crash helmets for moped riders

INSTITUTE FOR ROAD SAFETY RESEARCH SWOV

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PUBLICATION 1975-1E

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Preface

In August 1970 the Minister of Transport and Waterways asked the Institute for Road Safety Research SWOV to 'investigate the requirements crash helmets for moped riders should meet, both as regards the protection they should offer and as regards convenience of wear'. This assignment was related to the decision in principle to implement the compulsory wearing of crash helmets by moped riders.
In accepting the project, SWOV pointed out that although – especially as regards convenience of wear – numerous objections could be raised against the design of the present helmet for motorised two-wheeled vehicle users, it could be said right from the outset that *any helmet is better than no helmet* from the viewpoint of road safety. With regard to the research the proviso was made that in view of its urgency it would be based on data already collected or obtainable at an early date. Consequently, further research, especially into the road safety effect of compulsory wearing of crash helmets by moped riders, would seem necessary in order to put forward detailed modifications later.

The entire project was monitored by an Interdepartmental project group, consisting of representatives of the Ministries concerned with the subject.
In addition to the SWOV project group members, of whom P.C. Noordzij (research psychologist) and H.G. Paar (research engineer), were members of the Interdepartmental group on SWOV's behalf, contributions to the various sub-projects were made by (representatives of)
Netherlands Foundation for Statistics NSS, The Hague
Medical Records Association SMR, Utrecht
Research Institute for Road Vehicles TNO (IW-TNO), Delft
Department on Road Transport RDW, The Hague
Anthropobiological Laboratory of Amsterdam University, Amsterdam

In order to obtain an idea of the need and value of wearing crash helmets by moped riders, the data on moped riders as a group and their unsafety had to be supplemented by injury statistics and other data for this category of road users.
For this purpose, SWOV workers undertook documentation research into injury statistics for moped riders (and motorcyclists and scooter riders), originating mechanism and location, sub-divided into type of head injury, the human head's tolerance limits and the effect of wearing crash helmets. Furthermore, the Medical Records Association SMR was asked to process all its available data regarding injury to moped riders and motorcyclists/scooter riders. An enquiry amongst moped owners provided information on helmet ownership, and on people's ideas about wearing helmets; whereas a number of roadside counts gave an idea of the actual use of crash helmets by moped riders.
The injury data were also used in formulating the requirements that moped crash helmets should meet (including those relating to the area to be protected).

The research was completed in April 1972. In April 1973 the resultant report of the Interdepartmental project group was accepted by the Minister of Transport and Waterways.

This publication is an abridged version of the complete two part report 'Helmen voor bromfietsers' (Crash Helmets for Moped Riders). An English translation of the most important points from the first part: 'The Moped Rider and Road Safety: A description of moped owners as a group and of road risks of moped riders', and the whole of the second part: 'Requirements for Crash Helmets for Moped Riders' will be made available during the course of 1975.

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Introduction

The most important criterion in drawing up the requirements was to achieve the highest possible degree of safety. Endeavours were made to attain a helmet of maximum safety within the given possibilities.
The aspects relating to convenience of wear and purchase price were always considered, but in such a way that they were not made impracticable by over-exaggerated safety requirements.

As regards convenience of wear it may be assumed that this is determined both by the objective properties of the helmet and by publicity on the helmet and the way this publicity is put across. For such publicity the following elements are of importance:
1. The description of the group of moped owners.
2. The unsafety of moped riders.
3. Number and nature of injuries to moped riders.
4. The effect of wearing a helmet.
5. Ownership and use of helmets by moped riders and their attitude towards compulsory wearing.
6. The way in which the standards for moped crash helmets were established.
7. Recommendations on how to buy and wear crash helmets.

Up-to-date records will be kept of crash helmet ownership and use and of the accident and injury trends amongst moped riders.
These and some other proposed activities will be used for the periodical adjustment of the standards.

1. Description of the group of moped owners

Breakdown according to age group and sex

Estimates put the number of mopeds in the Netherlands in 1972 at around 2 million. Of every 100 mopeds, 23 are owned by young men aged 16–20, and 16 by girls aged 16–20. Together, therefore, this group of young people accounts for about 40 out of every 100 mopeds. Men aged above 20 also own 40 out of 100, whilst the remaining 20 are owned by women.
In other words: two-thirds of the total number of mopeds are owned by men. Recently, however, there has been a shift: women, especially those below age 21, now hold an increasingly bigger share.

