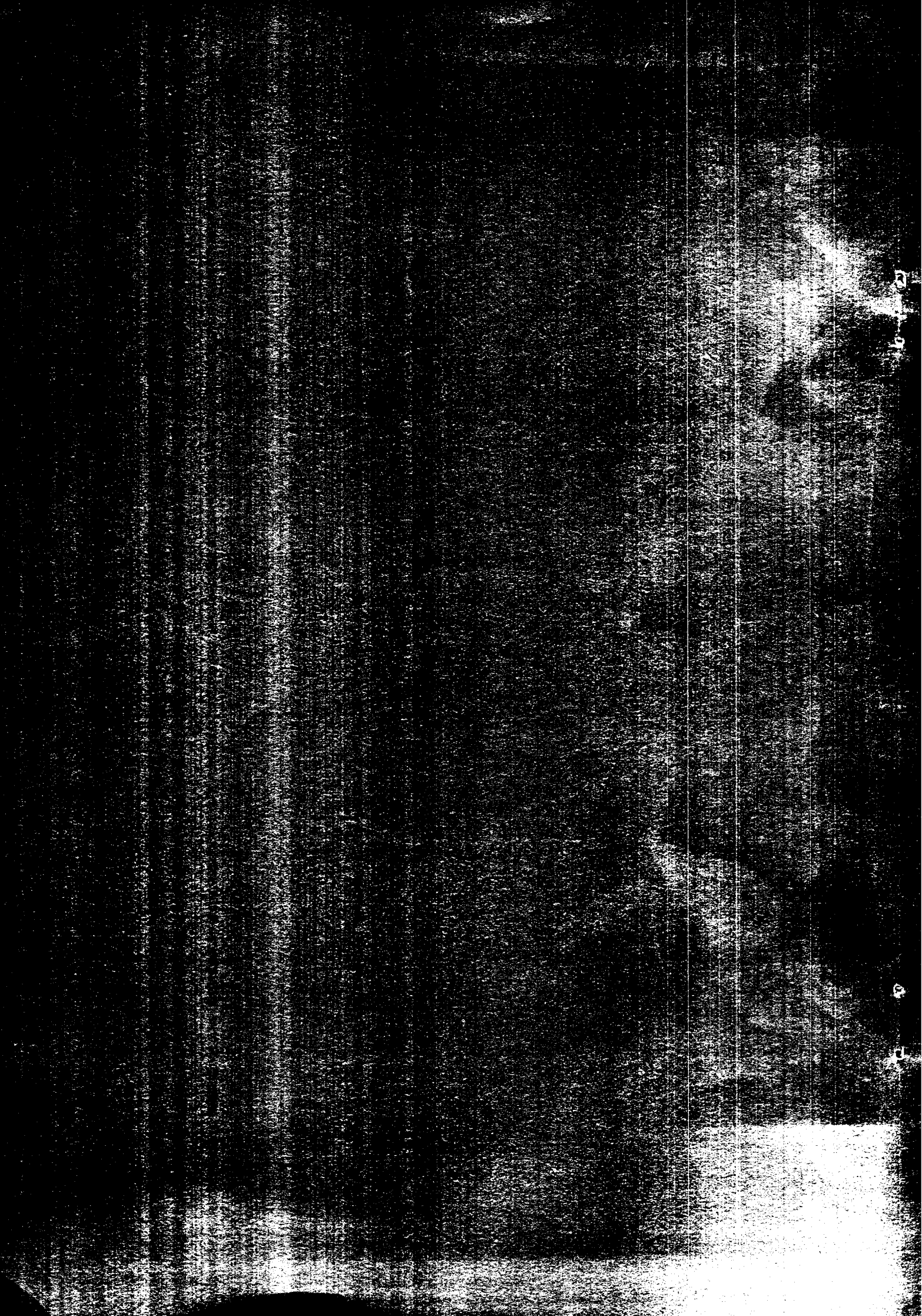"Cycle- and light powered two-wheeler-
riders accidents"

EEVC-WG 8


Final draft, 1984-05-07

List of members participating in the Working Group.

Prof. B. Aldman	Chalmers University	Sweden
Mr. P. Ardoino	Fiat Auto Spa	Italy
Dr.-ing. B. Bonis	Fiat Auto Spa	Italy
Mr. D. Cesari	ONSER	France
Mr. A. Edelman	SWOV	The Netherlands
Mr. P.W. Hoekstra (chairman)	RDW	The Netherlands
Mr. J.J.W. Huijbers (secretary)	SWOV	The Netherlands
Dipl.ing. K. Masseck	VFM	F.R.Germany
Dr. M. Ramet	ONSER	France
Dr. A. Sporner	HUK-verband	F.R.Germany
Dr.-ing. U. Stöcker	BAST	F.R.Germany
Dr. G.R.Watts	TRRL	United Kingdom
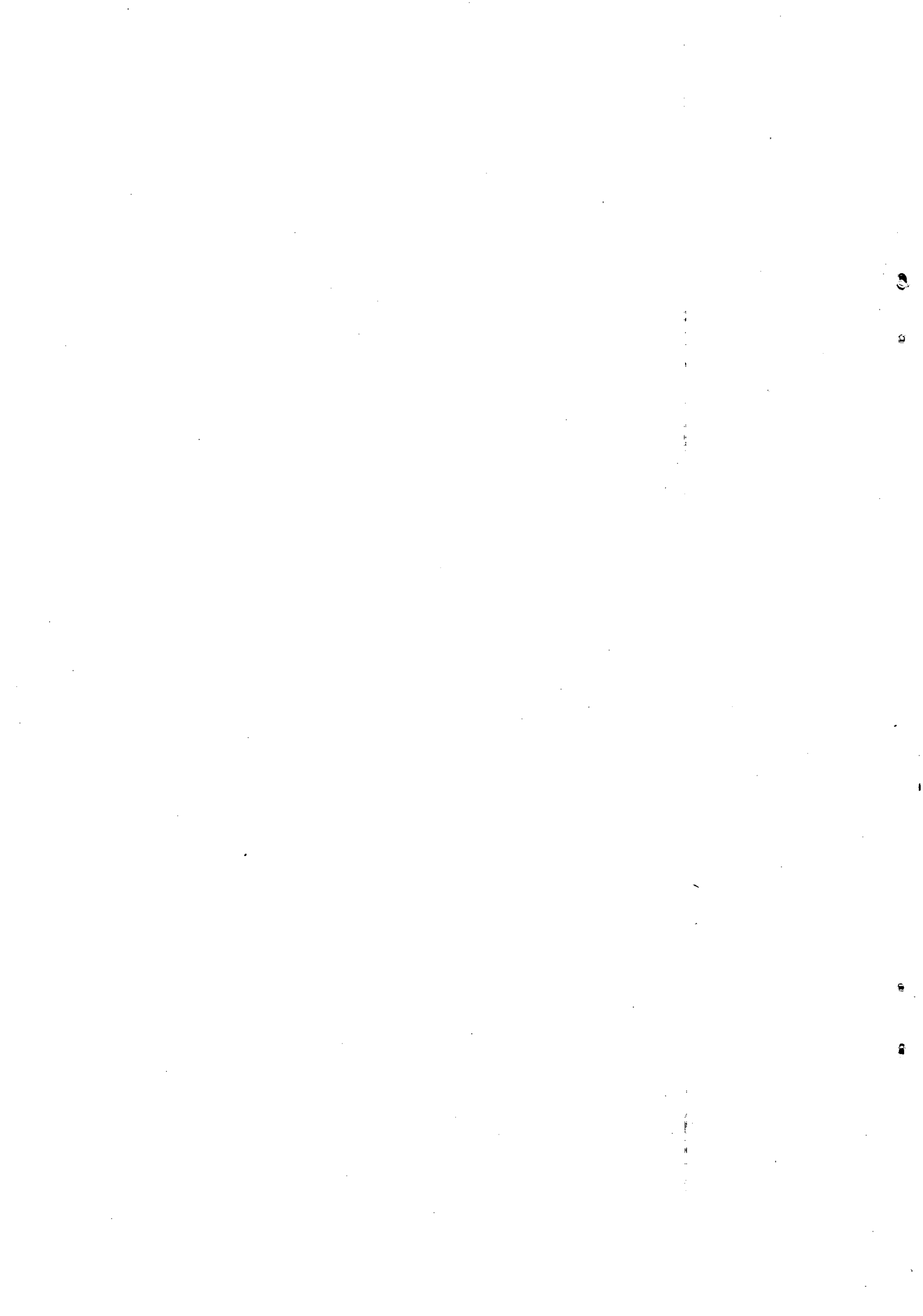
Introduction

In 1981 and 1982 the EEVC working group 7. "Pedestrian Injury Accidents"
was preparing its report. At that time the Dutch delegation suggested
that attention should be given to bicycle-car accidents because in the
Netherlands this accident type happened more frequent than the pedes-
trian-car accidents.

In 1982 the EEVC proposed to set up a new working group that would deal
with biclycles accidents and if possible, also light powered two-wheeler
accidents.

The Dutch members of EEVC were invited to prepare a starting paper for
this group. The intention of this working group, described in the paper
was agreed by EEVC and the group was set up. This intention is focussed
on number of accidents, integrated safety aproach, and international
coôrdination.

Concerning the number of accidents.

"Compared to other European countries the relative proportion of bicycle
casualties in the Netherlands is considerably higher, though the absolute
numbers of those killed and those injured as reported from the different
European countries also seem quite high. They indicate that proper
measures in this field may save thousands of lives and injured, while
reducing the severity of injuries".

Concerning an Integral Safety Approach.

"Some conclusions with regard to changes of the car drawn from studies of
pedestrian-car accidents may be useful for the bicycle-car situation too;
others may be indifferent but some may be contrary to the bicycle case.
For an integral approach to car safety, changes made (or to be made) for
the benefit of one group of road users have to be carefully checked
against knowledge about the characteristics of other groups.

This can be illustrated by- for instance -bumperheight, for which a SAE
recommendation exists, as well as an UN/ECE-Regulation. From research on
lateral car collisions a recommendation for a lower bumperheight may
follow.

From pedestrian accident research follows considerable doubt that the SAE recommendation is an advantage for pedestrians. Considering two-wheeler accidents the effects are even less predictable as yet".

Concerning international coördination.

"It seems that the study of car-bicycle accidents ultimately may contribute a great deal to improvement of traffic safety.
There is a need for accident data, there also seems to be a need for more experimental and human-tolerance data, as well as for better tools to gather those data.
Investigations on crash protection for two-wheelers are starting in several countries.
Research on crash protection for pedestrians has started more then ten years ago, which was followed some years later by international coördination. Now it seems to be the right moment for similar actions concerning bicyclists, while coördination is possible from an earlier stage".

As a result the main committee of EEVC gave the working group the following terms of Reference:

- To review the available accident data concerning fatal accidents and injuries to bicyclists of different ages, involved in road accidents in Europe and to examine the accident data of powered light two-wheelers. (The creation of an exact definition is the task of the group).

- Make recommendations including priorities for action on the vehicle to reduce the severity of such accidents and injuries. Recommendation may e.g. include direct measures to change bicycles and cars, as well as specified proposals for research.

Priority will be given to possible influences of certain proposed measures on the safety of bicyclists; changes to the car should be considered with respect to the benefit of non-occupant road users (see also WG 7).

During the first meeting of the working group, it was decided to deal

also with the light powered two-wheelers, because in some participating
countries the number of light powered two-wheeler casualties is higher
than that of the bicyclists, and because it was the group's opinion that
there were (great) similarities between the two categories of road users.
The group was aware of the difficulties that could rise because of
differences in definitions of light powered two-wheelers in the coun-
tries. Therefore the group decided to include a list of requirements
(including definitions) for light powered two-wheelers for the
different countries.

During the first meeting the group also decided to deal with accident
avoidance aspects related to vehicles.

The aim of accident avoidance is obvious and many efforts have already
been made by improving the construction of passenger cars and heavy
g ods vehicles (brakes,tires etc.) and by change in infrastructure
(e.g.bicycle lanes). "However, there is considerable scope for improving
the lighting and retro-reflectors fitted to many bicycles and for improving
the braking performance especially of rim brakes in the wet.

The decision of the group was that only specific two-wheeler,car and
heavy goods vehicle aspects in relation to two-wheeler accidents will
be described in this rapport.

It is not realistic to expect on a short term measures or solutions that
will prevent accidents from happening at all. Some elusive elements will
always remain. This is the main reason for injury prevention.

The aim of injury prevention is to prevent injuries or to mimimize injury
severity by influenzing the kinematics of the victim and to minimize
loads to the struck body parts,for instance by minimizing the relative
impact speeds between victim and struck objects.

History of bicycle and light powered two-wheeler

Bicycle

The question whether the first bicycle was designed by the Frenchman De
Sivrac or by the German Kessler in $\pm$ 1790 (ANWB [2]) is irrelevant since
it appeared some years ago that the first drawing of a bicycle was made
by Leonardo da Vinci or one of his pupils in $\pm$ 1450 (Gibbs-Smith [3]).
This bicycle was already chain driven (fig.1), contrary to the bicycles
made by de Sivrac and Kessler that had to be pushed forward.

The first bicycles driven by means of pedals had frontwheel drive. To reach a higher speed the frontwheel was enlarged (fig.2),even to such extent that it became dangerous when drivers fell off. Therefore the first "Safety bicycle" was designed by H.J. Lawson in 1874. It had a front and rearwheel of equal diameter and the rearwheel was chain driven. The first practical production machine, the "Rover Safety", were made in 1885 by John Starley (fig.3).

When later (1888) equiped with pneumatic tires, invented by the Irish ve- terinary surgeon John Dunlop, the safety bicycle caused a bicycle boom in Europe and America (Popish [1]).

The safety bicycle had a design similar to the present one, though it lacked the seat tube as a part of the frame structure.

Bicycle use in some countries became enormous, and will probably grow even more due to rising energy prices, increasing spare time and health care.

At this moment a lot of alternative bicycle designs and prototypes are produced. They have in common that the bicyclist is lying backwards and in some designs he or she is protected against weather conditions (Sientific American [5]).

Light powered two-wheeler.

According to Rauck [6] and Schneider [7] the first powered two-wheeler was constructed by Wolfmüller and Hildebrandt in 1894 (fig. 4). According to Elsevier [4] the first attempt to construct a (light?) powered two-wheeler dates from 1920; it is named the "Briggs and Stratton". (1894-1920: A matter of definition?).

The engine was connected directly to a wheel next to the rear wheel. In later years the engine could be found almost anywhere on the two wheeler, but nowadays the engine is normally placed under in the frame, between front and rear wheel, driving the rear wheel.

The use of the moped e.g. in the Netherlands increased strongly after 1960, but decreased after 1975 and is still decreasing.

