were also analysed in greater detail by reference to available accident statistics.

The Roadside Obstacles research started by reviewing and describing research discussed in the literature into the behaviour of obstacles upon impact. This literature study, finalised in 1973, also became an important part of the Roadside Obstacles report published by the OECD in 1975.
Partly as a result of the literature study, a start was made with subsidiary research on the relationship between collisions with obstacles on various types of roads and the distance between these obstacles and the edge of the road. This research will result in recommendations on the size of the obstacle-free area.

The Lighting Columns research was continued in order to ascertain what types of columns can be regarded as being low-aggressive for private cars in the event of head-on or sideways-on impacts. The results of this experimental research have been used by Rijkswaterstaat for recommendations to road authorities.

As a consequence of placing low-aggressive lighting columns, it emerged that if they are knocked over by an impact they may under certain condition be dangerous to other road users. SWOV investigated these hazards as well. A separate report was made on this research.

Besides reports and articles already published (see References) the following SWOV publications have already appeared or will be appearing on the subject of Roadside Obstacles:

1. Roadside obstacles; Literature study of research into the behaviour of obstacles upon impact (published in OECD, 1975, pp. 50-57; 89-119).
2. Lighting columns; Research on the behaviour of lighting columns in sideways-on and head-on impact tests with private cars (SWOV, 1978-2E).
3. Hazards with falling lighting columns; Considerations regarding the position of lighting columns low-aggressive for private cars (SWOV, 1978-3E).
4. Obstacle-free area; Research on the relationship between impacts with obstacles on various types of roads and the lateral distance between these obstacles and the edge of the road (SWOV, to be published).

The project leader for the Roadside Obstacles research, which is monitored by the Interdepartmental Project Group of the same name, is C.C. Schoon (Crash and Post-Crash Research Department SWOV).

Foreword

Part of SWOV's Roadside Obstacles research relates to lighting columns, with which severe impacts occur all too often. To reduce the severity of such impacts, lighting columns can be erected which slip off from the foundation or break at the base. There is then no need for a roadside safety structure purely for protecting the columns.

A consequence of erecting lighting columns low-aggressive for private cars, however, that a collision with them may endanger other road users. The column may fall on the shoulder, but it can of course fall on the carriageway instead, on a cycle path or in a parallel road. SWOV has also investigated the conditions in which this may happen and the relevant factors. Based on these investigations, considerations have been drawn up as to whether or not low-aggressive lighting columns should be placed on various types of roads in view of their potential danger while they are falling and after. The present publication deals with this. The data processed in it have already been discussed by the Interdepartmental Project Group on Roadside Obstacles set up by the Minister of Transport and Waterways.

This publication has been compiled by the project leader for the Lighting Columns research, C. C. Schoon, and A. Edelman, Head Crash and Post-Crash Research Department in collaboration with the Information Department.

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Introduction

A collision with a rigid lighting column may be very hazardous for car occupants. Impact tests by SWOV (SWOV, 1978) have demonstrated that the hazard is reduced if the column is designed so as to break off at the base or slip off from its foundation. The detached column can, however, be dangerous in two ways:
1. if it strikes road users while falling;
2. if it falls on the road and is hit by other vehicles or leads to sudden evasive action.

This publication will indicate when an impacted lighting columns is liable to fall on the road.
For this purpose data on 'lighting columns low-aggressive for private cars' are used. They originate form the impact tests referred to earlier with 10 and 12-m columns. Although the hazards with lighting columns with other dimensions may be no different, no findings are given as to these because they were not tested.
Further, a classification will be given of fatal car and moped accidents involving lighting columns. They are classified for inside and outside built-up areas, by day and night and by location (bend, straight road and intersection). They originate from further analysis by SWOV of accidents recorded by the Central Bureau of Statistics in The Netherlands CBS from 1968 to 1972. On the basis of these figures the implications of erecting low-aggressive columns and of impacts with these will be indicated for various types of roads and intersections.

1. Hazards with falling lighting columns

1.1. **Low-aggressive lighting columns**

SWOV has demonstrated with impact tests the possibility of designing lighting columns which are low-aggressive for private cars. When hit, such a column will break off at the base of slip of from its foundation. The publication Lighting columns (SWOV, 1978) gives more details and describes the impact tests.
Owing to the column breaking or slipping off it falls and may drop at a spot where it forms a traffic hazard. The risk of this happening depends on the type of road along which the column is erected.