Breakdown according to other aspects

Apart from age group and sex, moped owners were also sub-divided according to *social status*. The categories were: those employed, retired persons, schoolgoers and housewives. Seven out of ten male moped owners are in the employed category. Slightly more than half the young men up to age 20 who own a moped are, however schoolgoers. Out of ten female moped owners, four are housewives, and this also applies to the employed group. About two-thirds of the girls up to age 20 who own a moped are in the employed group.
The *job category* was sub-divided further in order to ascertain how moped ownership was spread over the various strata of the working population. Ownership by men was found to be lowest in the 'self-employed and higher-grade staff' category and highest in the 'manual workers' category, yet the category 'other employees' was not much lower. For women moped ownership is also lowest in the 'self-employed and higher-grade staff' category, but by far the highest in the 'other employees' category.
An investigation was also made into the relationship between the *prosperity class of the household* of which moped owners form part and moped ownership. In the case of men moped ownership generally increases as prosperity decreases. For women the middle classes are the most strongly represented.
As regards moped ownership, there were hardly any differences between the *regional residential areas*.
Nor was there hardly any demonstrable difference in moped ownership, broken down according to *degree of urbanisation of place of residence* of moped owners.
If the *riding experience* (the total number of kilometres covered as moped rider during entire life) is considered in relation to age group and sex, then it can be seen that for men a strong relationship exists between age and riding experience: the older they are the higher their riding experience. In the case of women the increase in riding experience with age is small. Moreover, the average riding experience of women is lower

than that of men.
In addition, the *average annual mileage* of moped riders was considered, broken down according to sex and age group. This showed that for both men and women the annual mileage decreases as the age increases. For all age group the annual mileage is less for women than for men.

2. The unsafety of moped riders

Number of casualties

Whereas moped rider and pillion passenger fatalities in 1960 were 390 (which was equivalent to 20% of the total number of road deaths in that year), moped deaths in 1970 totalled 540, or 17% of all road deaths in that year. The number of moped riders injured in 1970 is estimated at around 28,000, which is about 35% of the total number of persons injured on the roads in that year.

Death, casualty and accident rates

To permit a comparison to be made between the different categories of moped riders, broken down according to sex, age group and so on, allowance must of course be made for whether and to what extent these categories were in fact road-users. This latter factor can, for instance, be expressed in terms of the number of kilometres travelled during a certain period. In this same way ratios can now be drawn up with regard to the numbers of deaths, injuries and accidents for each category; these ratios are defined as follows:
Death rate: the number of *deaths* amongst moped riders aged 16 and above (data from CBS) per 100 million moped kilometres (calculated on the basis of the number of moped riders and the average annual mileage as stated in enquiries).
Casualty rate: the number of *casualties* (deaths + injuries) amongst moped riders aged 16 and above (CBS) per 100 million moped kilometres travelled (enquiries).
Accident rate: the number of *accidents* amongst moped owners (as stated in enquiries) per 100 million moped kilometres travelled (enquiries).

According to age group and sex

In 1970 the age groups 16–20 years and 50–plus accounted for 39% and 35% respectively of the total number of fatally injured moped riders. For the 16–20 years group this percentage corresponds to their share in the total number of moped owners (39% of the fatalities and 39% of the moped owners). For the 50–plus group the percentage of deaths is disproportionately high compared to their share in the total number of moped owners (35% deaths as against 15% ownership). If the lower annual mileages of this latter group are also taken into consideration, then we find that the group has – relatively – a very high number of deaths per 100 million kilometres, viz. 17.2, a death rate that is over three times higher than that of the remaining groups. And this phenomenon seems to have become more pronounced in recent years.
On the other hand, the accident rate for the 50–plus group seems to be below the

average. For the 16–20 age group the accident rate has gone up in recent years and is now two to three times higher than in the other groups.
The fact that olders riders suffer fewer accidents but have a higher death rate is possibly related to the physical condition and the lowered tolerance of older people.