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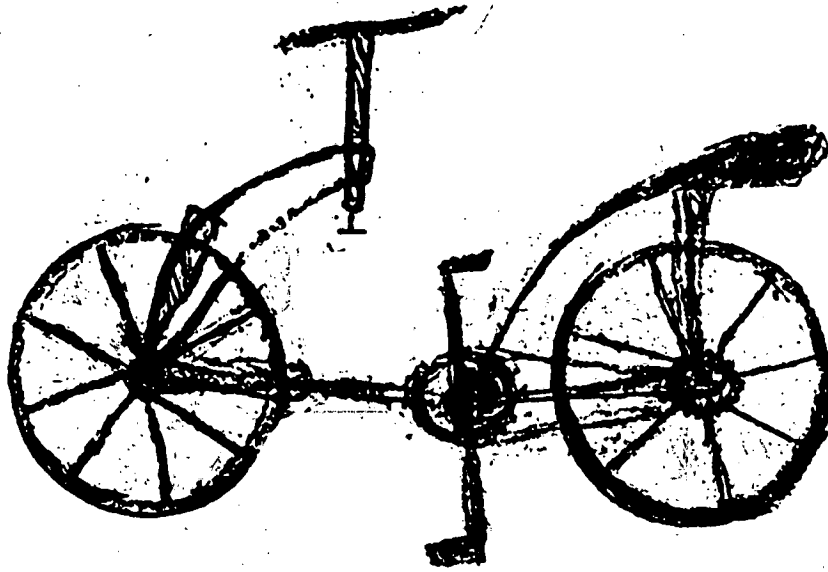   Ismaning (München): Eigenverlag P. Schneider.
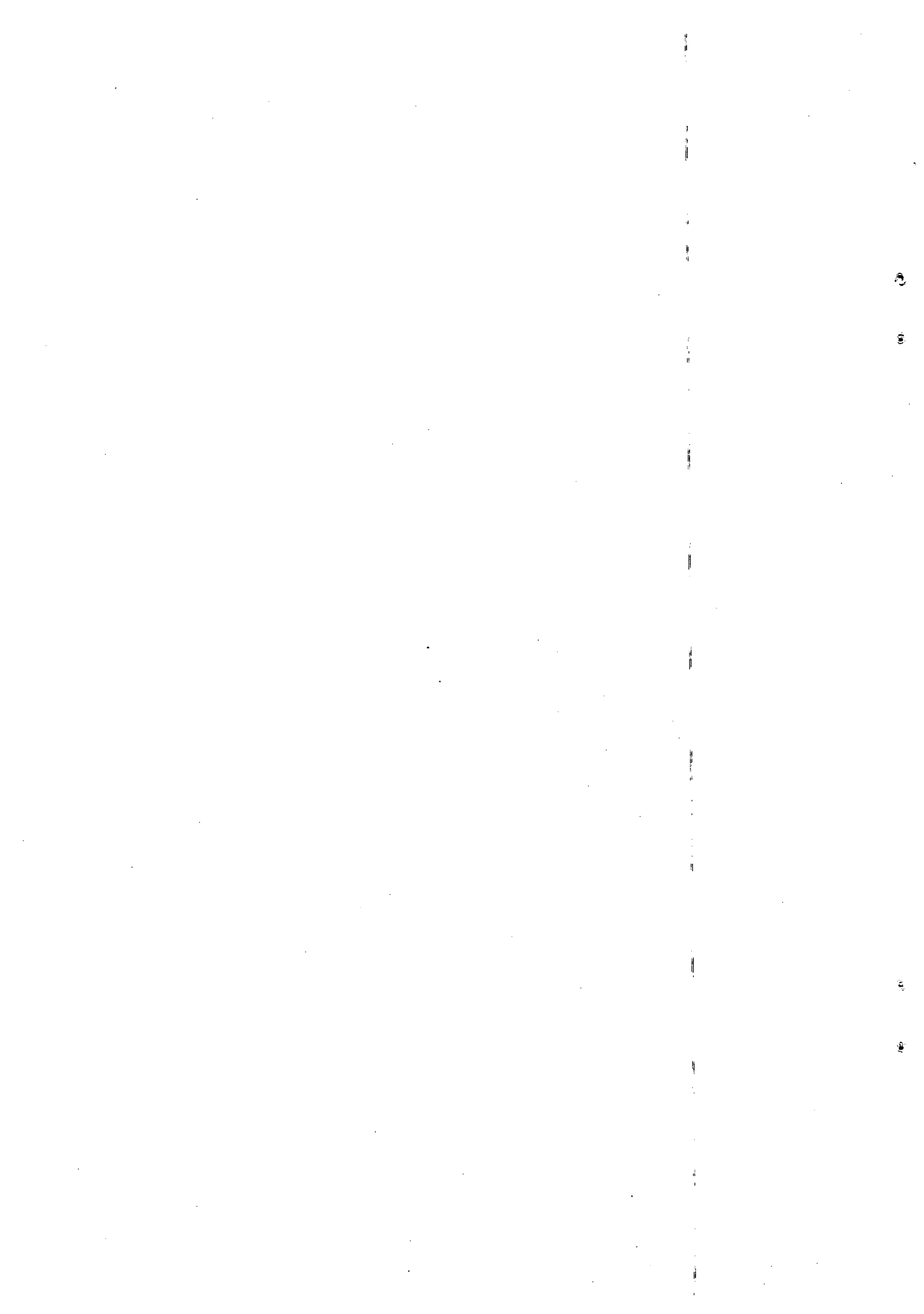
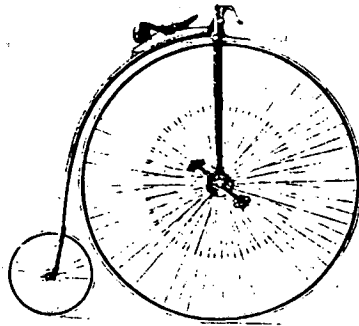fig. 1: Bicycle designed by Leonardo Da Vinci.
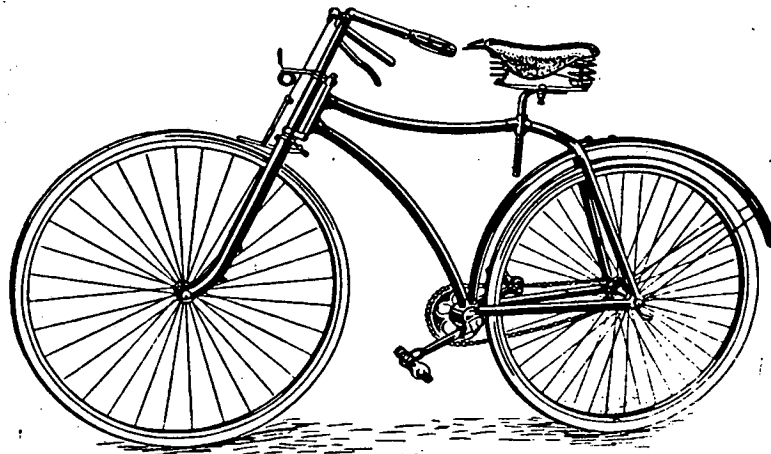

fig. 2: Bicycle with enlarged front-wheel.

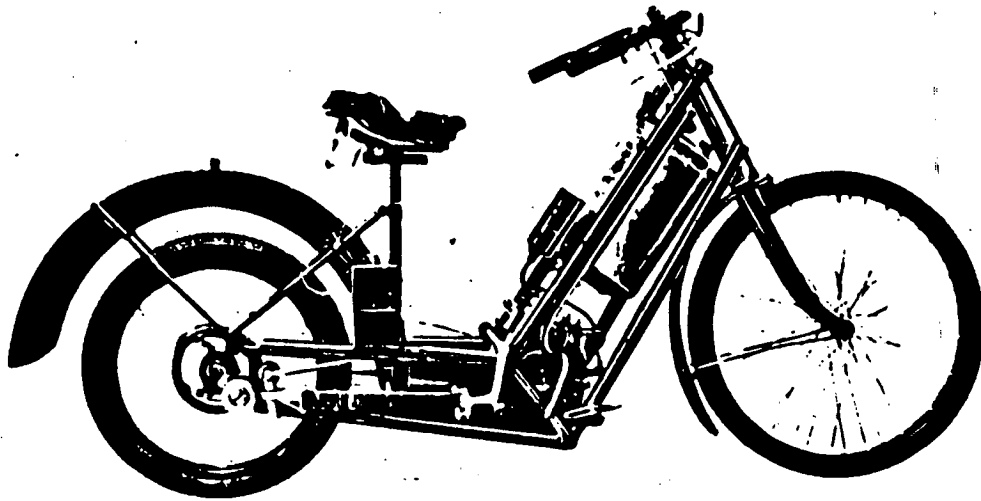fig. 3: Rover "Safety Bicycle".

Fig.4 : First patented, serially produced motorcycle by
Hildebrandt and Wolfmüller; München, 1894.

1. PRIORITIES AND RECOMMENDATIONS

1.1. INTRODUCTION

The working group has, based on the discussions in the group, pointed out priorities for action, general recommendations and recommendations for future research.
One of the conclusions is that the injury prevention research for two-wheeler riders got even less attention than injury prevention for pedestrians. (Working Group 7). More attention is necessary, especially since the accident process of the two-wheeler rider is even more complex than that of the pedestrian because of the contribution of the two-wheeler itself to the injury producing process. Also the speed of the two-wheeler rider and his position in traffic situations leads to other collision types and speeds at impact.

1.2. PRIORITIES FOR ACTION

1. The use of energy absorbing materials in the front struc-
ture of the car will be benificial for the two-wheeler
rider as well as for pedestrians. The exact locations on
the car where these materials should be applied is not
decided today. Never the less, preliminary results of
experiments using dummies indicate that impact location
of the two-wheeler rider's head on the car is somewhat
higher than in the case with pedestrian heads.
Second priority should be given to the side of the car
due to the relatively frequent occurring side collisions
with mopeds.
2. The use of well dimensioned side underrun-guards on heavy
goods vehicles, will reduce the effect of the serious and
relative numerous collisions of mopeds and bicyclists with
the side of heavy goods vehicles. The risk of getting run
over by the wheels will also be reduced.
3. Modern standards should be developed for lighting equipment,
including reflectors, and braking performance (especially
under wet conditions) of bicycles.

The introduction of a high-standard retroreflector at
the rear-end of the bicycle, will probably reduce the
effect of the frontal car collision with the rear-end
of bicycles, which is a serious type of collision.
At the sides of bicycles, spoke reflectors and/or
reflecting tires are recommended.

1.3. GENERAL RECOMMENDATIONS

. More attention should be given to accidents of bicycles
and light-powered two-wheelers, especially to:
- accident registration systems, e.g. underreporting of
these accidents by police
- standardization of definitions for a better comparison
of the results of national accident statistics and
research projects of the different countries. Especially
needed is a more uniform definition of the different
classes of light powered two-wheelers.
. When introducing a new legal measure, a proper before and
after evaluation study is necessary. Some reasons are:
- optimizing the measure
- giving arguments for possible introduction elsewhere.
. In view of the differences in the proportion of head injuries
between (not helmeted) cyclists and (helmet wearing) motorized
two-wheeler riders, it seems preferable that cyclists shall
wear a (specially designed) helmet too.
Padding of certain parts of the car might have a comparable
beneficial result, depending on whether the car or the ground
is the leading cause of injury.This question has to be answered
yet by research.
. The use of better or additional side mirrors on heavy goods
vehicles will give better overview to the truck driver. Even
the present EEC regulation is not sufficient.
. Riders of bicycles and mopeds should wear conspicuous clothing.
For day-time the use of a jacket of fluorescent material is
recommended.

Smaller areas of such material e.g. on armbands or
shoulderbands are less effective. The brightest materials
(highest luminance factor) should be used. Bands of re-
flective material applied to the jacket will help other
road users to recognise the presence of a rider. Spacers
(i.e. devices attached to the side of a bicycle to dis-
courage drivers passing too close when overtaking) are of
use and should be promoted as a low cost safety accessory.
However, it should be noted that the wearing of a conspi-
cuous jacket has an effect on the gaps left by overtaking
vehicles similar to that produced by the most effective
spacer.

The last recommendation is based on research and theoretical
considerations. In part it is supported by accident studies.

1.4. RECOMMENDATIONS FOR FUTURE RESEARCH

A. Real accident studies

Information of real accidents is needed to get better
insight in injury influencing parameters.
The first important question is: What is the leading cause
of injury taking into account speed at impact and collision
type: the car, the two-wheeler or the ground?
From this it may follow that for some collision types severe
injuries occur mainly due to very high impact speeds re-
gardless of other influences (for instance outside built-up
areas). In those cases accident avoidance measures seem to
be more suitable than injury reducing ones.
The next important question is: What is the influence of
car shape and car stiffness on kinematics and short and
long term injury and injury severity of the two-wheeler
rider. Again taking into account impact speed and collision
type, and also human parameters such as age, length and
mass distributions.

Whether accident avoidance or injury prevention
measures should be taken, may be decided with the help
of cost-effectiveness considerations.

B. Human Tolerance

Further research is needed on injury producing mechanisms
in order to develop more precise ranges of values of human
tolerance criteria as a function of age, mass, height,
impact speed (visco-elastic behaviour).
Special attention should be given to the influence of
translational and rotational accelerations of the head on
head (brain) injury.

C. Mathematical models

Computer models should be further developed and validated.
This validation should be based on real accident information
together with the results of cadaver or dummy experiments.
The development of a simple mathematical model, capable to
detect the kinematics of the rider versus the shape and
stiffness of the car, could be useful for standard test
procedures in the near future.

D. Dummies

The dummies presently available for pedestrian research
are not quite fit. For two-wheeler rider purposes this
deficit is analog. Further development is needed to obtain
dummies that give more realistic representations of two-
wheeler riders.

GENERAL

. The recommendations of A, B, C and D above must be seen as
complementary, so they strengthen each other. A trend must be
set to use as many tools as possible to solve this complex
problem.

This is an important argument for international coope-
ration and coordination of the research activities in
the various countries.
. Due to the fact that two-wheeler riders collide with
passenger cars and heavy goods vehicles in more different
collision types than pedestrians do and due to the diffe-
rent parts of the body of the two-wheeler rider that are
impacted in the different collision types, injury preven-
tion research should be focused on following collision
types: — *which rule of road.*

passenger car

- front of car to (left) side of bicycle/moped
- front of car to rear end of bicycle
- front of car to front of moped
- side of car to front of moped

heavy goods vehicle

- front of HGV to side bicycle/moped
- front of HGV to front bicycle/moped
- side of HGV to side of bicycle/front of moped
- side of HGV to front of bicycle/side of moped

single vehicle light-powered two-wheeler rider accidents.
. Research should be undertaken into long term consequences
of injuries. Very little is known about these consequences,
especially about their severity. This is considered a defi-
ciency of existing injury scaling systems.
. When using humans or human substitutes for two-wheeler rider
protection research, the choice should be such that they re-
present the age of the real accident victims e.g. for cyclists
5-25 years and older than 65.
For light-powered two-wheeler riders this age agroup is:
25-25 years.

. Research is needed for more reliable bicycle lighting
  equipment.
. Optimalization of crash helmets should be undertaken:
  - Legal standards should be based on appropriate bio-
    mechanical criteria.
  - The influence of the surface of the outer shell of the
    helmet in relation to rotational acceleration of the
    brain and its resulting injuries should be studied.
  - Research should be undertaken into the problem of
    losing crash helmets during accidents, although
    suggestions for improvements have been tabled in the
    relevant UN-ECE group of rapporteurs.

Summary

1. Importance of the problem.

In various EEVC-member countries it was concluded that over the
last decade a lot of attention was paid to problems related to
accidents with cars and those people using them; in recent years
attention shifted to other traffic participants and especially
to pedestrians for mainly two reasons

- at present they are largely unprotected and therefore
  vulnerable in today's very complex traffic scene
- statistics show that pedestrians actually form a large
  group of casualties.

Considering the work already done for those groups in many coun-
tries the public, Parliament, researchers and authorities became
aware of the growing importance of traffic safety problems for the
users of two-wheelers, relatively speaking but to some extent also
in absolute terms.

The accident statistics as described in **chapter I** indicate the follow-
ing figures for bicyclists and mopedriders (studied together be-
cause their position in traffic in many ways is comparable):

- in some countries this group is the second largest after
  car users in terms of killed and severly injured, in other
  countries it ranks third after car users and pedestrians
- the percentage of killed (light powered) two-wheeler users
  ranges from 6,7 (United Kingdom) to 28.4% (the Netherlands),
  with an average value of 15,8 % for the participating coun-
  tries (for pedestrians: roughly 22 % - 1979).

Chapter I gives a detailed description of those and other figures:
numbers of injured, of vehicles in use etc.; it relates those figures
to indicate some reasons for the variance between countries (numbers
of casualties per 100,000 vehicles and per 100,000 inhabitants in
various age groupes). Work is presented to indicate the important
influence on possible conclusions of differences in definitions and
requirements (differences in accident registration systems and the
related problem of "underreporting"; differences in the technicalities
of the vehicles). A separate paragraph describes the importance of
economic assessment of these accidents and remedial measures, and
some problems related to the available methods.

2. Description of bicycle and moped accidents

Chapter II gives details on typical types of accidents; accident
type, collision type and manoeuvre type are defined and related
(in-depth) studies are cited, indicating at the same time avai-
lable knowledge on resulting injuries and speed at impact.
All material available shows that cars most frequently are the
collision partners (50 to 90 %); there is no single category
of road users ranking second: it ranges from other two-wheelers
to heavy goods vehicles, depending on various factors.
Single vehicle moped accidents occur so frequently that they
deserve special attention.

It is shown that the frequency of an accident type is not the
only relevant parameter; some indication of the seriousness is
considered important too: a definition of "lethality" is sugges-
ted, indicating it's influence on priorities. This approach
gives more "weight" to collosions with HGV's.
By describing collision types and to some extent manoeuvre types,
it is shown which parts of the vehicles are mostly involved;
some similarity exists with pedestrian accidents, but additio-
nally the sides of cars and the sides and rear-end of HGV's are
involved (especially in crashes with mopeds), as well as some
parts of the two-wheeler.

The kinematics of a rider during a collision is indicated as
one of the important factors; due to the range of accident and
collision types for two-wheelers, a much wider variety of kine-
matics is seen for riders when compared with pedestrians;
especially the presence of the two-wheeler and its own speed
contribute.

As to injuries, literature gives a variety of distributions;
most studies are hard to compare, for reasons indicated in
paragraph 2.4.1., but some conclusions and tendencies are
noted. The -limited number of- studies available indicate that
the frequencies of injuries for various body-parts -and their
ranking- depends on the injury severity level considered and
on the type of two-wheeler.

Most studies conclude that the head has the highest frequency (especially when considering more severe injuries and for bi-cyclists with even higher frequencies than for moped riders); arms and legs come in second and third places.

The injury scaling problem associated with long-term impair-ment, as mentioned in EEVC [4] seems to be relevant for some two-wheeler accident types too.

The relative speed at impact is considered to be a very impor-tant factor. The limited number of studies indicating vehicle speeds show higher values than for pedestrian accidents: 50th percentile speed between 10 and 50 km/h, 90th percentile be-tween 37 and 72 km/h.