1.2. **Falling column**

When a column falls it is liable to drop on the impacting vehicle or on other road users. In a number of SWOV tests it did in fact fall on the test-vehicle's roof. But in no case was the dent in the roof more than 7 cm. It will therefore be assumed for the moment that a falling column will not be very dangerous to car occupants, especially since an American norm (Slechter, 1971) is that a roof dent up to about 8 cm is acceptable. Although car roof structures differ and a column is liable to break through a windscreen, a column falling on a closed car will not as a rule endanger its occupants. Occupants of open vehicles, however, do run a risk. Convertibles and soft-tops, however, account for fewer than 3 per cent of all motor cars.
The risk of a lighting column falling on other road users depends, inter alia, on the distance between the column and the point where such road users are likely to be, traffic density and the speed of impact with the column. The consequences can be serious, especially for motor cyclists, moped riders and cyclists or pedestrians.

1.3. **Fallen columns**

The column may fall on to the road. Then, the main danger is that vehicles might collide with it. Secondly, there is the danger of, for example, evasive action or head-to-tail collisions with vehicles that have stopped ahead of the column.

1.3.1. *Column on main carriageway*

If the column is on the main carriageway, it may be hit by either four or two-wheeled vehicles.
The hazard is apparently not great as regards four-wheeled vehicles, according to two studies in other countries. It has been found that a collision of this nature by an

American medium-size car at about 100 km/h is no more dangerous than an impact with a standing low-aggressive lighting column (Walton et al., 1972). Findings in Britain point in the same direction (Walker, 1974). On the basis of this, it can be assumed for the time being that if a column does fall on the road after a collision an impact by a four-wheeled vehicle against the column is unlikely to cause any serious danger to the vehicle's occupants.
Such an impact does, however, involve a hazard for two-wheeler riders. It will happen if the column is not observed (in time). The greatest danger thus exists in the evening and at nighttime if the road lighting is out or inadequate as the result of a collision.
Note: A column lying on the carriageway can be seen easier in the dark if it is provided with retroflective material. The material must of course be effective when the column is lying.

A column lying on the carriageway is more noticeable if the driver of an approaching vehicle has certain indications that there is something wrong. Such an indication might be the vehicle that first collided with the column and is now standing at an angle on the shoulder for instance. Or it might be a vehicle that has stopped in front of the column on the carriageway. A mixed traffic road usually carries more four-wheeled than two-wheeled vehicles. There is therefore more chance of car drivers being confronted first with a column lying on the carriageway. When they stop, they will indicate the position of the column with their vehicles and hence reduce the risk of a two-wheeled vehicle hitting the column.
In the daytime, two-wheeled vehicle riders will mostly observe a column on the carriageway (in time). This is more likely in the case of moped riders because their approach speed is lower than that of motor cyclists. This applies even more so to cyclists of course. The risk of two-wheeler riders hitting a fallen lighting column in the daytime is therefore slight. But such a collision can have very serious consequences for this category of road users.

Colliding with a column lying on the carriageway is not the only danger, but evasive action is also hazardous. Moreover, as stated above, head-to-tail collisions may be caused if vehicles stop in front of columns lying on the carriageway.

1.3.2. *Column on moped or cycle path*

A column on a cycle path is dangerous to moped riders and cyclists. The risk of a moped rider hitting a column on a cycle path is greater than on the main carriageway. There are three reasons for this. Firstly, there is more risk of an impacted column falling on to the cycle path than on to the main carriageway (See 2.3.3.). Secondly, there is no possibility of the column being indicated by four-wheeled vehicles. Thirdly, cycle paths are generally not lighted as well as main carriageways. As already stated, the consequences of such collisions may be serious.

1.3.3. *Location of the column*

The conditions under which a broken or slipped off column can fall on to the carriageway have become clear from impact tests. The position of such columns after

a collision depends mainly on the impact speed (See SWOV, 1978).
If a column is run into at a speed higher than about 35 km/h, it will fall roughly in the direction of movement of the impacting vehicle. Moreover, it never happened in the impact tests that the bottom of the column which was always flung in the direction of the impacting vehicle's movement landed more than 20 metres from its original position. With an approach angle of 15° and an impact speed over 35 km/h the lateral distance from the furthest point of the column to the row of columns never exceeded 6.5 m. On the basis of these tests it can be assumed that if a road or path runs parallel to the main carriageway about 7 m or more from the row of lighting columns there is little risk of an impacted column falling on it.
SWOV's tests and tests abroad (Nordlin et al., 1969) have shown that at impact speeds higher than about 35 km/h against low-aggressive columns there is little risk of the column falling on the main carriageway.