Although women generally have a higher accident rate than men, the death rate is higher for men than for women. This is, however, only attributable in part to the fact that considerable differences exist between men and women as regards the breakdown of moped ownership amongst the different age groups.

Other aspects

Riding experience and annual mileage

It is obvious that, generally speaking, an increase in riding experience brings a decrease in the accident rate, irrespective of the annual mileage. One exception to this rule is formed by moped riders with much riding experience but with a relatively low annual mileage. This group has a higher accident rate than the group with a comparable annual mileage but less riding experience. This presumably relates to older people who are already more accident-prone because of their age. It can also be seen that in general the accident rate decreases as the annual mileage increases, independent of the riding experience.
Moped riders with much riding experience and/or a high annual mileage are not involved much in accidents, though this does not mean that they also have a lower death rate. However, no figures are available on this, because no data are known on the riding experience and annual mileage of killed moped riders.

Social status, regional residential area and degree of urbanisation of place of residence

Employed persons and schoolgoers clock about the same number of kilometres per year; retired persons travel only two-thirds of this distance and housewives only half. In the 1970 accident rates, however, the ratios are completely different. Schoolgoers have by far the highest accident rate, followed by employed persons, then retired persons and housewives.
In recent years an increase in the death rate for moped riders has become apparent, particularly in the western part of the country and in the big cities.

Light and heavy mopeds

As regards the sub-division into light and heavy mopeds, it can be stated that light mopeds have a lower annual mileage than the heavy types. There is no obvious reason for assuming that riders of such 'fast mopeds' are exposed to a higher accident rate than riders of light machines. The difference in accident rates between heavy and light mopeds are much more probably attributable to differences between their riders resulting from age and experience.

Nature of the moped accident

Accidents can be broken down into: collisions with moving or parked vehicles, pedestrians, fixed objects, accidents involving rider only (skidding, etc.) and other accidents. If a sub-division is also made according to whether inside or outside the built-up area, then it is found that about three-quarters of the moped casualties inside the built-up area result from collisions with moving vehicles. This applies to a slightly lesser degree for accidents outside the built-up area. Inside the built-up area two-thirds of this number of casualties result from a flank collision; outside the built-up area this figure is somewhat less than half.

3. Number and nature of injuries to moped riders

In order to ascertain the way in which moped riders should be protected against injuries it was necessary to institute an investigation amongst moped riders into the most frequent types of injuries and to use this information as a basis for concluding what were the most vulnerable parts of the body.

Figures in Dutch and some foreign publications show that head injuries play a major role in moped accidents. In 1966, for instance, over 80% of all moped fatalities in the Netherlands were the result of head injuries (Central Bureau of Statistics in the Netherlands CBS). According to an investigation in the 1961–1962 period (CBS), 63% of the moped riders and 51% of the pillion passengers involved in non-fatal accidents in the Netherlands suffered head injuries.
Recent Dutch research in hospitals (Medical Records Association SMR) also shows that slightly more than half of all the injuries, for which moped riders were admitted to hospital, consisted of head/neck injuries. Within this group of head/neck injuries, the most frequent was 'commotio' (concussion of the brain), followed by 'severe intracranial injury' (brain damage) and 'minor injury' to head/neck.
In this investigation a check was also made into the severity of various injuries. It was found that the most severe injuries were sustained to the head/neck and chest; the least severe ones mostly involved the upper extremities; injuries of medium severity were most frequently those involving the lower extremities and the abdomen/pelvic girdle.
Apart from the frequent occurrence of head injuries, the proportionally high severity of such injuries bears witness to the need for head protection for moped riders.

Skull injury

Skull injuries (mostly fractures) originate when the force brought to bear on the head exceeds a certain value ('dull blow') or when the surface pressure between the impacting object and the head is too high (causing the skull to be pierced). In the case of skull injuries one can often deduce from the location of the fracture (or from the damage to the crash helmet, if one was worn) the place where the impact struck.
Current data show that, of the skull injuries, facial fractures occur most frequently, followed by fractures of the base of the skull. This is due to the fact that the base of the skull is a comparatively weak part because of the thin wall and the many holes in it for blood vessels and nerves. Apart from the base of the skull, the other main areas where fractures are sustained are the forehead and temple regions.
On the basis of crash helmet damage, researchers abroad concluded that more than 50% of the impacts were frontal. An investigation amongst motorcyclists and racing drivers involved in crashes when wearing helmets showed that in both groups the upper part of the crash helmet was only damaged in 15% of the cases.