3.   Injury influencing parameters

Contrary to the situation for car accidents, very little is known about these parameters for two-wheeler accidents. There-fore only a short description is given, mainly of a theoreti-cal and inferrential nature and based on general knowledge from studies of various accident types, indicating the probably most important factors for each of the collision types which seemed important from chapter II.

4.   Research methods and results

A global presentation of various research principles is given, indicating the advantages and disadvantages and especially indicating the usefulness of combining two or more methods. The following division is made:

a   accidents studies
         - accident statistics (police data level)
         - intermediate (hospital/insurance data;
           often local nature)
         - in- depth studies

<u>b</u>   experimental research methods
- full-scale tests
- component (or body segment) tests
- mathematical models

Until recently little research work was done specificly
relating to bicycles and mopeds (and then mainly accident
statistics). What has been done - and can be used to some
extent here too - was useally directed at pedestrians or
motorcyclists; nevertheless a few bicycle-related studies
are cited (accident-studies of various levels as well as
development work on mathematical models, together with the
necessary related full-scale and component tests).

5.   <u>Current knowledge in human tolerances</u>

The accident-situation for two-wheelers is different from the
situation for other groups of road-users, as mentioned before.
This fact may influence typical injury influencing parameters
(kinematics; loading place, direction and level) and therefore
one would have to look for typical cyclist and moped rider in-
formation regarding human tolerances. Only very few studies
have been performed especially for cyclists and moped riders
(and then mainly related to helmets and head tolerance); for
other elements one has to rely on work for pedestrians, motor-
cyclists and car users.
For various body-parts parameters and tolerance values are given,
for some of them the relevance for two-wheeler users has to be
studied further.

6.   <u>Injury prevention measures</u>

For bicyclists and light powered two-wheeler riders, in rela-
tion to other injury prevention measures.

Starting from the basic philosophy of the integral approach of a safe vehicle (integration of requirements for the benefit of various - groups of - road users), three aspects were, seperated:

1 proposals for the benefit of two-wheeler users,

2 consequences of these proposals for other road users,

3 consequences of requirements for the benefit of other road users on two-wheeler users.

6.1   As research work in this area started more or less recently, availability of literature is limited, especially regarding concrete proposals.
Based on information from earlier chapters, work concentrated on the car, the heavy goods vehicle, the two-wheeler and it's rider.

Regarding cars, as for the pedestrian - to - car accidents, interest is focussed on the stiffness of frontal parts. Some differences may exist: the generally somewhat higher - seating - position and a difference in the propulation (less younger children involved) may cause a different influence of various car-components on the kinematics and loading of the human body in a crash; for two-wheeler users the windshield and the higher parts of it's frame become important too. Considerations regarding the vehicle shape follow the same lines as for pedestrians.

Regarding heavy goods vehicles two approaches exist:

- improvement of shape and stiffness would be benificial at the vehicle-front, just as for cars.
- for the HGV-sides and - rear, concrete proposals are indicated regarding underrun-protection devices and improved rear-view mirror systems and requirements (accident avoidance).

Regarding the two-wheeler itself various protection devices
are discussed both for frontal and lateral collisions. Various
types have been developed for motorcycles; whether they can
be practically used on lighter two-wheelers and even whether
they are advantageous on such vehicles is unclear still.
This concerns side protection devices (e.g. knee-bars) as well
as knee-paddings for frontal collisions.
Avoiding sharp protrusions on two-wheelers will help against
-minor- injuries: examples introduced to some extent are
sunken filler caps and handle bar expander-pins.
For the passenger, especially the younger one, dress-guards at
the rear wheel and, until a certain age, child seats are con-
sidered important against e.g. spoke injuries.

Regarding the rider, various well-known possiblities are
described, such as safety helmets and protective clothing.
Although they are widely accepted (and helmets even mandatory)
in many countries for motorcyclists, this is not the same for
moped-riders and certainly not for cyclists (the use of special
types of cyclist-helmets has been introduced in some countries
nevertheless). Possible effects are indicated in the text.

6.2 Consequences for other road users

Little influence for others is expected from the obove pro-
posals regarding cars. Underrun guards should not create any
negative effects for other road users. Rear-view mirrors on
heavy goods vehicles might be dangerous for pedestrians and
bicyclists during overtaking manouevres, if not properly
designed.
Some doubt is expressed as to whether knee-passings may cause
a rider to fly into a cars compartment; helmets may be dange-
rous for unprotected road users.

6.3 Consequences of measures for the benifit of other
road users.

Bumperheight is determined in e.g. SAE- and ECE-prescrip-
tions, mainly for the car-to-car situation; serious doubts
are expressed on the propriateness of these values for pedes-
trians and two-wheeler riders.
Other requirements, e.g. for car-to-car crashes, are not
expected to have much effect on two-wheeler-riders.

7.   Testprocedures

Testprocedures, aiming at ensuring conformity of a vehicle or
component with relevant requirements, are discussed. The chapter
was kept short because a there are very few concrete proposed
measures to evaluate during type-approval,
and b a lot of development work has to be done on the methods
themselves (e.g. integration of integral tests, component tests
and/or mathematical models; development of a dummy).

8.   Accident prevetion

Injury prevention or minimization is clearly not the only and
possibly not the best way to protect road users; accident
prevention would be far be preferable, but it is not expected
to be effective enough for many years to come.
The chapter describes various elements of the vehicle-system
that may cause (or contribute to) accidents to happen.
Research work is described to improve these elements: active
lighting systems, reflectors, spacers, braking systems, stability
and manoeuvrability; as a special aspect, the influence of the
state of maintenance is discussed.
Various proposals are described; in many cases they might be
feasible for many countries because relevant technology has al-
ready been introduced in some other countries today.

EEVC-WG8

CHAPTER I

DESCRIPTION OF TWO-WHEELER ACCIDENT STATISTICS

1.1. Introduction.

The chapter deals with a comparative survey of the situation
of vehicle numbers and numbers of persons involved in acci-
dents in general. Special emphasis is placed on describing
the situation of·pedal cyclists and riders of light-powered
two-wheelers in the member countries participating in the
working group: France, Federal Republic of Germany, Great
Britain, Italy, The Netherlands and Sweden.The interpre-
tation of the data will have to be undertaken with great
caution since the definitions, e.g., of a light-powered
two-wheeler are different in the participating countries.
The definitions of a fatally, severely or slightly injured
accident victim can also differ considerably as well as the
associated parameter definitions in the national accident
statistics. Beyond that other influencing parameters should
be included in a comparative assessment as well, such as
mileage (vehicle-kilometers per annum), road network, land
use, topography and climatic conditions of the countries
under study.

This is just to show that a statistical analysis based on an
only one-dimensional way of looking at things (e.g., the
number of accidents in a population of a defined age group)
can easily lead to wrong conclusions. It is for this latter
reason that only the tendencies of developments are going
to be pointed out in this chapter.
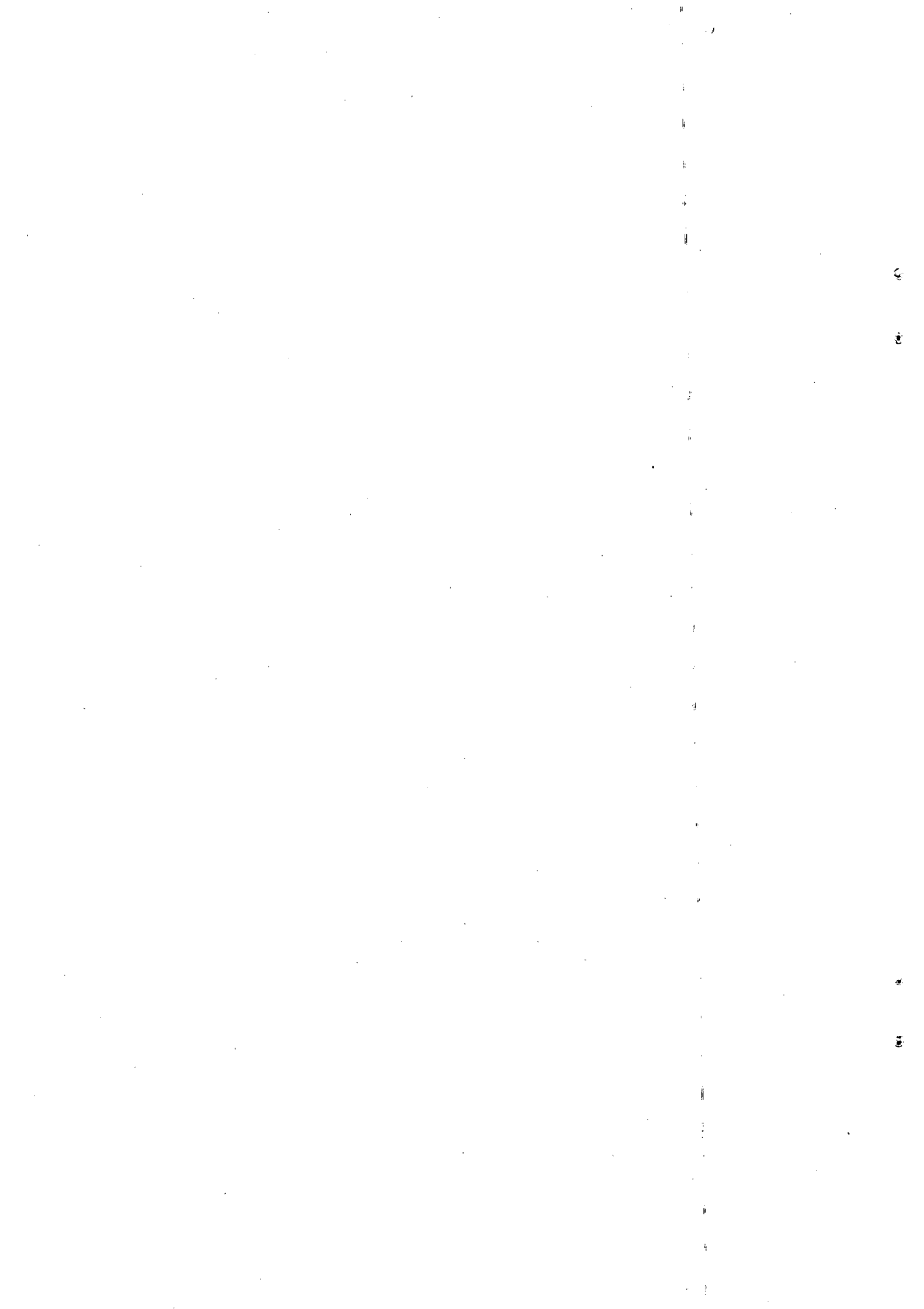
1.2. Definitions of bicycle, light-powered two-wheeler, road accident, killed, severely injured and slightly injured.

The definitions of bicycle, light-powered two-wheeler, road accident, killed, severely injured and slightly injured enabling a better classification of the numbers of accident victims within the overall context are summarized in Tables 1 to 5. The definitions of a bicycle found in Table 1 are largely based on the characteristics laid down in the Vehicle Codes , e.g. [1]. In some countries, bicycles are additionally subject to certain legal regulations, as listed by HORN [2] and in Table 2.

Defining a light-powered two-wheeler and thus its description is more difficult. In Table 3, the spectrum of the principal characteristics of a two-wheeler is represented on which a definition can be based. Taking the Federal Republic of Germany as an example, it can readily be seen that the moped is only one of the three classes of light-powered two-wheelers. According to the definitions given for mopeds and mokicks, the only difference between these vehicles appears to be the presence or absence of pedals or footrests. In contrast to that, the definition of a mofa as for the legal speed limit, minimum age of rider and driving licence regulations is a basically different one.
Legal speed limits for light-powered two-wheelers vary from 20 km/h (NL, snorfiets) to 48 km/h (GB, moped). The lowest possible first time user age group varies from 14 years (Italy) to 16 years (in most other countries).

Compulsory helmet use also does not apply in all countries to all categories of light-powered two-wheelers. And, furthermore, the regulations relating to the use of cycle lanes in the various countries have led to different forms of integrating the light-powered two-wheeler into road traffic as a whole: in some countries for light-powered two-wheelers it is mandatory to use cycle tracks, in others they may use them. Then there are countries where light-powered two-wheelers are banned from cycle tracks and others where they are tolerated with engine off.

Applicable definitions of a road accident in the various countries, which are summarized in Table 4, differ only slightly. It can be assumed that these are definitions of characteristic features. However, for the inclusion of accidents in the national accident statistics, the following additional information will generally be required:

- event site and time
- road users and vehicles involved
- direct causation factors and accident circumstances
  as recorded by the police
- accident injury consequences

The definitions of accident consequences applying to casualties in the various countries are summarized in Table 5. The definition of a person killed in an accident varies in terms of the time period applied in each country within which a victim dies, i.e., between 6 days and 30 days. A period of 30 days is used in the majority of the countries. The definitions of severely or slightly injured accident victims also differ considerably, the extreme case being the Italian statistics where such difference is not made at all. In most cases severely and slightly injured accident victims are distinguished by the kind of medical treatment required: hospitalization or out-patient treatment.

1.3. Total vehicle numbers (vehicle population).

The vehicle numbers grouped in vehicle categories are found in Table 6 for all the countries participating in the working group. It should be pointed out that these populations, being subject to dynamic development processes, cannot be regarded as stable quantities. The development of mofas in the Federal Republic of Germany is a good example. Mofas were introduced in 1966, in 1974 the mofa population exceeded a million and reached a peak in 1980 with 1.4 million vehicles. In 1981 there was a slump in the numbers of mofas and they went down to 1.2 million. The development of the mofa population from 1981 must be assessed in the light of another development, namely the introduction of the newly developed "Leichtkraftrad" in 1980 (80 cc, 80 km/h, min. age: 16 years).

Table 7 shows the numbers of vehicles in each vehicle
category per 100,000 inhabitants. The peak value in the
passenger car category, with a figure of 38,000, is dis-
played for the Federal Republic of Germany. Great Britain,
with 27,000, shows the lowest figure in this category. The
bicycle peak value is displayed for The Netherlands (76,000);
here again the lowest number is found in Great Britain (24,000).
France has the highest number of light-powered two-wheelers
(9,100) and Great Britain once more the lowest (700).

1.4. Statistical records on persons killed and injured in road accidents.

The total number of casualities with a breakdown in light-powered two-wheeler accident victims and users of bicycles involved in accidents are represented in diagrammatic form below for the years 1977-81. The development of the numbers of accidents in the various countries in the same time period is found in Figures 1 - 6. Compared with the overall develop-ment of numbers of accident victims, a striking decline in fatalities in the Federal Republic of Germany, The Nether-lands and Sweden is noticed.

The group of the severely injured also displays a slight downward trend with the exception of The Netherlands where a pronounced decline can be noticed in this group too. In all the countries under study, the numbers of the slightly injured also continued to decline. Great Britain, Italy and France, however, display a quite different development of the overall number of road accident victims. In Great Britain, all three categories display a slight downward trend. In Italy, the numbers of persons killed in accidents remained nearly constant, whereas the numbers of injured accident victims display an upward trend. Casualty numbers in France, apart from the absence of extremely low values and clear peaks, remained more or less constant.

The development of casualty numbers in the group of bicycle riders in the participating countries also displays con-siderable variations in the three casualty groups. In the Federal Republic of Germany, the numbers of killed bicycle riders display a clear decline; the numbers of the severely injured remained at a nearly constant level, whereas the numbers of the slightly injured increased considerably. The development of the numbers of casualties in France appears to be balanced in all three categories in the years 1977-81. In Great Britain, although the numbers of bicycle riders killed in accidents remained nearly constant during this period, the nummbers of severely and slightly injured acci-

dent victims display upward trends. The Italian statistics
show a slight decline in the numbers of accident victims in
both injury categories. In The Netherlands, the numbers of
killed bicycle riders dropped continuously (an exception
being the year of 1980) but is still on a high level.
The numbers of severly injured victims remained at a nearly
constant level whereas the numbers of the slightly injured
display increasing rates. In Sweden too, with the exception
of 1980, the statistics show a clear decline in the numbers
of killed riders of bicycles whereas an overall rising trend
is displayed by the overall number of severely and slightly
injured accident victims.

In the group of light-powered two-wheeler riders involved in
accidents, the statistics display a clear downward trend in
the numbers of casualities in France, Great Britain, The
Netherlands and Sweden. The reductions in this category in
France and Sweden even appear disproportionally high. In
the German statistics the absolute numbers of riders and
passengers of light-powered two-wheelers involved in fatal
accidents display clearly downward sloping curves. The
numbers of the severely and slightly injured increased till
1980. In 1981, a reverse in trend took place and the numbers
again reached the values recorded in 1977. In Italy, the
numbers of persons killed remained nearly constant during
the time period considered, whereas slight increases were
found in the numbers of injured accident victims.