The position is different at impact speeds lower than about 35 km/h. The bottom of the column is not flung away as fast, and therefore the column may fall in front of the impacting car with the lantern in front. The distance between the farthest part of the fallen column and the column's original place may be as much as 20 m.
Owing to the weight of the arm and the lantern, the column may even fall sideways in the direction in which the lantern is pointing. Although such a sideways fall caused by a low-speed collision occurred only once in the SWOV tests, tests abroad (Nordlin et al., 1969) have also shown that this is liable to happen. The greatest lateral distance between the fallen column and its original position at such impact speeds will therefore probably be in the original direction of the lantern and not in the opposite direction owing to the weight of the lantern.
Going by the SWOV tests, it can be assumed that a 10-metre column will, at worst, come to rest about 7 m over the edge of the road. This may happen if the column falls at right angles to the longitudinal axis of the road. 12-metre columns can in that event fall about 9 metres over the edge of the road. In the tests, the columns were located about 1.5 m from the edge line; the approach angle was 15°.
Note: One of SWOV's impact tests indicated that an aluminium column which split lengthways on impact owing to a defect in manufacture may break off quite differently. This can have considerable influence not only on impact characteristics, but the position of the column after the collision will then be unpredictable. It was not possible to check whether this was an exceptional case.

2. Fatal accidents involving lighting columns

The extent of the hazards caused by a falling or fallen lighting column cannot (yet) be expressed in the form of Dutch accident statistics. The reasons are the small number of low-agressive lighting columns already placed (since others hardly ever fall, if at all) and that Dutch accident recording does not specify accidents with a fallen column as such.

It can, however, be indicated where and when such accidents are likely. For this, fatal car accidents involving (mostly aggressive) lighting columns were analysed. The fact that lighting columns were involved does not mean that the fatal injury was caused directly by colliding with the column. If all these columns had been low-aggressive ones there would have been potential hazards at the indicated sites through these columns falling. The analysed car accidents relate to the years 1968 to 1972 (See Table 1.) They account for 70 per cent of all fatal accidents involving lighting columns.

Besides these car accidents, corresponding figures are given for moped accidents. They account for 20 per cent of all fatal accidents involving lighting columns (See Table 2). Although analysis of these moped accidents is not really part of the research into the hazards of falling lighting columns, the figures are nevertheless given in order to indicate where and when such accidents with (standing) columns happen. This is because possible measures relating to the hazards of falling lighting columns (for instance changing their positions) may have implications for the number of moped collisions with standing columns.
Detailed figures for other road-user categories are not given because they relate to a total of only about 10 per cent of all fatal accidents involving lighting columns.

2.1. **Fatal car accidents**

For all fatal car accidents involving lighting columns in The Netherlands from 1968 to 1972, a classification was made according to bend, straight road and intersection inside and outside built-up areas and for daytime and nighttime (See Table 1).
In bends and on straight roads, both inside and outside built-up areas, there are more nighttime than daytime car accidents.
In total, there are twice as many car accidents at night as during the day.
At night, 41 per cent of all fatal car versus lighting column accidents happen inside built-up areas and 25 per cent outside.
In the daytime there is hardly any difference as between inside and outside built-up areas.
Accidents on straight roads account for over half the number of all accidents (inside built-up areas 31 per cent, outside 21 per cent).

Location on road		Fatal car accidents involving lighting columns					
		Number	%	Number	%	Number	%
Bend	inside	5	2.2	35	15.8	40	18.0
	outside	10	4.5	24	10.9	34	15.4
	total	15	6.7	59	26.7	74	33.4
Straight road	inside	21	9.5	47	21.3	68	30.8
	outside	17	7.7	29	13.1	46	20.8
	total	38	17.2	76	34.4	114	51.6
Intersection	inside	12	5.4	9	4.1	21	9.5
	outside	9	4.1	3	1.4	12	5.5
	total	21	9.5	12	5.5	33	15.0
Total	inside	38	17.1	91	41.2	129	58.3
	outside	36	16.3	56	25.4	92	41.7
	total	74	33.4	147	66.6	221	100.0

Table 1. Fatal car accidents involving lighting columns* in The Netherlands from 1968 to 1972.

* the fatal injury was not necessarily caused directly by the collision with the lighting column.