Brain injury

Determining factors for brain injury are:
a. deformation of the skull
b. linear accelerations and decelerations
c. angular accelerations

The fact that deformation of the skull may also cause brain damage is almost self-evident. Skull fractures will therefore be mostly accompanied by 'secondary brain damage'.
When a moped comes to an abrupt standstill in a collision, the rider (and/or pillion passenger) will shoot onwards at almost the same speed that he was travelling immediately prior to the impact. If he hits something with his head, then linear accelerations occur. The resultant displacement of, and pressure differences in, the brain matter can cause injury.
If the head is caught fast behind something, then angular accelerations occur due to the sudden twisting of the head. Little is known about the effect of angular accelerations. It may be assumed, however, that they could be important factors in the occurrence of brain injury. The provisional impression, though, is that the tolerance of the head to angular accelerations is such that these will not constitute any problems in normal cases.

4. The effect of wearing a helmet

Positive effects

Since 1941 the effect of wearing crash helmets has been regularly reflected in statistics and publications. American researchers found that after the wearing of crash helmets had been made compulsory for motorcyclists, the total number of motorcycle accidents resulting in fatalities decreased by 21%; the number of accidents involving injuries went down by 34%. In Australia research work was done covering a large number of factors. The researchers concluded that the risk of fatal injury in an accident was reduced to about a third when the motorcyclist wore a helmet.
By compiling the material from a number of divergent random examples, it was calculated that on average the risk of death was 40% lower when a crash helmet was worn. The reduction of the risk of head injury when a crash helmet is worn was calculated in the same way at approx. 30%.
In view of such factors as the riding conditions, the composition of the 'vehicle population', the riders (especially the composition according to age groups) and the quality of the helmet, these percentages may be regarded as a low estimate for the present situation as regards moped riders in the Netherlands.
On the basis of the data in Section 3 Number and nature of injuries to moped riders, it may be anticipated that a crash helmet will certainly provide protection against skull injury and secondary brain injury (as a result of a skull fracture) but less against primary brain injury (when skull is intact).

Negative effects

From time to time suppositions are made about incidental negative effects of wearing crash helmets. Restriction of hearing and/or field of vision or a slackening of attention as a result of a feeling of discomfort are claimed to contribute towards the occurrence of accidents. The (heavy) weight of the helmet, the possibility of it getting caught behind something or badly fitting helmets are alleged to aggravate the consequences of an accident.
No support for such suppositions could be found in the literature studied. In a large number of organisations abroad, where motorcycle accidents are registered, not one single case was known where the wearing of a crash helmet had caused an injury that would otherwise not have been sustained.

5. Ownership and use of helmets by moped riders

In 1970 an enquiry was held amongst moped owners, as described in 'The Moped Rider and Road Safety' (see Preface). This revealed that a clear-cut difference existed in helmet ownership between men and women: 28% as against 11%. At the same time it can also be seen that crash helmet ownership has increased by over 50% in two years' time.
The helmet ownership percentage for male and female moped owners increases in proportion to the increase in the annual number of kilometres travelled. This relationship is most marked amongst young moped riders. Owners of heavy mopeds possess twice as many crash helmets as owners of light mopeds.

A number of roadside counts made by SWOV in the spring and autumn of 1971 and 1972 in order to gain an idea of the use of helmets by moped riders revealed that the percentages had clearly increased since 1971. In autumn 1972 a sharp increase in helmet use by pillion passengers was also observed.

N.B. End 1974 about two out of three moped owners were in possession of a crash helmet (inquiry) and about two out of three moped drivers wore a crash helmet at that date (roadside counts).