The magnitude of the numbers of pedal cycle and light-
powered two-wheeler accidents in the various countries is
seen clearly when relating them to the total number of road
casualties. The percentage of killed pedal cyclists and
users of light powered two-wheelers in 1981 is given in
table 8. The table shows in particular the importance of
the accident involvement of this category of two-wheeler

users in The Netherlands. As an example, the percentage of
killed pedal cyclists is from two to four times as high as
in other countries.
Great Britain with an overall rate of about 7 p.c. is the
only country clearly remaining below the 10 p.c. level.

When the vehicle population is changing, the casualty rate
in terms of the number of casualties per 100,000 vehicles
shows the trend more clearly. The rates for killed pedal
cyclists and users of light-powered two-wheelers for 1981
are found in Table 9. The table shows that if calculations
are performed on this basis The Netherlands no longer are
outside of the accident patterns displayed by the other
countries participating in the study. In this case, it is
Sweden which shows up as a positive example with its low
rates both for fatal pedal cycle and fatal light-powered
two-wheeler accidents. The Federal Republic of Germany shows
up as the leading country in the group of fatal light-
powered two-wheeler accidents.

The absolute numbers of killed and injured users of bicycles
and riders or passengers of light-powered two-wheelers, classified
into age groups, are shown in Tables 10 to 15 for the countries
under study.

In all countries, fatality, severe and slight injury peak
values are reached in the age group of 10 to 14 year-old
users of bicycles. The age group of 65 years and over also
displays a high frequency of fatalities. In the Federal
Republic of Germany, fatalities in the age group of 65 years
and over are three times more frequent than in the age group
of 10 to 14 year-old riders of bicycles, the ratio for the
severely injured accident victims being 1 : 2. Similar
ratios were found in The Netherlands. In Sweden and Italy,
the comparison revealed still more unfavorable figures for
the elderly.

The numbers of accident victims among the riders and pas-
sengers of light-powered two-wheelers reach peak values at
a later age, namely in the group of the 15 to 17 year-olds.
Compared with the bicycle riders aged 10 to 14 years, the
fatalities displayed numbers which, on average, were two
or three times as high.

With the exception of Italy, the numbers of fatalities in
the age group of 65 years and over are generally much lower
than in the case of cyclists.

Tables 16 - 21 show the numbers of accident victims per
100,000 inhabitants of each age group. High frequencies
and peak values are similar to those found in the absolute
numbers (with the exception of Sweden where fatality and
injury peak values are reached in the higher age groups of
bicycle users). A striking fact, revealed by the Italian
and Swedish statistics, is the fairly low fatality rate in
the group of 10 to 14 year-old juveniles generally considered
to be a particularly high-risk group. Compared with these
numbers, the increased fatality rate for the elderly, espe-
cially in the age group of 65 years and over, should be
noted, in particular.

Fig. 7 and 8 show population-based numbers of casualties
enabling a comparison between the countries participating
in the study. The numbers of killed and injured pedal cyclists
are given in Fig. 7 and the numbers of killed and injured
users of light-powered two-wheelers in Fig. 8.

Extremely high casualty figures for pedal cyclists are dis-
played by the Netherlands and the Federal Republic of Germany.
This applies to all degrees of injury severity, but particulary
to the group of severe injuries. Once more, the diagrams are
an evidence of the fact that the proportion of persons aged 65
and over increases disproportionally with increasing injury
severity, Great Britain being the exception.

The variation in the numbers of casualties per 100,000 in-
habitants for users of light-powered two-wheelers is not as
large as for pedal cyclists. They are narrowly concentrated
around the age group of the 16-year-olds. France, The Nether-
lands and the Federal Republic of Germany display the highest
figures in all these accidents. France, in particular, displays
a remarkable death rate for the age group over 40 years.

1.5. Unreported accidents.

The most important systematic error in all national accident
statistics results from the material damage and injury
accidents which are not reported.
These so-called unreported accidents can reach considerable
values, particularly with decreasing accident severity.
Various studies have been consulted:

Sweden:
ROOSMARK/FRÄKI [4] and THORSON/SANDE [5] concluded that on the
whole not more than half of the traffic casualties are reported
in the national accident statistics. In the case of material damage,
unreported numbers are estimated at 85 p.c. even.
BUNKETORP [11] determined,based on a regional study in Göteburg a
correction factor to describe the relationship between the overall
number of accidents and those recorded by the police.
For fatal accidents a factor of 1.0 was found, for severe injury
accidents 1.4 and for light injury cases 1.8. This corresponds to
unreported rates of 0 p.c. for fatal accidents, one of 29 p.c.
for severe injury cases and one of 45 p.c. for light injury
accidents.

Denmark:
NORDENTOFT [6] revealed in 1972 in the Odense area an estimation
of unreported injured accident victims of more than 60 p.c.
Unreported numbers are reportedly particulary high in the case
of single-vehicle injury accidents.

Switzerland:
HEHLEN [7] reports a high percentage inside urban areas at 70 p.c.
and outside urban areas at 63 p.c. The unreported accidents of
cyclists were estimated at 81 p.c., and for mofa riders at 74 p.c.

The Netherlands:

A study on unreported numbers, published in 1982, was conducted in
The Netherlands (MAAS [9]). This study was based on the time period
1977-79 and revealed that the proportion of unreported numbers
appeared to have remained unchanged over the entire period.

A comparison with police accident records for 1979 showed that in
the case of accident victims hospitalized as a consequence of their
accidents only 17 p.c. appear to remain unreported. The underreporting
seems to be a function of mode of transport.

The "CBS/SMR" ratio of reported accidents (police information/hospital
information) is in vehicle categories and pedestrians the following.

CAR OCCUPANTS	MOPEDS	BICYCLES	PEDESTRIANS
98 P.C.	97 P.C.	82 P.C.	78 P.C.

Germany:

A study conducted by LENHARDT [10] in 1982 (still unpublished) was
based on approximately 4,000 accidents and arrived at an estimated
percentage of unreported numbers of about 54 p.c. The numbers of un-
reported cases drop with increasing severity. The proportion of un-
reported fatalities is estimated at 4.8 p.c.,in the case of severely
injured accident victims 22.3 p.c. and in that of slightly injured
victims 37.5 p.c.

The global estimate of 54 p.c. comprises material damage accidents.
A breakdown in vehicle categories and pedestrians has not been under-
taken in this conjuction.

Great Britain:

PEDDER [12] revealed the numbers of unreported accidents shown
in the table 23. The figures are based on data collected by
PEDDER (1977-1978) and BULL (1973) at Birmingham Accident Hospital
and by HOBBS at a hospital in Berkshire.

The comparison shows how difficult it is for a regional study
of this nature to arrive at a conclusive result of general
validity. The times of data collection (PEDDER, 1977-78;
BULL, 1973) and the legal framework and social conditions
applying therewith certainly would also affect an interpre-
tation of the large differences found in the estimates, but
also differences in sample sizes of the studies may contri-
bute to this.

1.6. Injury severity and hospitalization of users of two-wheelers (including an approach to an overall economic assessment)

It has generally been found that data are not collected in any of the participating countries on the various degrees of injury severity and length of in-patient treatment on a national scale. The research findings available are results of regional studies and thus involve the problem of translation to be of value at national level.

A thorough analysis would additionally have to consider the economic significance of human accident costs which apart from hospital costs (during the period of a victim's hospitalization) also include e.g. the production loss during the period of a victim's inability to work (involving a much larger time (and cost) factor than the period of treatment as an in-patient). However, these are aspects which would be outside of the scope of a regional study on a medical treatment facility concentrating on the classification of injuries into appropriate categories (e.g. AIS, OAIS, MAIS).

For the Federal Republic of Germany, first hints for an analysis of the time and cost factors involved in treating accident victims are found in the studies conducted by OTTE [14] and in the comparison of OTTE's findings with the results obtained by WILLEKE [15]. In table 23, the periods of hospitalization relating to the various degrees of injury severity (OAIS) are shown (on average in terms of days).

Attention is to be paid to the fact that WILLEKE's study is based on an all-road-user sample whereas OTTE concentrated on the users of two-wheelers only. The term "sum total of days of in-patient treatment" may include readmittance to the hospital, where necessary. The number of cases studied here was 123. Based on 282 case studies, OTTE arrived at average periods of in-patient treatment (including complications or not) as stated on the last line in table 23.

For the calculation of the costs of treatment, the average length of hospitalization in each AIS group was linked with the hospital costs/day charged currently by the Medical University of Hanover (DM 310.--). The costs of medical treatment for users of motorized two-wheelers involved in injury accidents with resulting injuries of the OAIS 2 category (without complications) are thus estimated at DM 3,950.--. If complications have to be considered in addition, the costs rise to DM 10,000.-- (base: 123 cases).

A survey concerning the length of the hospitalization in relation to the severity of injuries (MAIS) can be found in a study by DANNER [16]. One remarkable result of the study is that the high number of leg injuries with long treatment period are dominating at the injury-scale MAIS 3, whereas at MAIS 4 and 5 the head injuries determine the injury pattern (Table 24).

A study conducted by KRUPP [17] describes the periods of hospitalization and the resulting costs for severely in-jured riders of bicycles and motorized two-wheelers. The medical treatment costs and the costs with a breakdown into categories accounting for the absence and presence of effects on earning capacity, as estimated by health insurance companies or insurance companies for occupational accidents, are found in table 25.

A survey among nearly all hospitals in The Netherlands [18] shows as a result the following average number of days in hospital for bicyclists and users of powered two-wheelers: bicyclists 18 days; moped riders 20 days; motor-cyclists 20 days. The average total costs per patient don't differ so much: bicyclists 6200 HFL; moped riders 6900 HFL; motorcyclists 6800 HFL.

In the TRRL study conducted by HOBBS [8] the periods of hospitalization and degrees of accident severity are con-sidered separately for cyclists and users of motorized two-wheelers. In the case of cyclists, the degrees of in-jury severity primarily fall into the AIS 2 and 3 categories.

On account of the limited number of case studies, the periods
of hospitalization were classified into those of less or
greater than two days. The group of accident victims with
injuries in the AIS 2 category mainly involved periods of
in-patient treatment of $\nleq$ 2 days (57 out of 83 cases). In
the case of injuries of the AIS 3 category, the period of
hospitalization is clearly greater than two days (in 22 out
of 29 cases). In 57 out of 85 cases, accident victims of the
group of users of motorized two-wheelers, whose injuries
had been classified as corresponding to AIS 2, had to under-
go hospital treatments of $\nleq$ 2 days. The peak value reached
by the injury cases of the AIS 3 category also exceeds two
days of hospitalization by far: between 11 and 20 days in
27 out of 100 cases. Injury cases corresponding te AIS
categories other than 2 or 3 were so few that statistically
significant information was not obtained.

1.7. Summary.

The chapter presents a survey of the national accident
statistics of the countries represented in the working
group.The frequencies of injuries of cyclists and users
of light-powered two-wheelers are considered at greater
depth.At the beginning, the numbers of registered vehicles
are presented and the definitions of a bicycle and ,á light-
powered two-wheeler as applicable in the various countries,
summarized. In the case of the numbers of injured accident
victims, given as overall figures and with a breakdown by
vehicle categories, the distributions found are fairly
heterogeneous and often also display falling trends, in
particular in the case of fatalities. A consideration of
the development of vehicle numbers in each vehicle category
needs to be included in the study. In addition, the numbers
of vehicles per 100,000 inhabitants need te bo considered
both in the evaluation of the numbers of accidents and in
the assessment of relative accident numbers. Due to the
complex nature of the relationships and the basically dif-
ferent definitions given, e.g., of light-powered two-wheelers,
a ranking of the countries by their rates of injured acci-
dent victims was refrained from in this conjunction.

With respect to the numbers of unreported accidents, there
is still the problem of translating the results of regional
studies to the conditions at national level. On the whole,
it was found that the percentages of unreported accidents tend
to increase with decreasing injury severity.

No statistically supported findings on a national level can
be given on the correlation between injury severity and periods
of hospitalization. Only initial data material is available from
regional studies.

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FRANCE:	A VEHICLE WHICH HAS AT LEAST 2 WHEELS AND IS PROPELLED ONLY BY MUSCULAR FORCE.
FEDERAL REPUBLIC OF GERMANY:	BICYCLE MEANS ANY VEHICLE WHICH HAS AT LEAST TWO WHEELS AND IS PROPELLED SOLELY BY THE MUSCULAR ENERGY OF THE PERSONS ON THAT VEHICLE, IN PARTICULAR BY MEANS OF PEDALS OR HANDCRANKS.
ITALY:	BICYCLE IS A VEHICLE WITH TWO OR MORE WHEELS, PROPELLED BY MUSCULAR POWER THROUGH PEDALS OR SIMILAR MECHANISM.
THE NETHERLANDS:	NO EXACT LEGAL DEFINITION " A CARRIAGE OR VEHICLE THAT ISN'T A MOTORVEHICLE". (WVR art. 1.1)
SWEDEN:	1. A VEHICLE DESIGNED TO BE PROPELLED BY PEDALS WHICH IS NOT A TOY VEHICLE. 2. ELECTRICAL WHEEL-CHAIR DESIGNED FOR A MAXIMUM SPEED OF 15 KM/H.
GREAT BRITAIN:	HAS NO POWER ASSISTANCE AND INCLUDES TOY CYCLES RIDDEN ON THE CARRIAGEWAY, TANDEMS AND TRICYCLES. (FROM SEPT. 1983 THE DE-FINITON OF PEDAL CYCLES FOR THE PURPOSE OF REGULATIONS HAS BEEN CHANGED TO INCLUDE "ELECTRICALLY ASSISTED PEDAL CYCLES"; 0,2 KW, 24 KM/H)

Table 1: Definition of a bicycle

REQUIREMENTS FOR BICYCLES	FEDERAL REPUBLIC OF GERMANY	FRANCE	ITALY	THE NETHERLANDS	GREAT BRITAIN	SWEDEN
BRAKES						
- ONE FRONT AND ONE REAR	X	X	X	-	X	-
- ONE BRAKE	-	-	-	X	-	X
LIGHTING						
- HEADLAMP WHITE	X	X	X	X	X	X
- REARLAMP RED						
- BY DAY AND NIGHT	X	-	X	-	-	X
- BY NIGHT OR POOR VISIBILITY	-	X	-	X	X	-
REFLECTORS	X(1)					
- ON PEDALS						
- OBLIGATORY	X	X	X	X	-	-
- ADMITTED	-	-	-	-	X	X
- RED REAR	X	X	X	X(3)	X	X
- WHITE FRONT	-	-	-	-	-	-
WHITE REAR MUDGUARD	-	-	-	X(2)	-	-
REFLECTING TIRES ADMITTED	X(1)	-	X	X	X	X
BELL	X	X	X	X	-	X
OTHER CONSTRUCTION REQUIREMENTS	X	-	-	X(4)	-	-

1) IN 1983 ALL NEW BICYCLES MUST HAVE REFLECTORS IN THE SPOKES OR REFLECTING TIRES
2) YELLOW REFLECTING IS ADMITTED
3) ADDITIONAL HIGH-PERFORMANCE REFLECTOR(MIN1000MCD/LX) REQUIRED, SEPERATE FROM THE REARLAMP (-REFLECTOR)
4) SOME REQUIREMENTS ON THE SEATING POSITION OF CHILD-PASSENGERS UNDER AGE 10

Table 2: Some of the relevant legal requirements for bicycles [3]

NAME OF CLASS	FEDERAL REPUBLIC OF GERMANY			FRANCE	GREAT BRITAIN	ITALY	THE NETHERLANDS		SWEDEN
	MOFA	MOPED	MOKICK	CYCLOMOTEUR	MOPED	CICLOMOTORI	SNORFIETS 4)	BROMFIETS (1) 4A)	MOPED 17)
CLASS INTRODUCED IN	1965	1954	1967	1970	1977	1959	21.4.1976	SINCE 21.11.1966 WITH PEDALS	JULY, 1.1952
SPEED LIMIT [km/h]	25	40	40	45	48 10)	40	20 5)	30/40 5A)	30
PISTON DISPLACEMENT [cc]	≤ 50	≤ 50	≤ 50	≤ 50	≤ 50	≤ 50	≤ 50 6)	≤ 50 6)	≤ 50
MINIMAL AGE [years]	15	16	16	16 1)	16	14	16	16	15
HELMET OBLIGATORY SINCE	NO	24.7.78	24.7.78	1979	1973	NOT YET OBLIGATORY	NO	YES, SINCE 1.2.1975	SEPT. 1.1978
DRIVING LICENCE	ONLY THEOR. TEST CERTIFICATE	YES	YES	NO	YES	NOT NECESSARY	NO	NO	NO
DRIVING ON BICYCLE TRACKS ALLOWED/MANDATORY	MANDATION	NOT ALLOWED	NOT ALLOWED	MANDATION	PERMITTED 11)	NOT ALLOWED	MANDATION 7)	MANDATION 7)	ALLOWED
PEDAL OR FOOTREST	PEDAL	PEDAL	FOOTREST	PEDAL	PEDAL 12)	NOT SPECIFIED	PEDAL	PEDAL	NO REQUIREMENTS
MIN. AND MAX. DIAMETER OF THE WHEELS	B.T. MIN. 580 3)	NOT SPECIFIED	NOT SPECIFIED	NOT SPECIFIED	NO 13)	NOT SPECIFIED	254 mm ≤ 305 mm	≥ 405 mm	NO REQUIREMENTS
MAXIMUM MASS [kg]	NOT SPECIFIED	NOT SPECIFIED	NOT SPECIFIED	NOT SPECIFIED	250 14)	16 (ENGINE)	NO LIMIT 8)	NO LIMIT	2 WHEELS: NO LIMIT; 3 WHEELS: 400
ADMITTED NUMBER OF PASSENGERS	0	1	1	1 2)	1 15)	0	1	1	0
BRAKES	2	2	2	2	2 16)	2	2 9)	2 9)	2