Location on road		Fatal moped accidents involving lighting columns					
		Daytime		Nighttime		Total	
		Number	%	Number	%	Number	%
Bend	inside	2	3.2	7	11.1	9	14.3
	outside	2	3.2	5	7.9	7	11.1
	total	4	6.4	12	19.0	16	25.4
Straight road	inside	13	20.6	19	30.1	32	50.7
	outside	3	4.8	5	7.9	8	12.7
	total	16	25.4	24	38.0	40	63.4
Intersection	inside	3	4.8	2	3.2	5	8.0
	outside	1	1.6	1	1.6	2	3.2
	total	4	6.4	3	4.8	7	11.2
Total	inside	18	28.6	28	44.4	46	73.0
	outside	6	9.6	11	17.4	17	27.0
	total	24	38.2	39	61.8	63	100.0

Table 2. Fatal moped accidents involving lighting columns* in The Netherlands from 1968 to 1972.

* the fatal injury was not necessarily caused directly by the collision with the lighting column.

One out of every five fatal car versus lighting column accidents happens at nighttime on a straight road both inside and outside a built-up area.
At intersections there are fewer accidents than in bends and on straight road (15 per cent, 33 per cent and 52 per cent respectively).
It should be borne in mind, however, that no data are known about, for example, traffic densities and numbers of lighting columns as related to location; the stated percentages must therefore be regarded merely as indications. And besides, the numbers are too small for statistically reliable findings.

2.2. **Fatal moped accidents**

The same classification was made for moped accidents as for car accidents.
Table 2 shows that fatal moped versus lighting column accidents happen very infrequently at intersections (11 per cent) and often on straight roads inside built-up areas (52 per cent).
The proportion of these accidents inside built-up areas is about three times that outside (73 per cent and 27 per cent respectively).
The proportion of nighttime accidents is nearly twice that of daytime accidents (62 per cent and 38 per cent respectively).
Here again, no data are known as to traffic densities, numbers of lighting columns as related to location, etc., and once again the numbers are too small for statistically reliable findings.

3. Considerations regarding the positioning of low-aggressive lighting columns

As no conclusions can (yet) be drawn from accident studies regarding the secondary hazards of impacted lighting columns low-aggressive for private cars, the indications from the impact tests already referred to will have to suffice. The conditions of such tests are therefore important in considering the secondary hazards and determine the limited nature of the findings. The tests related to 10 and 12-m columns 1.5 m from the (imaginary) edge of a road, placed so as to be impacted by cars at an angle of 15° (See SWOV, 1978).
It was also assumed that in placing lighting columns which are low-aggressive for private cars, a separate cycle path or parallel road is not protected with one or more roadside safety structures.

3.1. **Location of lighting columns outside built-up areas**

The roads on which lighting columns are located outside built-up areas were classified by types as follows: dual carriageway motorways with and without safety strip, single carriageway motorways, single carriageway roads with and without separate cycle paths, and intersections and junctions.

3,1.1. *Dual carriageway motorways with safety strip*

Column in roadside area
10-metre lighting columns are often placed in roadside areas. A low-aggressive lighting column located there will after an impact, (in case of right-hand traffic) at the worst fall on to the right-hand lane of the impacting vehicle's original carriageway. (This is liable to happen if the column falls at right angles to the longitudinal axis of the road, which is possible at low impact speeds). The left-hand lane will remain free. If there is an unprotected cycle path or parallel road about 7 m or more from the row of lighting columns, there is little risk of a column falling on such a path or road (See 1.3.3.).

Column in central reserve
An impacted central reserve column may fall on either lane of the impacting vehicle's original carriageway.
The question is whether it can fall on the *other* carriageway. If a central reserve does not need to be protected with one or more roadside safety structures it should preferably be at least 20 m wide (RWS, 1974). With such a width there is hardly any danger of a column impacted near the vehicle's own carriageway falling on to the other carriageway. This danger would only emerge if the central reserve was narrower than, say, 8.5 m. Moreover, the risk of a car crashing through the central reserve and hitting a lighting column near the other carriageway is slight with a 20-metre

wide reserve. But the risk increases as the reserve becomes narrower. If both carriageways are lighted with a single row of columns in the middle of the central reserve an impacted column may fall (partly) on to one of the carriageways if the reserve is narrower than about 14 m.

3.1.2. *Dual carriageway motorways without safety strip*

Column on roadside area
If the impacted column falls at right angles to the road's longitudinal axis (which may happen at low impact speeds) a (10 m) column may fall on both lanes of the impacting vehicle's original carriageway.
If there is an unprotected cycle path of parallel road about 7 m or more from the row of lighting columns, there is little risk of a column falling on to such a path or road.

Column in central reserve
The same applies as to dual carriageway motorways with a safety area.