The 1970 enquiry further showed that one out of three interviewees objected to the compulsory wearing of a crash helmet. Important groups in this respect were young people and people in higher prosperity classes. The remarkable fact is that these are also the groups which have a high percentage of helmet ownership.
We are justified in assuming that objections are hardly, if at all, based on doubts about the usefulness of the crash helmet, since almost all moped owners said, when asked, that they appreciated its usefulness.

N.B. Since the end of the research (April 1972) new requirements became valid for moped helmets (August 1973) and a wide-spread information campaign was carried out; in the mean time the Minister of Transport and Waterways announced the compulsory wearing of moped helmets, which came into effect by the 1st of February 1975.

6. The way in which the standards for moped crash helmets were established

Functional requirements for helmets

A selection had to be made from the SWOV's list of possible functional requirements for helmets. The most important functional requirement was, of course, that the helmet should offer maximum protection against injury in an accident. Aspects relating to convenience of wear and purchase price always had to be taken into consideration, but mainly in such a way that they were not jeopardised because of extremely stringent safety standards.

Standards for moped crash helmets

At the start of the investigation the Research Institute for Road Vehicles TNO (IW-TNO) was given the task of listing helmets and accessories, listing the standards and determining the properties considered of relevance for the crash helmets marketed in the Netherlands. At the end of 1971 this assignment was concluded with a report forming the basis for the evaluation of the technical possibilities.
On the basis of the above data and the injury statistics, an 'ad-hoc' working group (under the chairmanship of the director of the Institute for Road Safety Research SWOV with representatives from the Research Institute for Road Vehicles TNO (IW-TNO), the Department on Road Transport RDW and SWOV), which was established by the monitoring Interdepartmental project group, concerned itself with the elaboration of these requirements. A number of supplementary tests by IW-TNO proved necessary, and contact was also established with the Anthropobiological Laboratory of Amsterdam University. The ad-hoc working group completed its work in mid–1972 with the report Requirements for moped crash helmets.
The final formulating and drafting of the approval standards does not form part of the SWOV project but falls under the competency of the Department on Road Transport RDW.

The most important function of the crash helmet is to absorb the shock of an impact. Consequently, minimum requirements were set for the *shock-absorbing properties.*
As far as the size of the *area to be protected* is concerned, the basic premise used was that most fractures occur in the forehead and temple region. From this it can be deduced that the area to be protected must be as big as possible and must cover in particular the front and sides. One restriction is that the moped rider's vision must not be hindered. Also the helmet must not extend too far down at the back so that the head retains sufficient freedom of movement and neck injuries are prevented during accidents. Protection of the ears is certainly permitted, but is not a requirement.
From injury data it cannot be concluded that *penetration* of sharp or pointed objects plays a rôle in accidents (suffered by non-wearers of helmets). On the other hand,

in view of the limited data available, it cannot be concluded irrefutably that penetration of the skull therefore does not occur. In any event the international penetration standard, as is applicable to motorcycle helmets, will be adopted.

No requirements have been set as regards the lateral *rigidity* of the helmet shell. The reason for this is that it is extremely difficult to construct a helmet which will protect the head against crushing (when helmet is run over or wedged fast). Consequently, the rigidity standard for present motorcycle helmets does not guarantee such protection either. A crash helmet which would provide sufficient protection against crushing would be much too heavy. In any event, the absorbant material alone is able to absorb the shock in the event of an impact, provided at least that the material is compact enough.

As regards convenience of wear, the *weight* of the helmet is very important. From the viewpoint of comfort (especially for long yourneys) a lightweight helmet is preferable to a heavy one. In view of the foregoing, it must therefore be possible to manufacture extremely lightweight crash helmets which will still meet the requirements.

Attention was likewise devoted to a well-fitting *size and shape*. It is desirable that the helmet should really enclose the head and not rest on top of it (too small). Although a helmet that is (slightly) too big is less of a drawback, one must make sure that the helmet cannot slide about too much on the head or slip down in front of the eyes, which would mean that it would not be protecting the parts it ought to be protecting. The helmet size will have to be indicated by the normal measurements used for hat sizes.

An investigation was also made into how the helmet should react when *scraped* along a rough road surface: abrasion must remain within reasonable limits, yet without adversely influencing the shock-absorbing effect. (It is quite conceivable that in an accident the rider and helmet may be scraped along an uneven road surface and may then crash into, say, a kerbstone).