1) 14 YEARS OLD WITH A SPECIAL SCHOOL TRAINING
2) PLUS PASSENGER IF LESS THAN 14 YEARS OLD
3) MINIMUM OUTER DIAMETER OF THE BACK TYRE
4) "BUZZLE BIKE"
4A) MOPED
5) IN "WOONERVEN" NOT FASTER THAN "WALKING SPEED"
5A) 30 km/h IN BUILT UP AREAS; 40 km/h OUTSIDE BUILT UP AREAS (AND 5))
6) ≤ 50 CC OR APPROVED ELECTROMOTOR
7) SOME TRACKS MANDATED, OTHER TRACKS ALLOWED WITH ENGINE OFF
8) 50 kg FOR "EMPTY" VEHICLE, FULLY READY FOR USE
9) > 5 m/s² (BOTH BRAKES TOGETHER)

10) MUST HAVE A DESIGN SPEED NOT GREATER THAN 48 km/h IF REGISTERED LATER THAN AUGUST 1977
11) PERMITTED IN SOME CASES BUT NEVER MANDATORY
12) IF REGISTERED BEFORE AUGUST 1977 MUST BE EQUIPPED WITH PEDALS BY MEANS OF WHICH THE MOPED IS CAPABLE OF BEING PROPELLED
13) NO REQUIREMENTS FOR PNEUMATIC TYRES, 670 mm MIN. DIAMETER FOR NON-PNEUMATIC TYRES
14) 250 kg IF REGISTERED LATER THAN AUGUST 1977
15) ONE PASSENGER IF PROPER SEAT FITTED
16) EITHER MUST HAVE A SINGLE SYSTEM WITH TWO MEANS OF OPERATION OR TWO SYSTEMS OPERATING INDEPENDENTLY
17) SINCE JANUARY 1984 MOPEDS ARE DIVIDED INTO CLASS I AND CLASS II. CLASS I: MOPED OLD DEFINITION CLASS II: VEHICLE KERB MASS 60 kg AND A TRANSMISSION INCLUDING TWO GEARS OR AN AUTOMATIC TRANSMISSION WITHOUT STEPS

Table 3: Definitions and requirements for light-powered two-wheeler

FEDERAL REPUBLIC OF GERMANY:	ACCIDENTS IN ROAD TRAFFIC WITH KILLED OR INJURED PERSONS ON PUBLIC ROADS AND PLACES (REGISTERED IN OFFICIAL STATISTICS; StVUNFG, BGBL. 1982, 2069).
FRANCE:	ACCIDENT IN ROAD TRAFFIC WHICH GENERATES AT LEAST ONE VICTIM OCCURRING ON A PUBLIC OPEN ROAD AND INVOLVING AT LEAST ONE VEHICLE OR RIDDEN ANIMALS.
GREAT BRITAIN:	ONE INVOLVING PERSONAL INJURY OCCURING ON THE PUBLIC HIGHWAY (INCL. FOOTWAYS) IN WHICH A VEHICLE IS CONCERNED, AND WHICH BECOMES KNOWN TO THE POLICE.
ITALY:	ROAD ACCIDENT IS A COLLISION INVOLVING VEHICLES OR ANIMALS ON PUBLIC ROADS, WICH GENERATES PERSONAL INJURIES.
THE NETHERLANDS:	ACCIDENTS INCLUDED ARE THOSE 1. WHICH OCCURRED OR ORIGINATED ON A HIGH-WAY OR STREET OPEN TO PUBLIC TRAFFIC 2. WHICH RESULTED IN ONE OR MORE PERSONS BEING KILLED OR INJURED AND 3. IN WHICH AT LEAST ONE MOVING VEHICLE WAS INVOLVED.
SWEDEN:	ACCIDENTS INCLUDED ARE THOSE 1. WHICH OCCURED OR ORIGINATED ON A WAY OR STREET OPEN TO PUBLIC TRAFFIC 2. WHICH RESULTED IN ONE OR MORE PERSONS BEING KILLED OR INJURED AND 3. IN WHICH AT LEAST ONE MOVING VEHICLE WAS INVOLVED.

Table 4: Definition of a road accident for national statistics for casualties

FEDERAL RE- PUBLIC OF GERMANY	KILLED	SEE ECE*
	SEVERELY INJURED	AN INJURY FOR WHICH A PERSON IS DETAINED IN HOSPITAL AS AN 'IN-PATIENT'
	SLIGHTLY INJURES	AN INJURY FOR WHICH A PERSON IS NOT HOSPI- TALIZED
FRANCE:	KILLED	VICTIM DIED IMMEDIATELY OR DURING 6 DAYS AFTER THE ACCIDENT
	SEVERELY INJURED	ACCIDENT VICTIM WHO HAS SUSTAINED A TRAUMATISM NEEDING MEDICAL TREATMENT WITH AT LEAST A 6 DAYS' STAY IN THE HOSPITAL
	SLIGHTLY INJURED	ACCIDENT VICTIM WHO HAS SUSTAINED A TRAUMA NEEDING MEDICAL TREATMENT WITH LESS THAN A 6 DAYS' STAY IN THE HOSPITAL
GREAT BRITAIN	KILLED	SEE ECE*
	SEVERELY INJURED	AN INJURY FOR WHICH A PERSON IS DETAINED IN HOSPITAL AS AN 'IN-PATIENT',OR ANY OF THE FOLLOWING INJURIES WETHER OR NOT HE IS DE- TAINED IN HOSPITAL: FRACTURES,CONCUSSIONS, INTERNAL INJURIES, CRUSHINGS, SEVERE CUTS AND LACERATIONS, SEVERE GENERAL SHOCK REQUIRING MEDICAL TREATMENT, INJURIES CAUSING DEATH 30 OR MORE DAYS AFTER THE ACCIDENT
	SLIGHTLY INJURED	AN INJURY OF A MINOR CHARACTORS SUCH AS A SPRAIN, BRUISE OR CUT NOT JUDGED TO BE SEVERE, OR SLIGHT SHOCK REQUIRING ROADSIDE ATTENTION
ITALY	KILLED	ALL PERSONS, WHO DIE WITHIN THE NEXT SEVEN DAYS AFTER THE ACCIDENT
	SEVERELY/ SLIGHTLY INJURED	ARE NOT DISTINGUISHED IN ITALIAN STATISTICS
THE NETHER- LANDS	KILLED	SEE ECE*
	SEVERELY INJURED	VICTIMS WHO ARE HOSPITALIZED FOR MORE THAN ONE DAY
	SLIGHTLY INJURED	OTHER INJURED VICTIMS
SWEDEN	KILLED SEVERELY INJURED	SEE ECE* FRACTURE, CONCUSSION, INTERNAL LESIONS, CRUSHING, SEVERE CUTS AND LACERATION, SEVERE GENERAL SHOCK REQUIRING MEDICAL TREATMENT AND ANY OTHER SERIOUS LESIONS ENTAILING DETENTION IN HOSPITAL
	SLIGHTLY INJURED	ALL INJURED NOT BELONGING TO KILLED OR SEVERELY INJURED

Table 5: Definition of casualties; distinction between persons
killed, severly or slightly injured in road accidents.
*ECE Definition of killed: any person who was killed outright or who
died within 30 days as a result of the accident
(For further definitions see ECE [19]).

	CARS	GOODS VEHICLES	MOTOR CYCLES	MOPEDS	MOFAS/ SNORFIETS	PEDAL CYCLES *
FRANCE	19 725	2 568	645	4 900	-	19 000
FEDERAL REPUBLIC OF GERMANY	23 730	1 307	690	652	1 224	38 500
ITALY	17 686 (1980)	1 338 (1980)	828 (1980)	3 461 (1980)	-	17 500
THE NETHER- LANDS	4 594	339	114	700	10	10 800
SWEDEN	2 893	186	16	205	-	6 000
GREAT BRITAIN	14 796	2 286	973	398	-	13 000

* ROUGH ESTIMATED DATA

Table 6:   Vehicle population in 1981 (in 1000)

(1000s)			
CARS	PEDAL CYCLES	LIGHT- POWERED TWO-WHEELERS	INHABITANTS 1 9 8 1
FRANCE	36	35	9.1	53,960
FEDERAL RE- PUBLIC OF GERMANY	38	64	3.0	61,680
GREAT BRITAIN	27	24	0.7	55,830
ITALY	31	31	6.1	57,200
THE NETHER- LANDS	32	76	5.0	14,250
SWEDEN	35	72	2.5	8,320

Table 7:   Vehicle numbers (in 1000) per 100,000
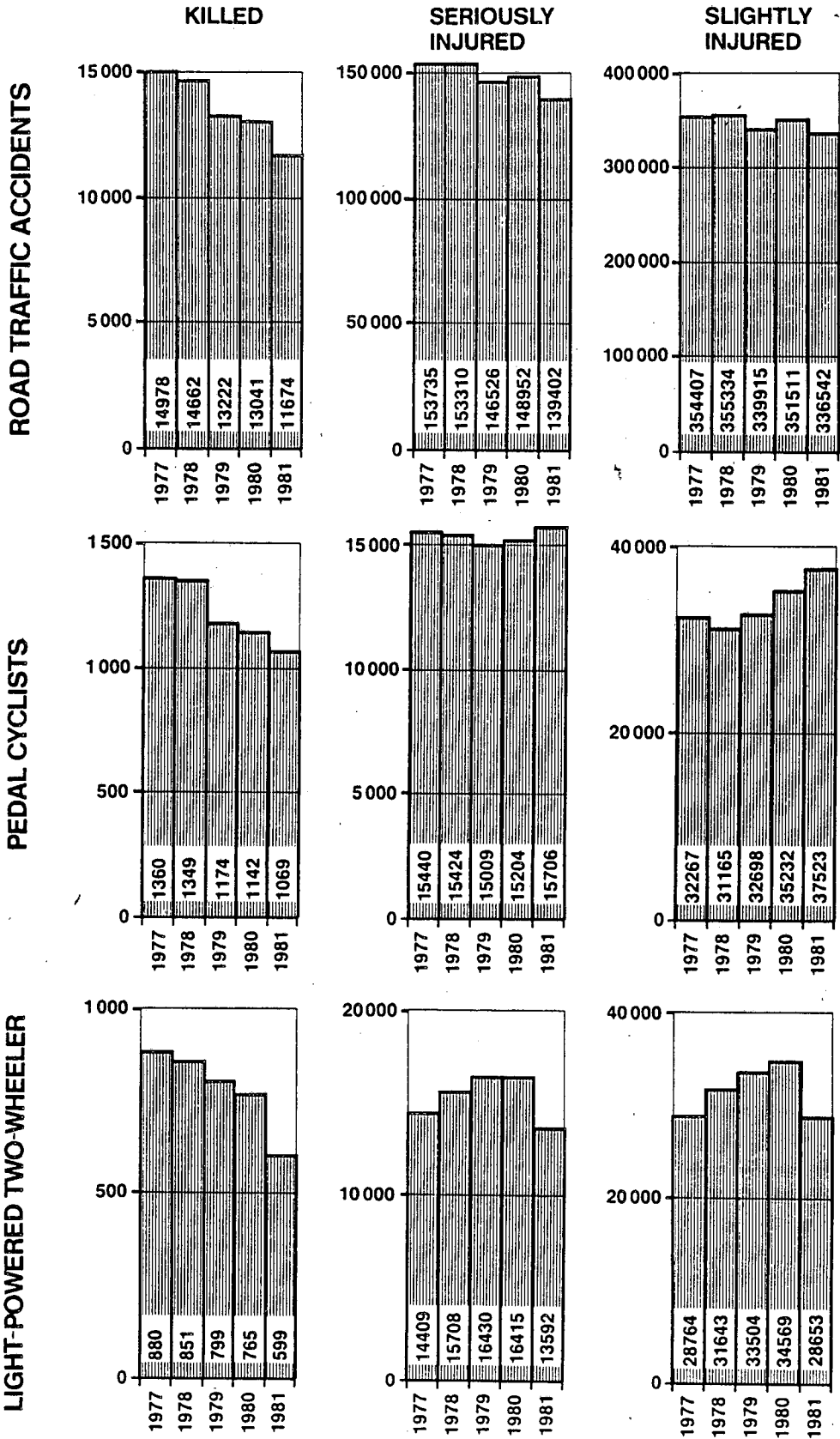   inhabitants in 1981
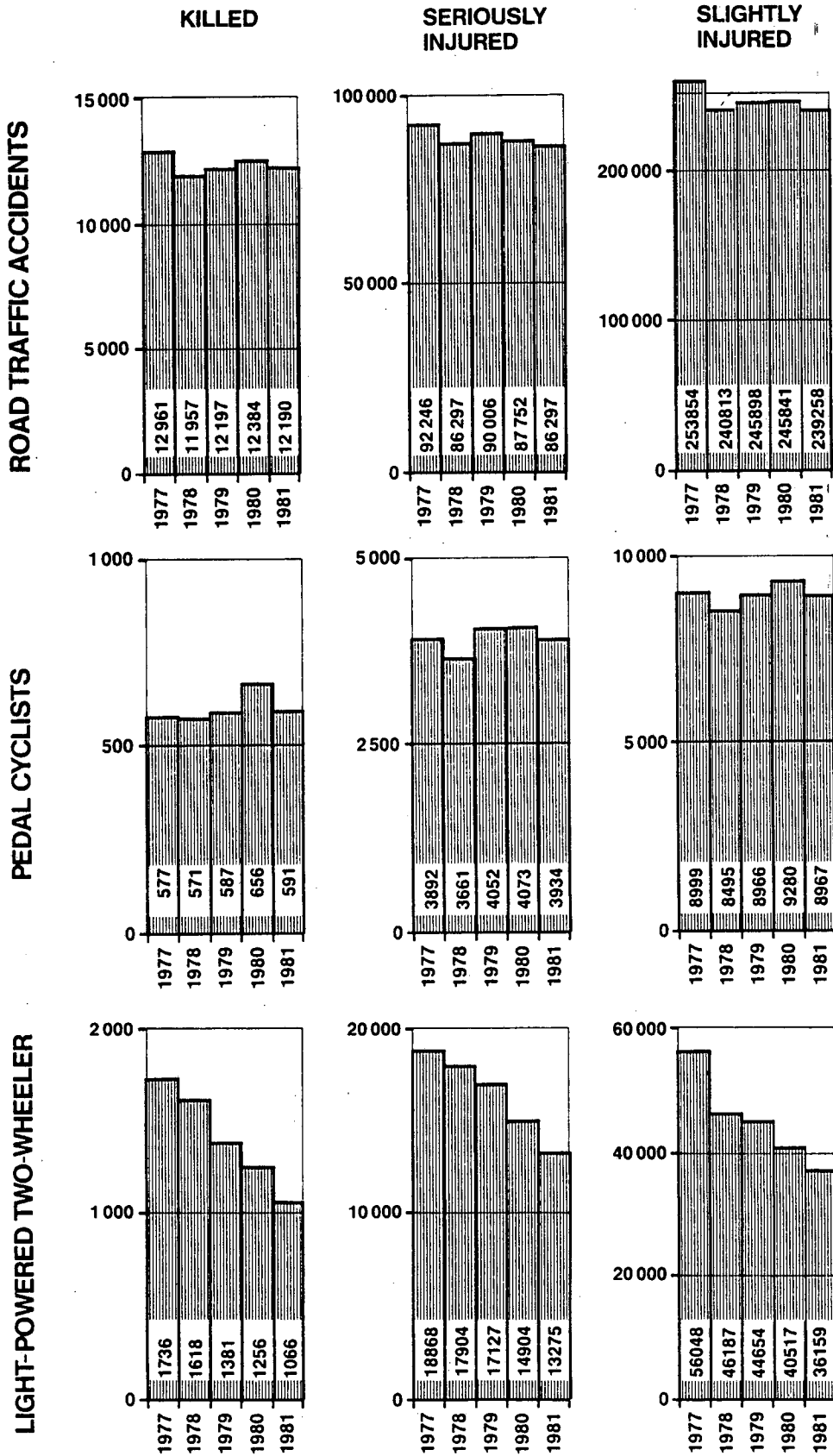
FEDERAL REPUBLIC OF GERMANY