Implications for dual carriageway motorways
At an impact speed lower than 35 km/h a lighting column may fall on the impacting vehicle's original carriageway. Such low impact speeds are not often likely on motorways. An American accident analysis (Garrett & Tharp, 1969) showed that the percentage of collisions with obstacles on motorways at an impact speed lower than 50 km/h was very low. This suggests that on Dutch motorways the number of *low*-speed collisions with lighting columns will be low too.
On this assumption, there will also be little risk of a lighting column falling on the impacting vehicle's original carriageway. The risk of a column in the central reserve falling on the other carriageway depends on the width of the reserve. If each of the two carriageways is lighted with a separate row of lighting columns, the risk is slight where the central reserve is 20 m or more wide. The same applies to a central reserve of a least 14 m if both carriageways are lighted by a single row of lighting columns in the middle of the reserve. The danger to motor cyclists will also be slight in such cases.
The possible consequences if there is a cycle path or parallel road a short distance from the main carriageway are indicated in 3.1.4.

3.1.3. *Single carriageway motorways*

When a lighting column either on the right or the left of the road is hit, there is a risk (at a low impact speed) of its falling on both lanes.
If there is a cycle path or parallel road about 7 m or more from the row of lighting columns there is little risk of a lighting column falling on such a path or road.

Implications for single carriageway motorways
As driving speeds on such roads will not be much lower than on dual carriageway motorways, there is little risk – as with dual carriageway motorways – of an impacted lighting column falling on the carriageway. Should this nevertheless happen, any evasive action on single carriageway roads will be more hazardous than on dual carriageway roads. This of course depends on the density of oncoming traffic.

The implications for cycle paths and parallel roads are indicated in 3.1.4.

3.1.4. *Single carriageway roads with separate cycle path*

When a lighting column either on the left or right side of the road is hit, there is a risk (at low impact speeds) in both cases of its falling on both lanes.
If the cycle path is about 7 m or more from the row of lighting columns and the row is in between the main carriageway and the cycle path or parallel road, there is little risk of the column falling on to the path or road either at high or low impact speeds.
Note: Where there is an adjoining cycle path the situation is basically comparable with that of single carriageway roads without a separate cycle path (See 3.1.5.).

Implications for single carriageway roads with separate cycle path
Average speeds on such roads will generally be a little lower than on motorways. The speed at which a car collides with a lighting column on a single carriageway road is also assumed to be lower.
The risk of the column falling on the impacting vehicle's original carriageway will be greater than in the case of motorways. The danger to motor cyclists on this category of roads is therefore greater, but this is (partly) offset by the possibility of a warning from a four-wheeled vehicle.
Because of the relatively low approach speed of moped riders (and especially of cyclists) there is a *fair* chance of a column lying on the cycle path being observed in the *daytime.*
At *nighttime,* however, when a quarter of the collisions with lighting columns outside built-up areas occur (See Section 2), a lighting column lying on a cycle path is more dangerous, also because the lighting of cycle paths is often poorer than that of the main carriageway. As there is usually no possibility of a warning from a four-wheeled vehicle, there is more chance of the fallen column being hit on a separate cycle path than on an adjoining one. Especially if there is dense moped or cycle traffic at night, the danger caused by a fallen column on a separate cycle path is not acceptable unless the cycle path remains adequately lighted.

For largely preventing a column falling on to a cycle path closer than about 7 m to the row of lighting columns, low-aggressive lighting columns could be placed *behind* the cycle path (depending on a NEN standard determining the location of piping and cables, see NEN, 1974 a + b).
Note: Allowance should be made for the location of lighting columns relative to cycle paths also in view of the relatively large number of fatal moped accidents involving lighting columns (See Section 2).
Another possibility of preventing a lighting column falling on the cycle path is, on the analogy of a test abroad, to connect the tops of the columns with a cable.
Where traffic is dense, both on the main carriageway and the cycle path, protection with one or more roadside safety structures may be considered for various other reasons too. This not only prevents a column being hit and falling on the cycle path but also prevents a vehicle running off the road from riding on the cycle path.

Placing only rigid lighting columns does not solve these problems since these can hardly have any protective effect for moped riders or cyclists. Moreover the risk to car occupants is much greater than with one or more roadside safety structures or lighting columns low-aggressive for private cars.

Note: The situation as regards parallel roads is largely the same as for separate cycle paths, except that four-wheeled vehicles may give warning of a fallen column.