Moreover, the helmet should still function properly under *extreme temperatures* (both at $-20°$C and at $+50°$C), when exposed to *moisture* and to the influence of *petrochemical products* (oil, petrol).

Requirements were also formulated in relation to elements such as *chin-straps* and *fixed peaks*. The other separate elements did not necessitate such for the time being, partly because there was no need for them, and partly because not enough was yet known about their effect.

7. Recommendations on how to buy and wear crash helmets

The intention is that, if the wearing of helmets by moped riders is made compulsory, the crash helmets will be provided with a label of approval. But even an approved helmet will fulfil its purpose only if the prospective wearer always bears the following points in mind.

A proper fit is of importance for effective protection and for comfort of wear. Attention should be paid to the following points:
1. Basically, the helmet must provide adequate cover for the temples and forehead, as these are the most vulnerable parts of the skull.
2. The size indicated in the helmet must correspond to the circumference of the head in centimetres; the head must be measured on a level with the eyebrows and the 'bump' at the back of the head (the point where the skull goes inwards).
3. Apart from being the correct size, the helmet must fit snugly all round the head without being too tight.
4. The helmet must be worn in such a way that it covers the forehead to just above the eyebrows; in this case it must still just be possible to see the edge of the helmet.
5. At the back of the head the helmet must go down as far as the 'bump', yet without the outer edge of the helmet shell touching the neck or back when the head is bent back.
6. When the chin-strap is fastened, it should hardly, if at all, be possible to push the helmet back and forth with the hand against the scalp.

A heavy helmet in inconvenient when worn for a long time. Nor does a higher weight mean that the helmet provides better protection. So bear the weight of the helmet in mind.

A decrease of hearing due to wearing a helmet is mainly caused by wind noise. The occurrence of this in the case of a helmet which reaches down over the ears is minimal if the helmet closes tightly around the ear, and if any hard shell over the ear has no irregularities or is covered with cloth.
A helmet that covers the ear does not automatically offer better protection against impact injuries, but certainly does protect against cold and rain and against superficial injuries. Protection against the influences of the weather can also be achieved through the correct choice of accessories (peak, visor or cover). Very convenient in this respect is the presence of fastening points on the helmets. When accessories are being purchased, the following points should be borne in mind:
1. When riding no hindrance should be caused by, say, the accessory coming loose, obstructing the rider's view or raising the wind resistance.
2. Accessories which protrude must either give way or break loose if they get caught behind anything.

3. Material and shape must be such that in the event of deformation or breaking loose during an accident no extra risk of injury can arise.

All closures of approved helmets will have passed the same tests. A slide-grip or buckle fastener is, however, more troublesome than a press-stud fastener, both for putting on and removing the helmet.
In the case of a fastener which also serves for adjusting the length, the length cannot always be set properly. Consequently, a separate length adjustment is preferable which, though it can always be altered, is fixed only once. This could be combined with, say, a press-stud.
In addition, a helmet with a shell which passes along at the front of the head on a level with the chin is more difficult to take off (especially when this has to be done by others after an accident).

When the helmet is worn the chin-strap must always be fastened with as little play as possible.
The use of what is termed the 'chin-cup' involves the risk of the chin-strap being pushed forwards off the chin, which would cancel out the function of the chin-strap. On the other hand, the use of a chin-cup means that the chin-strap can be worn with less play without causing much difficulty. It must, however, always be possible to remove the chin-cup, so that the strap can normally be fastened underneath the jaw. The choice is therefore left to personal preference.

The safety of the road user is enhanced if he is easily visible and conspicuous. So choose a crash helmet with a conspicuous colour.

Once the helmet has been hit in an accident, its shock-absorbing effect – even if there is no visible external damage – may have been reduced, thus making it necessary for the helmet to be replaced.
It is also recommended that the inside of the helmet should be inspected from time to time, because it is quite possible that certain substances, used for grooming the hair, may affect the helmet interior.

Lastly, it should be pointed out once again that the prospective user should – in his own interest – make sure that the helmet he chooses is provided with a label of approval.