	KILLED	SERIOUSLY INJURED	SLIGHTLY INJURED

ROAD TRAFFIC ACCIDENTS

KILLED
- 1977: 14978
- 1978: 14662
- 1979: 13222
- 1980: 13041
- 1981: 11674

SERIOUSLY INJURED
- 1977: 153735
- 1978: 153310
- 1979: 146526
- 1980: 148952
- 1981: 139402

SLIGHTLY INJURED
- 1977: 354407
- 1978: 355334
- 1979: 339915
- 1980: 351511
- 1981: 336542

PEDAL CYCLISTS

KILLED
- 1977: 1360
- 1978: 1349
- 1979: 1174
- 1980: 1142
- 1981: 1069

SERIOUSLY INJURED
- 1977: 15440
- 1978: 15424
- 1979: 15009
- 1980: 15204
- 1981: 15706

SLIGHTLY INJURED
- 1977: 32267
- 1978: 31165
- 1979: 32698
- 1980: 35232
- 1981: 37523

LIGHT-POWERED TWO-WHEELER

KILLED
- 1977: 880
- 1978: 851
- 1979: 799
- 1980: 765
- 1981: 599

SERIOUSLY INJURED
- 1977: 14409
- 1978: 15708
- 1979: 16430
- 1980: 16415
- 1981: 13592

SLIGHTLY INJURED
- 1977: 28764
- 1978: 31643
- 1979: 33504
- 1980: 34569
- 1981: 28653

Figure 1

FRANCE

	KILLED	SERIOUSLY INJURED	SLIGHTLY INJURED

ROAD TRAFFIC ACCIDENTS

KILLED (scale 0–15 000): 1977: 12 961 | 1978: 11 957 | 1979: 12 197 | 1980: 12 384 | 1981: 12 190

SERIOUSLY INJURED (scale 0–100 000): 1977: 92 246 | 1978: 86 297 | 1979: 90 006 | 1980: 87 752 | 1981: 86 297

SLIGHTLY INJURED (scale 0–200 000): 1977: 253 854 | 1978: 240 813 | 1979: 245 898 | 1980: 245 841 | 1981: 239 258

PEDAL CYCLISTS

KILLED (scale 0–1000): 1977: 577 | 1978: 571 | 1979: 587 | 1980: 656 | 1981: 591

SERIOUSLY INJURED (scale 0–5000): 1977: 3892 | 1978: 3661 | 1979: 4052 | 1980: 4073 | 1981: 3934

SLIGHTLY INJURED (scale 0–10 000): 1977: 8999 | 1978: 8495 | 1979: 8966 | 1980: 9280 | 1981: 8967

LIGHT-POWERED TWO-WHEELER

KILLED (scale 0–2000): 1977: 1736 | 1978: 1618 | 1979: 1381 | 1980: 1256 | 1981: 1066

SERIOUSLY INJURED (scale 0–20 000): 1977: 18868 | 1978: 17904 | 1979: 17127 | 1980: 14904 | 1981: 13275

SLIGHTLY INJURED (scale 0–60 000): 1977: 56048 | 1978: 46187 | 1979: 44654 | 1980: 40517 | 1981: 36159

Figure 2

GREAT BRITAIN

	KILLED	SERIOUSLY INJURED	SLIGHTLY INJURED

ROAD TRAFFIC ACCIDENTS

KILLED (scale 0–10 000):
- 1977: 6614
- 1978: 6831
- 1979: 6352
- 1980: 6010
- 1981: 5846

SERIOUSLY INJURED (scale 0–100 000):
- 1977: 81681
- 1978: 82518
- 1979: 80544
- 1980: 79390
- 1981: 78259

SLIGHTLY INJURED (scale 0–300 000):
- 1977: 259766
- 1978: 260446
- 1979: 247617
- 1980: 243200
- 1981: 240735

PEDAL CYCLISTS

KILLED (scale 0–400):
- 1977: 301
- 1978: 316
- 1979: 320
- 1980: 302
- 1981: 310

SERIOUSLY INJURED (scale 0–6 000):
- 1977: 4723
- 1978: 4748
- 1979: 4920
- 1980: 5234
- 1981: 5194

SLIGHTLY INJURED (scale 0–20 000):
- 1977: 18429
- 1978: 17453
- 1979: 18405
- 1980: 19252
- 1981: 19802

LIGHT-POWERED TWO-WHEELER

KILLED (scale 0–150):
- 1977: 112
- 1978: 94
- 1979: 73
- 1980: 74
- 1981: 81

SERIOUSLY INJURED (scale 0–5 000):
- 1977: 3661
- 1978: 3311
- 1979: 2882
- 1980: 2900
- 1981: 2873

SLIGHTLY INJURED (scale 0–12 000):
- 1977: 10752
- 1978: 9120
- 1979: 7881
- 1980: 7744
- 1981: 7597

Figure 3

ITALY

Figure 4

THE NETHERLANDS

	KILLED	SERIOUSLY INJURED	SLIGHTLY INJURED

ROAD TRAFFIC ACCIDENTS

KILLED

1977	1978	1979	1980	1981
2583	2294	1976	1997	1807

SERIOUSLY INJURED

1977	1978	1979	1980	1981
22481	21505	18987	18622	17560

SLIGHTLY INJURED

1977	1978	1979	1980	1981
41714	40626	37637	38005	35945

PEDAL CYCLISTS

1977	1978	1979	1980	1981
500	460	393	426	356

1977	1978	1979	1980	1981
4236	4057	3853	4261	4123

1977	1978	1979	1980	1981
7761	7748	7511	8543	8539

LIGHT-POWERED TWO-WHEELER

1977	1978	1979	1980	1981
275	253	182	191	158

1977	1978	1979	1980	1981
5661	5041	4170	4051	3693

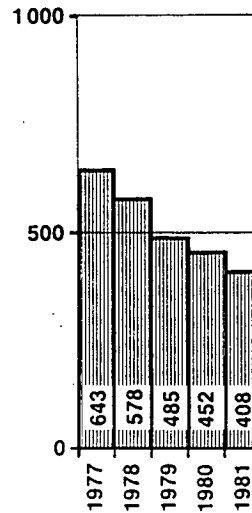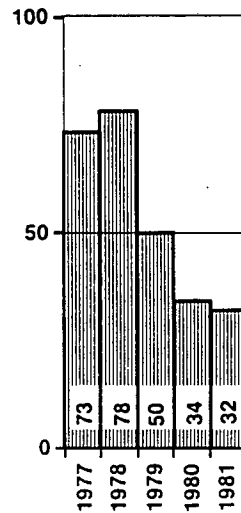| 1977	1978	1979	1980	1981
12707	11578	10162	10001	8846

Figure 5

SWEDEN

Figure 6

1 9 8 1	PERCENTAGE OF KILLED PEDAL CYCLISTS IN TRAFFIC	PERCENTAGE OF KILLED USERS OF LIGHT -POWERED TWO-WHEELER IN TRAFFIC	T O T A L
FEDERAL REPUBLIC OF GERMANY	9,2	5,1	14,3
FRANCE	4,8	8,7	13,5
GREAT BRITAIN	5,3	1,4	6,7
ITALY	7,6	10,6	18,2
THE NETHERLANDS	19,7	8,7	28,4
SWEDEN	9,7	4,1	13,8

Table 8:   Percentage of pedal cyclists and users of light-
            powered two-wheelers killed in road traffic

1 9 8 1	NUMBER OF KILLED/100 000 VEHICLES	
	BICYCLISTS	LIGHT-POWERED TWO-WHEELERS
FEDERAL REPUBLIC OF GERMANY	2,8	31,5
FRANCE	3,1	21,8
ITALY	3,5	25,2
THE NETHERLANDS	3,4	22,6
SWEDEN	1,3	16,0
GREAT BRITAIN	2,4	20,3

Table 9:   Number of killed pedal cyclists and users of light-
            powered vehicles per 100.000 vehicles

FEDERAL REPUBLIC OF GERMANY (1981)

AGE GROUPS		0-5	6-9	10-14	15-17	18-20	21-24	25-34	35-44	45-54	55-64	≥ 65	UKN	TOTAL
PEDAL CYCLISTS	KILLED	10 (2)	69 (3)	137 (3)	54 (-)	21 (-)	16 (-)	43 (-)	67 (-)	118 (-)	118 (-)	416 (-)	- (-)	1061 8
	SEVERELY INJURED	308 (57)	1710 (28)	3908 (42)	1708 (17)	722 (3)	573 (2)	906 (2)	1231 (1)	1381 (-)	1247 (-)	1990 (-)	28 (-)	15554 (152)
	SLIGHTLY INJURED	724 (327)	3206 (103)	9788 (93)	4828 (39)	2223 (15)	1845 (8)	3162 (5)	3593 (2)	3177 (2)	2176 (-)	2709 (-)	92 (-)	36929 (594)
LIGHT-POWERED TWO-WHEELERS	KILLED	- (-)	- (-)	14 (11)	221 (21)	67 (6)	21 (3)	31 (-)	47 (-)	53 (-)	41 (-)	104 (1)	- (-)	557 (42)
	SEVERELY INJURED	4 (4)	10 (9)	259 (146)	7289 (633)	1838 (135)	592 (26)	789 (25)	869 (10)	906 (13)	498 (7)	531 (8)	8 (-)	13592 (1016)
	SLIGHTLY INJURED	22 (22)	22 (21)	341 (229)	16119 (1449)	4040 (375)	1338 (64)	1737 (51)	1861 (35)	1605 (17)	785 (11)	726 (3)	57 (-)	28653 (2277)

FRANCE (1980)

AGE GROUPS		0-4	5-9	10-13	14-15	16-17	18-19	20-24	25-34	35-44	45-54	55-64	≥ 65	TOTAL
PEDAL CYCLISTS	KILLED	2	46	85	30	22	13	29	68	66	74	66	149	656
	SEVERELY INJURED	14	424	773	395	252	136	186	371	325	370	322	467	4073
	SLIGHTLY INJURED	26	622	1718	1049	840	463	658	935	794	835	645	720	9360
LIGHT-POWERED TWO-WHEELERS	KILLED	0	5	10	93	186	114	108	129	95	180	136	191	1256
	SEVERELY INJURED	4	22	171	2036	3662	1966	1531	1457	1014	1275	940	761	14905
	SLIGHTLY INJURED	31	59	420	5472	10910	5898	4765	4403	2755	2855	1690	1116	40513

GREAT BRITAIN (1981)

AGE GROUPS		0-4	5-9	10-14	15	16	17-19	20-29	30-39	40-49	50-59	60-69	≥ 70	TOTAL
PEDAL CYCLISTS	KILLED	5	13	66	18	15	29	19	17	18	32	23	53	310
	SEVERELY INJURED	19	547	1444	343	285	491	651	378	292	327	234	168	5179
	SLIGHTLY INJURED	131	2216	7011	1775	1614	2577	3527	1890	1377	1302	908	600	24928
LIGHT-POWERED TWO-WHEELERS	KILLED	0	0	1	2	29	14	9	3	7	4	7	5	81
	SEVERELY INJURED	0	0	26	24	1139	679	316	177	191	184	94	37	2867
	SLIGHTLY INJURED	0	1	31	25	2987	1885	968	521	456	446	168	67	7555

Table 10 - 12: Killed and injured pedal cyclists and users of
light-powered two-wheelers by age groups
(FRG, F, GB); passenger casualties in brackets

ITALY (1981)

	AGE GROUPS	- 5	6-9	10-14	15-17	18-20	21-24	25-29	30-44	45-54	55-59	60-64	≥ 65	TOTAL
PEDAL CYCLISTS	KILLED	- (1)	20 (-)	48 (3)	18 (-)	6 (-)	8 (-)	12 (-)	33 (-)	65 (1)	43 (-)	59 (/)	275 (-)	608 (5)
PEDAL CYCLISTS	INJURED	40 (30)	368 (27)	1378 (38)	623 (39)	311 (7)	261 (4)	228 (3)	929 (5)	874 (2)	572 (1)	1797 (3)	154 (4)	8087 (206)
LIGHT-POWERED TWO-WHEELERS	KILLED	- 3	- 4	48 8	181 21	49 6	25 3	13 -	70 2	97 2	68 -	47 -	183 2	800 57
LIGHT-POWERED TWO-WHEELERS	INJURED	1 (65)	- (93)	2452 (726)	10870 (1726)	4733 (625)	2078 (213)	1282 (75)	3028 (95)	2321 (39)	1080 (16)	780 (11)	1760 (15)	30889 (3944)

THE NETHERLANDS (1981)

	AGE GROUPS	0-4	5-9	10-14	15-19	20-24	25-34	35-44	45-54	55-64	65-69	70-74	≥ 75	TOTAL
PEDAL CYCLISTS	KILLED	1 (1)	18 (3)	52 (1)	28 (-)	17 (1)	21 (1)	21 (-)	14 (-)	39 (1)	34 (-)	39 (1)	61 (2)	345 (11)
PEDAL CYCLISTS	SEVERELY INJURED	18 (20)	323 (21)	830 (16)	638 (15)	266 (6)	325 (5)	279 (3)	287 (2)	364 (2)	209 (-)	227 (-)	260 (-)	4033 (90)
PEDAL CYCLISTS	SLIGHTLY INJURED	22 (58)	431 (64)	1686 (52)	1595 (69)	782 (14)	981 (12)	693 (4)	607 (3)	631 (2)	260 (-)	258 (-)	267 (1)	8252 (287)
LIGHT-POWERED TWO-WHEELERS	KILLED	- (-)	- (-)	2 (1)	89 (6)	6 (-)	7 (-)	1 (-)	8 (-)	15 (1)	7 (1)	4 (1)	9 (-)	148 (10)
LIGHT-POWERED TWO-WHEELERS	SEVERELY INJURED	- (-)	- (8)	48 (39)	2398 (203)	280 (22)	176 (10)	115 (2)	129 (7)	110 (7)	56 (7)	30 (1)	36 (2)	3381 (312)
LIGHT-POWERED TWO-WHEELERS	SLIGHTLY INJURED	1 (2)	- (10)	44 (122)	5750 (594)	770 (69)	413 (32)	300 (16)	253 (23)	212 (20)	70 (6)	44 (2)	33 (1)	7914 (932)

SWEDEN (1981)

	AGE GROUPS	0-2	3-6	7-14	15-17	18-19	20-24	25-34	35-44	45-54	55-64	≥ 65	UKN	TOTAL
PEDAL CYCLISTS	KILLED	-	-	5	3	2	3	1	5	6	7	44	-	76
PEDAL CYCLISTS	SEVERELY INJURED	-	19	147	68	26	49	80	85	84	107	147	-	812
PEDAL CYCLISTS	SLIGHTLY INJURED	1	24	288	150	72	121	223	166	146	147	167	6	1511
LIGHT-POWERED TWO-WHEELERS	KILLED	-	-	5	13	2	1	-	1	2	-	-	-	32
LIGHT-POWERED TWO-WHEELERS	SEVERELY INJURED	-	-	46	254	11	9	6	11	17	17	-	-	408
LIGHT-POWERED TWO-WHEELERS	SLIGHTLY INJURED	-	-	48	441	18	12	18	14	17	30	3	-	648

Table 13 - 15: Killed and injured pedal cyclists and users of light-powered two-wheelers by age groups (I, NL, S); passenger casualties in brackets

FEDERAL REPUBLIC OF GERMANY (1981)

ACE GROUPS		0-5	6-9	10-14	15-17	18-20	21-24	25-34	35-44	45-54	55-64	≥65		TOTAL
PEDAL CYCLISTS	KILLED/ 100 000	0.283	2.76	2.74	1.7	0.695	0.435	0.52	0.73	1.55	2.00	4.36		1.72
	SEVERELY/ 100 000	8.73	68.4	78.16	53.71	23.91	15.57	10.95	13.41	18.19	21.10	20.84		25.25
	SLIGHTLY/ 100 000	20.51	128.24	195.76	151.82	73.61	50.13	382.3	39.14	41.86	36.82	28.37		59.95
LIGHT-POWERED TWO-WHEELERS	KILLED/ 100 000	-	-	0.28	6.95	2.22	0.57	0.375	0.512	0.698	0.694	1.09		0.904
	SEVERELY/ INJURED	0.113	0.4	5.18	229.21	60.86	16.09	9.54	9.47	11.94	8.43	5.56		22.06
	SLIGHTLY/ 100 000	0.623	0.88	6.82	506.89	133.7	36.36	21.00	20.27	21.15	13.28	7.60		46.51

FRANCE (1980)

ACE GROUPS		0-4	5-9	10-13	14-15	16-17	18-19	20-24	25-34	35-44	45-54	55-64	≥65	TOTAL
PEDAL CYCLISTS	KILLED/ 100 000	0.1	1.1	2.6	1.9	1.3	0.8	0.7	0.8	1.1	1.2	1.3	2.0	1.2
	SEVERELY/ 100 000	0.4	10.4	23.3	24.6	14.5	8.0	4.4	4.3	5.4	5.8	6.5	6.2	7.6
	SLIGHTLY/ 100 000	0.7	15.3	51.8	65.2	48.3	27.3	15.6	10.9	13.2	13.0	13.1	9.6	17.4
LIGHT-POWERED TWO-WHEELERS	KILLED/ 100 000	-	0.1	0.3	5.8	10.7	6.7	2.6	1.5	1.6	2.8	2.8	2.6	2.3
	SEVERELY/ 100 000	0.1	0.5	5.2	126.6	210.6	115.9	36.3	17.0	16.8	19.9	19.1	10.2	27.7
	SLIGHTLY/ 100 000	0.8	1.5	12.7	340.3	627.4	347.8	113.0	51.3	45.7	44.6	34.3	14.9	75.2