3.1.5. *Single carriageway roads without separate cycle path*

If a lighting column either on the right or left side of the carriageway is hit, there is a risk on both cases of its falling on both lanes.

Implications for single carriageway roads without separate cycle path
If there is no separate cycle path alongside the main carriageway, a column on the road forms a hazard to two-wheeler riders. As cars travel slower on such roads than on motorways, there is more risk of the column falling on the carriageway.
The more four-wheeled vehicles there are, the slighter the risk is of a two-wheeled vehicle hitting the fallen column. A four-wheeled vehicle is then more likely to give warning of the column. Since moped riders and cyclists ride slower they run less risk than motor cyclists.
A collision with a column must not of course lead to the road lighting becoming inadequate.

3.1.6. *Intersections and junctions*

A collision with a lighting column on an intersection may cause it to fall on the intersection.
At intersections there is also the specific hazard of a falling column hitting pedestrians, moped riders, cyclists or motor cyclists.

Implications for intersections and junctions
In absolute terms there are not many fatal car accidents at intersections and junctions involving lighting columns. But this does not mean that there are also few collisions with lighting columns with less serious consequences.
Neither in the daytime nor at nighttime will there be many pedestrians, moped riders, cyclists or motor cyclists on intersections outside built-up areas.
The risk of an impacted lighting column falling on such road users will be slight; moreover a falling column will cover a larger area only at impact speeds below about 35 km/h.
At impact speeds higher than about 35 km/h the column will fall roughly in the track of the vehicle. There is a greater risk of road users in this track being hit by the vehicle that has collided with the column than by the falling column itself.
Rigid columns can only partly prevent these road users from being hit directly by a vehicle. Moreover, the great risk run by car occupants remains.

A column lying on an intersection will be observed more readily, both at nighttime and in the daytime, than one lying somewhere on a straight road section. Road users have certain expectations of traffic at an intersection and about the intersection itself. They will be paying more attention and will tend to observe a column lying on an intersection earlier. It is of course important for the intersection to remain adequately lighted even if one column is hit, so that a fallen column is still quite visible even at night.

3.2. **Location of lighting columns inside built-up areas**

3.2.1. *Roads*

What has been said as regards roads outside built-up areas also applies to the same types of roads inside, though impact speeds are more likely to be low. Specific problems inside built-up areas are formed by foothpaths and the existence of buildings. If there is a pavement or a cycle path within about 7 m of the row of lighting columns, there is a risk of a column falling on them. If there are buildings within the distance a falling column may crash into a house.

Implications for roads inside built-up areas
As there will be more moped riders, cyclists and pedestrians on paths and along roads inside built-up areas than outside, a *falling* column is more likely to strike such roads users inside a built-up area.
The risk of being struck by a falling column is greater at lower impact speeds than at higher ones because in the former case the column may fall sideways thereby covering a larger area within which it is a hazard.
It should be considered whether the reduced risk to motor vehicle occupants counterbalances the increased risk run by moped riders, cyclists and pedestrians. Relevant factors in this are road-user densities on cycle paths and footpaths according to time of day, as related to the risk of a lighting column being hit by a car.
Table 1 shows that cars often collide at night with lighting columns on 'straight roads' inside built-up areas. Cycle paths and footpaths will be used least at nighttime. If fairly dense traffic has to be allowed for on cycle paths at nighttime, it may still be justified to use low-aggressive columns provided lighting is still adequate even if a column is knocked down. Otherwise, different solutions will have to be sought (See 3.1.4.).
As there is a comparatively large number of fatal moped accidents involving lighting columns inside built-up areas on 'straight roads' (See Table 2), it is advisable to place lighting columns as far as possible from the cycle path.
If streets are arranged so that speeds cannot be high (for instance in residential yards), impact speeds will be so low that a collision with a rigid column will not often cause a serious accident. If only rigid columns are used this will prevent a falling column from striking pedestrians and/or cyclists or crashing into a house.
The implications as regards a *fallen* column are analogous to similar situations outside built-up areas.

3.2.2. *Intersections and junctions*

In a collision with a lighting column at an intersection, there is a danger of its falling on the intersection. Especially inside built-up areas the danger exists of the falling column striking pedestrians, moped riders, cyclists and motor cyclists.