GREAT BRITAIN (1981)

AGE GROUPS		0-4	5-9	10-14	15	16	17-19	20-29	30-39	40-49	50-59	60-69	≥70	TOTAL
PEDAL CYCLISTS	KILLED/ 100 000	0.2	0.3	1.6	2.0	1.6	1.1	0.3	0.2	0.3	0.5	0.4	1.0	0.6
	SEVERELY/ 100 000	0.6	14.4	33.3	37.4	31.1	18.6	8.4	5.1	4.8	5.1	4.3	3.1	9.5
	SLIGHTLY/ 100 000	4.0	58.5	161.5	193.8	176.4	97.6	45.7	25.7	22.4	20.3	16.5	11.1	45.8
LIGHT-POWERED TWO-WHEELERS	KILLED/ 100 000	0	0	<0.1	0.2	3.2	0.5	0.1	<0.1	0.1	0.1	0.1	0.1	0.1
	SEVERELY/ 100 000	0	0	0.6	2.6	124.5	25.7	4.1	2.4	3.1	2.9	1.7	0.7	5.3
	SLIGHTLY/ 100 000	0	<0.1	0.7	2.7	326.4	71.4	12.5	7.1	7.4	7.0	3.0	1.2	13.9

Table 16 - 18: Killed and injured per 100.000 inhabitants of
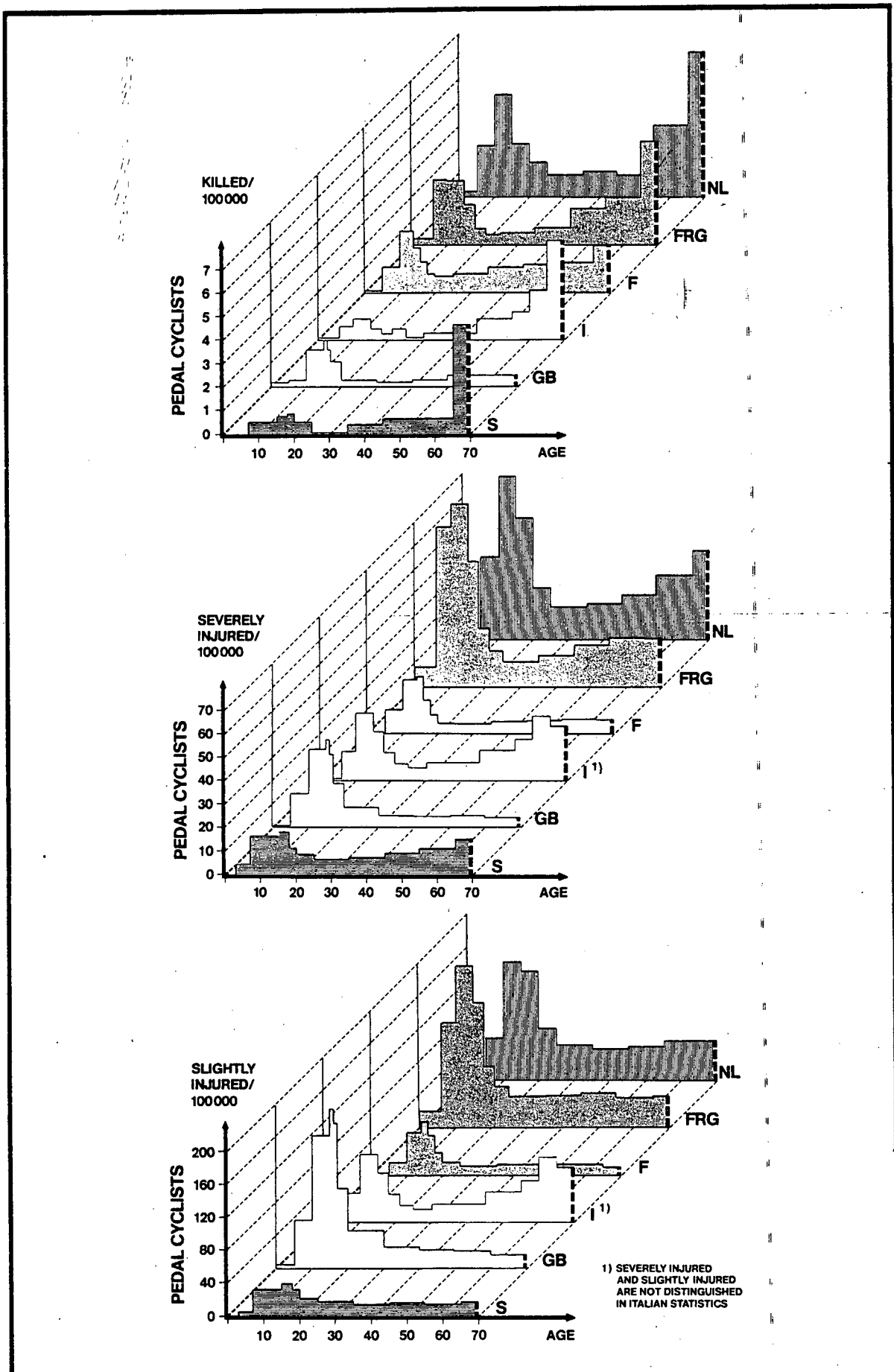age groups;pedal cyclists and users of light-
powered two-wheelers (FRG, F, GB)

ITALY (1980)

	AGE GROUPS	0-5	6-9	10-14	15-17	18-20	21-24	25-29	30-44	45-54	55-59	60-64	≥65	TOTAL
PEDAL CYCLISTS	KILLED/ 100 000	0.1	0.6	0.9	0.5	0.3	0.5	0.1	0.3	0.9	1.2	2.1	4.2	1.1
	INJURED/ 100 000	1.2	13.1	29.2	21.2	12.3	7.3	5.8	7.9	13.1	18.1	28.1	23.2	14.3
LIGHT-POWERED TWO-WHEELERS	KILLED/ 100 000	0.05	0.1	1.1	5.4	2.8	0.9	0.4	0.6	1.4	2.0	2.6	2.7	1.5
	INJURED/ 100 000	0.09	0.1	49.1	374.4	175.7	57.1	32.3	27.6	32.7	35.1	32.7	22.0	52.8

THE NETHERLANDS (1981)

	AGE GROUPS	0-4	3-9	10-14	15-19	20-24	25-34	35-44	45-54	55-64	65-69	70-74	≥75	TOTAL
PEDAL CYCLISTS	KILLED/ 100 000	0.23	2.16	4.36	2.23	1.47	0.94	1.09	0.93	3.03	6.22	8.87	9.40	2.49
	SEVERELY/ 100 000	4.27	35.41	69.66	51.92	22.13	14.03	15.28	19.18	27.60	38.23	50.31	38.79	28.86
	SLIGHTLY/ 100 000	8.99	50.95	143.12	132.3	62.67	42.25	37.70	40.46	47.69	47.56	57.18	39.98	59.76
LIGHT-POWERED TWO-WHEELERS	KILLED/ 100 000	-	-	0.25	7.55	0.49	0.30	0.12	0.53	1.20	1.46	1.11	1.34	1.11
	SEVERELY/ 100 000	-	0.82	7.16	206.8	24.58	7.92	6.38	9.00	8.72	11.52	6.78	5.67	25.85
	SLIGHTLY/ 100 000	0.33	10.29	13.66	504.5	68.29	18.94	17.03	17.30	17.26	13.90	10.19	5.06	61.91

SWEDEN (1981)

	AGE GROUPS	0-2	3-6	7-14	15-17	18-19	20-24	25-34	35-44	45-54	55-64	≥65		TOTAL
PEDAL CYCLISTS	KILLED/ 100 000	-	-	0.55	0.81	0.91	0.55	0.08	0.43	0.68	0.72	4.69		0.91
	SEVERELY/ 100 000	-	4.81	16.30	18.38	11.60	8.94	6.59	7.42	9.52	11.03	15.67		9.76
	SLIGHTLY/ 100 000	0.35	6.08	31.93	40.54	32.14	22.08	18.37	14.49	16.55	15.15	17.80		18.15
LIGHT-POWERED TWO-WHEELERS	KILLED/ 100 000	-	-	0.55	3.51	0.89	0.18	-	0.08	0.22	-	-		0.32
	SEVERELY/ 100 000	-	-	5.10	68.65	4.91	1.64	0.49	0.96	1.93	1.75	-		4.90
	SLIGHTLY/ 100 000	-	-	5.32	119.2	8.04	2.19	1.48	1.22	1.93	3.09	0.32		7.79

Table 19 - 21: Killed and injured per 100.000 inhabitants of age groups; pedal cyclists and users of light-powered two-wheelers (I, NL, S)

Fig. 7: Killed and injured pedal cyclists per 100.000 inhabitants/age group (dotted lines for age 70 stands for age group ≥ 65)
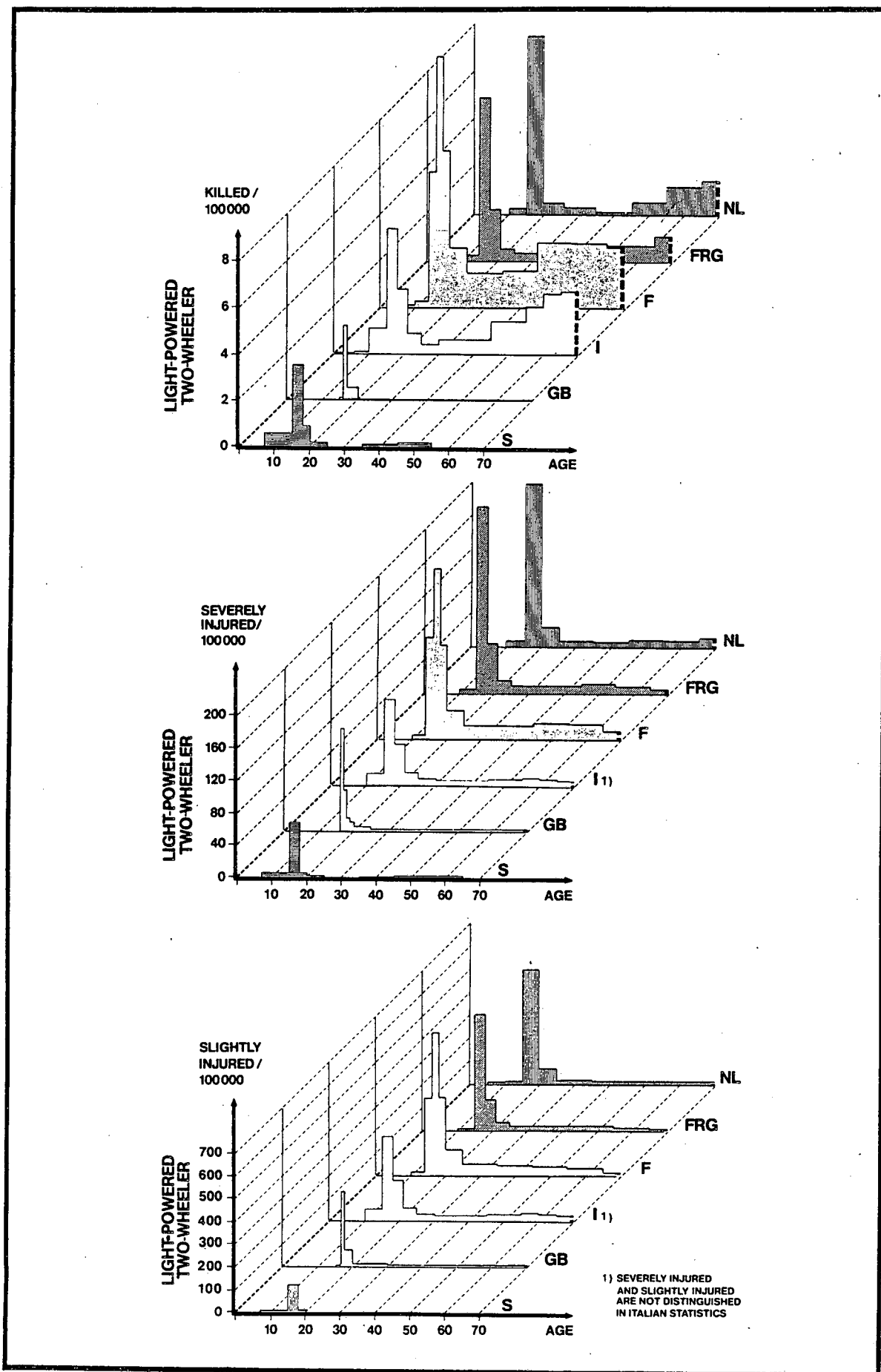
Fig. 8: Killed an injured users of light-powered two-wheelers per 100.000 inhabitants/age (dotted lines for age 70 stands for age group ≥ 65)

	TWO WHEELED MOTOR VEHICLES			PEDAL CYCLE		
	SLIGHTLY INJURED P.C.	SERIOUSLY INJURED P.C.	TOTAL SAMPLE SIZE 1)	SLIGHTLY INJURED P.C.	SERIOUSLY INJURED P.C.	TOTAL SAMPLE SIZE 1)
PEDDER/12_7	58	29	540	91	83	459
BULL /13_7	37	28	145	81	65	145
HOBBS /8_7	45	27	754	71	59	488

1) FATALITIES HAVE BEEN EXCLUDED

Table 22: Casualties in non-reported accidents

	OAIS	1	2	3	4	5	6
ALL ROAD USERS	ACCORDING TO WILLEKE	3	16	42	59	53	5
USERS OF TWO-WHEELERS Σ = 123 CASES	ACCORDING TO OTTE (WITHOUT COMPLICATIONS)	-	13	31	32	-	-
	ACCORDING TO OTTE (WITH COMPLICATIONS)	-	33	80	58	-	6
	ACCORDING TO OTTE (SUM TOTAL OF DAYS OF IN-PATIENT TREATMENT)	-	35	83	87	-	-
USERS OF TWO-WHEELERS Σ = 282 CASES	ACCORDING TO OTTE ON AVERAGE	3	16	32	39	29	1

Table 23: Length of hospitalization indays related to OAIS

TIME IN HOSPITAL	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6
UP TO 2 WEEKS	29	36	9	-	1	2
UP TO 2 MONTHS	4	55	60	10	9	-
UP TO 1 YEAR	1	5	37	10	5	-
OVER 1 YEAR	-	-	-	2	-	-

Table 24: Length of hospitalization of injured motorcyclists
         (base: 275 cases) [16]

	USERS OF BICYCLES		MOTORIZED TWO-WHEELERS	
	WITHOUT EFFECTS ON EARNING CAPACITY	WITH EFFECTS ON EARNING CAPACITY	WITHOUT	WITH
LENGTH OF IN-PATIENT TREATMENT *	11	34	11	43
COSTS /̄DM_7	1800	5900	1900	7800

Table 25: Time and cost factors involved in hospitalization
         with and without effects on earning capacity [17]

* [Days]
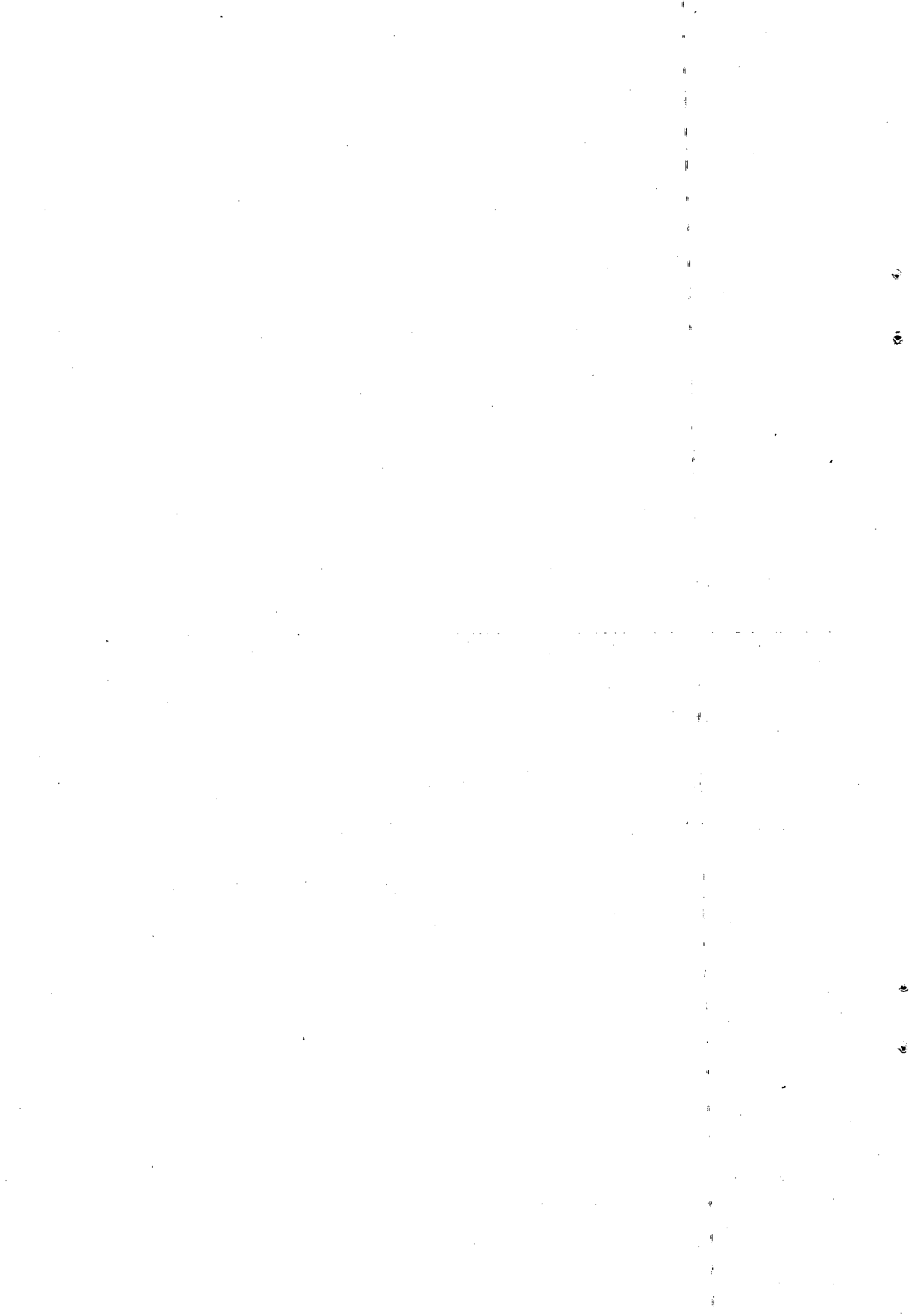
EEVC WORKING GROUP 8

Bicycle and moped injury accidents.