Implications for intersections and junctions

In absolute terms there are few fatal car accidents involving lighting columns at intersections inside built-up areas. Unlike intersections outside built-up areas, there may be many pedestrians, moped riders, cyclists and motor cyclists at intersections in built-up areas. Another difference is that impact speeds on intersections in built-up areas will generally be lower than outside. Hence, there is more risk of an impacted column falling outside the vehicle's track. Road users on intersections inside built-up areas are thus liable to be struck by a *falling* column if low-aggressive lighting columns have been placed. If there are many pedestrians, moped riders, cyclists and motor cyclists at the location, it should be considered whether the increased risk to these road users (especially in daytime) is warranted by the reduced risk to car occupants (in the daytime and at night).

What applies to a column falling on an intersection outside a built-up area also applies inside built-up areas. Firstly: a column *lying* in an intersection will be observed earlier than one somewhere on a straight road section. Secondly: the intersection should still remain adequately lighted at night after one column has been hit, so that a column lying there will also be visible at night.

4. Conclusions

4.1. General

Low-aggressive lighting columns will easily break at the base or slip off their foundation when hit by private cars or heavier vehicles.
They may consequently cause a hazard for other road users if they fall on vehicles or strike pedestrians or two-wheeled vehicle users. The extent of the hazard depends on the location of the column, traffic density and impact speed.

A column may also be hazardous when lying on the carriageway. If a four-wheeled vehicle collides with a column there is apparently no great risk of severe injury to the occupants. A collision is very definitely hazardous for two-wheeler riders. The risk of such a collision increases as the fallen column is less likely to be observed. This will apply mostly after dark. Possibilities of making such columns more visible are to ensure that the rest of the lighting does not fail and to use retroflective aids.
There is also a danger of evasive action causing an accident, or of head-to-tail collisions occurring with a vehicle standing before a fallen column.

The place where a low-aggressive lighting column lies after an impact is closely related to the impact speed. At speeds higher than 35 km/h, it will come to rest more or less in the vehicle's direction of travel and never (or rarely ever) on the impacting vehicle's original carriageway.
At speeds under about 35 km/h the column may fall in the direction of the lantern; there is then a possibility of its coming to rest at right angles to the road's longitudinal axis.

Available accident statistics are inadequate for statistically reliable findings but do give indications of places and times of potential hazards that falling or fallen lighting columns might cause if low-aggressive lighting columns were to be placed en masse. Of all fatal accidents involving lighting columns, 70 per cent are *car* accidents. Of these fatal car versus lighting column accidents, few happen at intersections (15 per cent) and many on straight roads (52 per cent); 21 per cent happen at night on straight roads in built-up areas.

The location of the lighting column is also of importance to the *moped rider,* because of the possibility of colliding with a standing column. 20 per cent of all fatal moped versus lighting column accidents involve moped riders. Accidents at intersections are few; about two out of every three happen on straight roads. Inside built-up areas there are about three times as many moped lighting columns accidents as outside.

The extent of the danger caused to other road users by impacted low-aggressive lighting columns cannot yet be indicated in absolute terms. This is because certain data were not available during the research and hence a number of assumptions had to be made. The conclusions must therefore be treated with some circumspection.

4.2. **The relationship between lighting column location and dangers in falling**

In considering the placing of lighting columns low-aggressive for private cars, it should invariably be examined whether the reduced primary collision risk to car occupants counterbalances the dangers caused when the column falls.
The implications for the location of lighting columns as regards the hazards when they fall are based largely on impact tests. The points of departure must therefore be borne in mind, i.e.: 10 and 12-metre columns, an approach angle of 15° and a distance between column and edge of the road of 1.5 m. It was also assumed that when low-aggressive lighting columns are placed a separate cycle path or parallel road is not protected with one or more roadside safety structures.

4.2.1. *Outside built-up areas*

Dual carriageway motorways
On motorways outside built-up areas it can hardly be assumed that low-aggressive lighting columns after impact will fall on the impacting vehicle's original carriageway owing to the small number of collisions likely to occur at a speed under about 35 km/h. The risk of a lighting column in the central reserve falling on the other carriageway depends on the width of the reserve. If both carriageways are lighted by a separate row of lighting columns, the risk is slight with a central reserve width of 20 m or more. The same applies to a central reserve width of at least 14 m when both carriageways are lighted by a single row of lighting columns in the middle of the reserve. On these conditions, it is justified to place low-aggressive lighting columns on such roads.

Single carriageway motorways
In view of the higher impact speeds that are likely, vere few lighting columns will be flung by an impact on the carriageway of single carriageway motorways. Notwithstanding the risk of evasive actions, it is justified to place low-aggressive lighting columns on such roads.

Single carriageway roads with separate cycle path
Speeds on these roads will often be lower than on motorways. This is also assumed to apply to impact speeds. There will therefore be a somewhat greater risk of the column falling on the carriageway. The risk to motor cyclists would also appear to be greater, therefore, but is (partly) offset by the possibility of a four-wheeled vehicle giving a warning.

There is much more danger to road users on cycle paths located close to the carriageway, because there is a very big risk of an impacted column falling on such paths. Lighting columns are often placed between cycle path and main carriageway, with a distance of less than about 7 m between the row of columns and the cycle path.

Particularly at nighttime, when the risk of colliding with a lighting column is greatest, a column lying on the cycle path might be observed by moped riders too late because the lighting of cycle paths is often poorer than that of the main carriageway. Especially where there is dense moped traffic at nighttime, there is a big risk of a serious accident if the cycle path lighting has become inadequate through one or more columns no longer providing any light owing to a collision.
On such roads, an endeavour should be made to place low-aggressive lighting columns so that there is little risk of their falling on the cycle path if they are hit. This could be done by placing the columns behind the cycle path (depending on a NEN standard determining the location of piping and cables).
Another possibility is to connect the tops of the columns with a cable on the analogy of a test abroad.
To prevent a column being hit and falling on the cycle path or a vehicle running off the road riding on the cycle path, it may be considered providing one or more roadside safety structures. The use of rigid lighting columns must not be regarded as a solution for these problems.
If none of these possibilities is practicable, it could be considered lighting not the entire road but only dangerous points for instance. Here, too, the crash aspects should be weighed against the pre-crash aspects.

On the whole, the same considerations apply to parallel roads as to separate cycle paths.

In connection with moped accidents it should furthermore be considered whether lighting columns along cycle paths cannot be placed so that there is a reduced risk of moped riders colliding with them.

Single carriageway roads without separate cycle path
In view of the lower speeds, on single carriageway roads without separate cycle paths the risk of an impacted low-aggressive lighting column falling on a carriageway will be greater than on motorways. The more four-wheeled vehicles there are, the slighter is the risk of a two-wheeled vehicle hitting a fallen column. It is therefore justified to place low-aggressive columns provided the lighting still remains adequate if the column is hit.

Intersections and junctions
At intersections outside built-up areas there are in absolute terms few fatal car accidents involving lighting columns. At impact speeds under about 35 km/h, the impacted falling column may strike road users, but there is little risk of this because there will be few of them on the intersection. A fallen column will generally be observed more readily at an intersection than on a straight road section because road users pay more attention when approaching an intersection. Care should be taken after dark that the intersection remains adequately lighted after one column has been hit.
It can be concluded that it is justified to place low-aggressive lighting columns at intersections outside built-up areas on the assumption that there are few two-wheeled vehicles (or pedestrians).

4.2.2. *Inside built-up areas*

Roads

What applies to secondary dangers of lighting columns on types of roads outside built-up areas generally also applies to the same types inside.

Inside a built-up area, however, a falling column is more likely to strike a pedestrian or a moped rider or cyclist than outside. This is due to the presumably lower impact speeds owing to which an impacted column may fall sideways and thus cover a larger area.

Lighting column accidents inside built-up areas are relatively frequent at nighttime when there are usually few moped riders, cyclists or pedestrians in the streets. Despite the risk of falling columns, the placing of low-aggressive columns is therefore justified.

As regards collisions by two-wheeled vehicles with a fallen column inside built-up areas: on roads with a parallel cycle path within about 7 m of the row of columns it will not be justified to erect low-aggressive columns, especially if there is dense moped traffic at nighttime, if the cycle path becomes poorly lighted because a collision has put the lighting out of action. Possible solutions are indicated in 4.2.1.

In streets with a yard function with rigid lighting columns a collision with such a column is unlikely to cause a serious car accident. As the column will not break off, predestrians and cyclists will not be struck by it and it will not crash into a house.

Intersections and junctions

In absolute terms there are few fatal car accidents involving lighting columns at intersections inside built-up areas. There are two noticeable differences compared with intersections outside built-up areas. Firstly: at intersections inside there will be more motor cyclists, moped riders, cyclists and pedestrians. Secondly: impact speeds will be lower and hence there will be a greater risk of a falling column striking these road users.

As to a column that has fallen at an intersection, the same applies as for intersections outside built-up areas.

At intersections and junctions inside built-up areas, therefore, the secondary hazards of a collision with a low-aggressive lighting column will be great because of the motor cyclists, moped riders, cyclists and pedestrians.

In every case it will have to be considered whether the increased hazard for these road users compares with the reduced hazard for car occupants.

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* Only in Dutch