Chapter II

"Detailed description of bicycle and moped accidents".

2.   DETAILED DESCRIPTION OF BICYCLE AND MOPED COLLISIONS

2.1   INTRODUCTION

This chapter deals with some more detailed data of bicycle and moped accidents, such as collision partners, collision types, resulting injuries and speed at impact.

This data is in general not available from national statistics. Therefore most of the information is obtained through special accident studies.

Nevertheless, as is the case in the Netherlands, useful and more detailed information is gathered on a national base by the police and computerised at the Road Accident Record Office.(VOR)

To give direction to the injury prevention research of bicyclists and moped riders, some priorities in the distributions of accident types and collision types are made in the Netherlands (Huijbers [9]).A lot of criteria may be used for this but for some practical reasons magnitude and severity were used.

For magnitude the number of killed and severely injured road users are used.

Severity of road accidents is a very complex term. A lot of dimensions are involved,such as damage, injury, cost of delays etc.

In injury prevention research the injury dimension of accident severity is used. But injury can also be distinguished in place, nature and severity.

Injury severity is complex too and can be defined by threat to life, disability etc. Scaling with the Abbreviated Injury Scale (AIS) seems to be the most appropriate for this moment, although there is some concern about the influence of long term effects on the scaling; (EEVC [4]).

For the Dutch accident situation the number of killed or severily injured road users for the accident and collision types were only available.

Therefore as a criterion for injury severity 'lethality' was used.

(Lethality = 100 x number of killed / (number of killed + number of severely injured)).

There is a general problem concerning the accident data of different countries with regard to motorized two-wheelers. The problem is that in most cases this group cannot be divided into motorcycles and mopeds, the last one may even contain several types.
This is needed for a proper comparison of the data, since the distribution of these two groups differ considerably for the different countries.

Another more general problem in comparing the results of the different accident studies is caused by sample differences, e.g. the large differences in underreporting figures for the different countries as shown in chapter 1; in the Netherlands reporting of killed and severely injured road users is complete enough to use this information to indicate priorities in injury prevention research.

The chapter starts with a description of collision opponents of the two-wheeler riders,with respect to kind of opponent (accident type) and with respect to collision direction (collision type), with some information about the manoeuvre of the collision opponents just before the accident. Thirdly the resulting injuries (injury pattern) will be described. A review of the impact speed, as mentioned in a number of accident studies concludes this chapter.
Information about braking (of the collision partners) before, during or after the collision, as was described in the report of EEVC Working Group 7 about Pedestrian Injury accidents, was not found in literature.

2.2   ACCIDENT TYPE

2.2.1   INTRODUCTION

The particular combination of a two-wheeler and its collision opponent is called accident type (for instance bicycle-car; moped-car; moped-heavy goods vehicle).
The distribution of collision opponents will depend on the severity class of injuries considered, therefore a large variety of distributions in the various studies may be noticed.

2.2.2 GREAT BRITAIN

The distribution of collision opponents (motor vehicles only)
for bicyclists according to Hardy [7] is:

car and taxi	75%
light goods vehicle	9%
heavy goods vehicle	3%
medium goods vehicle	1.5%
others	11.5%

The group consists of the accidents in 1974, reported by the
police.

There is no information about the collision partners of mopeds.

More recent information (1980) from national statistics [16]
about accident types of two-wheeler casualties, excluding
accidents with three or more vehicles, reported to the police is
given in Table 1:

The car is the most frequent collision partner in bicycle and
two-wheeled motor vehicle accidents (73.1%; 60.3%) followed
by the light goods vehicle and two-wheeled motor vehicle for the
bicyclist (6.1%; 6.1%) and the light goods vehicle for the two-
wheeled motor vehicle rider (4.8%).

The share of single vehicle accidents (no pedestrian involved)
for two-wheeled motor vehicle users is much higher (23.7%) than
for the pedal cycle users (7.7%). In fact these shares will
probably be much larger due to the already mentioned under-
reporting.

2.2.3 GERMANY

A distribution of collision partners in Germany for 1982 is given
in Table 2.

The group consists of killed road users in a single vehicle acci-
dent or in collision with a car or a heavy goods vehicle.

The table shows that in collisions with another road user the
car is in most cases the collision partner (55% for bicyclists
and 57% for motorized two-wheeler riders).

Single vehicle accidents occur more often with motorized two-
wheeler riders (13%) than with bicyclists (11%).

2.2.4 THE NETHERLANDS

The Dutch data of the distribution of accident and collision
types based on police information for 1978 and 1979 are avai-
lable seperately or fatal two-wheeler accidents and for acci-
dents in which the two-wheeler riders were taken into hospital
for at least one day.
The data was coded by the "Dienst Verkeersongevallen registra-
tie" (VOR), manipulated by SWOV and reported by Huijbers [9].
These accidents are very well reported as already stated:
almost 100% of the two-wheeler fatalities and 80% of the hospi-
talized casualties are reported by the police (Maas [10].

The bicycle and moped accidents can be divided into the follo-
wing groups.

A - Accidents with a pedestrian or a (parked or moving) vehicle
B - Accidents with no other vehicle or pedestrian involved,
    divided into 1) collision without obstacle (tree, pole, animal,
                                                            etc.)
              2) collision with an obstacle.
C - Multi (>2) vehicle accidents.
    For 1979 the total numbers of killed and severely injured
    bicyclists and moped riders are divided over these groups:

A :

	Killed	Severely injured
Bicyclist	89%	79%
Moped rider	72%	78%

B1 : The shares for bicyclists and moped riders are identical:

Killed	Severely injured
4%	8%

B2 :

	Killed	Severely injured
Bicyclist	1%	3%
Moped rider	17%	7%

C : 5 - 10%

The group defined in A will be considered for the
distribution of collision partners.
The results for 1979 are shown in Table 3 and visua-
lized in fig. 1 and 2.

FATALITIES

The car is the most frequent collision partner for bicyclists
(62%) and moped riders (48%).
The second most frequent collision partner is the heavy goods
vehicle:
23% for bicyclists and 21% for moped riders.

SEVERELY INJURED

For the severely injured the car is also the most frequent
collision partner for bicyclists (69%) and for moped riders (74%).
The second most frequent collision partner is the moped for
bicyclists (10%) and for moped riders themselves (7%), together
with the heavy goods vehicle (7%) for moped riders.
When lethality is used as a severity criterion, the collision
with a tram or train has maximum severity because there are
no registered severely injured patients. But the amount of these
accidents is small.
For bicyclists the collision with a heavy goods vehicle has the
next priority, followed by the collision with a delivery van.
The collision with a car does not seem to be so severe.
For moped riders the collision with a motorcycle (or a scooter)
has the next priority, followed by the heavy goods vehicles and
delivery vans.
The collision with the car does not seem to be relatively so severe
(relatively; fig. 1 and 2).

2.2.5. USA

In Cross [2] a distribution from the USA is given. This group
consists of bicycle casualties.
In 87% the car was the collision opponent and in 9% a pick-up or
van.

2.2.6. SUMMARY

As can be seen in Chapter one underreporting of bicycle and moped
accidents is very high in most of the countries. This is especially
the case for single vehicle two-wheeler accidents and for the less
severe injury accidents.

In all studies mentioned <u>cars</u> are the most frequent collision
opponents, rating from 50 to 90% of all opponents in bicycle
and moped accidents. This is more or less similar to the situation
for pedestrians as mentioned in EEVC [4]. Second are <u>vans</u> and
<u>heavy goods vehicles</u>. In the Netherlands <u>mopeds</u> are the second
most frequent collision partner for the injured bicyclists and
moped riders.
With motorized two-wheelers single vehicle accidents (in collision
with an obstacle) happen relatively often.
If a (single) criterion like lethality may be used, for accident
severity, collision with <u>heavy goods vehicles</u> seem to be
the most severe accident type for bicyclists and the second
severest for moped riders.
The accident between a moped and a <u>motorcycle</u> or <u>scooter</u> seems
to be the most severe for moped riders.
The collision with a car does not seem to be very severe in relation
to the other accident types.

From this it looks quite obvious that the attention of injury
prevention research for bicyclists and moped riders should be
focused on the confrontation with <u>cars</u> magnitude) and <u>heavy</u>
<u>goods vehicles</u> (severity).
The single vehicle motorized two-wheeler accidents happen so often,
that this accident type must be considered too.

2.3.   <u>COLLISION TYPE</u>

2.3.1. <u>INTRODUCTION</u>

A collision type is a particular combination of impact sites of
the two-wheeler and its collision opponent (for instance front
of a two-wheeler against side of a car).
The different collision types with probably result in different impact
places on the body, for some types caused by the car and for others by the two-
wheeler. This may cause different injury patterns.
This paragraph mainly deals with the car-to-bicycle, car-to-moped,
heavy goods vehicle-to-bicycle and heavy goods vehicle-to-moped
accident types. As far as possible, collision type or impacted
sites of two-wheelers and its opponents are given, as specified
in the different accident studies. Comparison of the results of these
different studies is clearly limited due to sampling differences
as mentioned earlier.

2.3.2. GREAT BRITAIN

Whitaker [15] gives a summary of impact sites on motorized
two-wheelers. Frontal impacts occur in 59%, followed by lateral
impacts in 38% of the cases.
More left side than right side impacts were found. No information
is given about the impacted sites of the collision opponent.

BICYCLE - HEAVY GOODS VEHICLES

Riley [17] studies fatal accidents involving heavy goods vehicles:
37% of the bicyclists hit the front of a heavy goods vehicle,
57% the side and only 2% the rear end.
No information about the impacted site of the bicycle.

2.3.3. GERMANY

Otte [12] states that in bicycle-to-car accidents 46% of all
casualties occur with collision type front of car-side of bicyclist,
followed by the collisions type front of car-rear end of bicyclist (20%)
(fig. 3 and 4).
In frontal collision (front of car-front of bicyclist) 17% of the
persons were killed or injured and in side collisions (side of
car-front of bicyclist) 15% of the casualties occurred. The distri-
bution of some collision types causing casualties for motorized
two-wheelers is:
28% in collision type front of car - side of motorized two-wheeler
24% in collision type front of car - front of motorized two-wheeler
21% in collision type side of car - front of motorized two-wheeler.
From this information it seems that the distribution of the collision
types for the motorized two-wheeler-to-car accidents is much more
homogeneous that the distribution of the bicycle-to-car accidents.
The collision type front of car - rear of two-wheeler occurs
relatively often for the bicyclist but not for the motorized two-
wheeler.
The distribution of collision-types for heavy goods vehicles can be
seen in a study of the HUK-Verband, Büro für Kfz-Technik, which
treats the problem of truck-accidents [18].

In almost 80% of all bicycle-accidents the contact area on the
truck was the front or the right side, in nearly equal proportions.
For the light powered two-wheelers the contribution is a little
more homogeneous. (fig. 4a).

2.3.4.   THE NETHERLANDS

For the Dutch accident situation priorities for injury prevention
research within the distribution of collision types (1978/1979) were
based on the criteria magnitude and severity ("lethality"), see
par. 2.1. Huijbers [9]. First of all the collisions were categorised
in some collision types (fig. 5).

BICYCLE-TO-CAR ACCIDENTS (fig.6)

Most of the cyclists were hit in the side by the front of the car
(type F1): 65% of those killed and 60% of the severely injured. The
left side of the bicycle was hit twice as much as the right side.
The other collision types did not occur so much: of these the
types F2 and F3 were most important. The collision with the side
of the car happened most of the time with the front of the bicycle
(type S1): in 10% of the cases with severely injured cyclists.
With lethality as a criterion, collision type F3 (front of car-rear
end of bicycle) was the most severe.

MOPED-TO CAR ACCIDENTS (FIG. 7)

In the case of moped-to-car accidents the collision type F1
(front of car - side of moped) dominated too: 62% of the
killed moped riders. The severely injured moped riders were hit
nearly as often sideways (F1) as frontal (F2) by the front of
the car (39%; 31%),
Frontal collisions with the side of the car happened nearly as
frequently for the killed moped rider (13%) as for the severly
injured. The collision type F3, where the front of the car hit the
rear end of the moped, did not occur so much as for cyclists
(3% killed; 1% severely injured); although this collision type had
the highest "lethality" in analogy with the bicycle-to-car accident.
The opposite rear-end collision (R1) happened for 10% of the
severely injured moped riders. The lethality from this type was
minimal because there were no killed moped riders registered
in this collision type.

BICYCLE-TO-HEAVY GOODS VEHICLE ACCIDENTS (FIG. 8).

The collision front of heavy goods vehicle-to-side of bicycle
(F1) happened most frequently (42% for killed and severely
injured cyclists).

The second most frequent collision type was F2 (front of heavy
goods vehicle-to-front of bicycle) for killed (19%) and S1
(side of heavy goods vehicle-to-front of bicycle) for severely
injured cyclists (18%). The frontal collision with the rear end
of the heavy goods vehicle (R1) happened relatively often with
severely injured cyclists (11%).

The collision types F2, F3, S2 and R2 have nearly the same and
highest lethality.

MOPED-TO-HEAVY GOODS VEHICLE ACCIDENTS (FIG. 9)

The collision type distribution for this accident type is more
or less homogeneous.

Collision type F1 dominated for killed moped riders but the colli-
sions with the front of heavy goods vehicles (F1 and F2) happen
nearly as frequently as the collision with the rear end (R1) for the
severely injured moped riders (28%), followed by the collision
with the side of the heavy goods vehicle (S1).

The collision type side of moped-to-side of heavy goods vehicle
(S2) seems to be the most severe, followed by F1.

2.3.5.   ## USA.

Data from the USA about impact points from car -to- bicycle
crashes in Roland [14] show nearly the same pattern as in the
Netherlands:

	car	bicycle
front	63.2%	25.6%
left side	10.7%	49.6%
right side	23.4%	21.2%
rear	1.9%	3.6%

The sides of the car are struck more frequently than in the
Netherlands. This may be due to differences in injury severity
in the samples. There is no information about collision types.

2.3.6. Manoeuvres:

The majority of accidents involving cyclists and moped riders
in urban areas take place at road junctions (OECD [20]).In Great
Britain accident statistics show that nearly two-thirds of injury
accidents involving a pedal cycle occur at junctions (Downing [21]).
In a study of accidents occurring at intersections the Danish
Council of Road Safety Research [22] found that for urban accidents
involving a bicycle and another vehicle the most frequent manoeuvre
type was where each was traveling on a different road before the collision.
This was also the finding in a British study of national accident statistics.
According to Gauss [18] nearly 45% of the heavy goods vehicle-two-wheeler
accidents happened when one of the vehicles was changing direction.

2.3.7. Summary.

For the determination of the collision types that have to be studied
in the next chapter a distribution of the collision types for the
various countries was made.
This information gives also some indication on which parts of the
motorvehicle have to be taken into consideration in injury
prevention work for bicyclists and moped riders
For the decision what collision types have to be studied, one may
use the number of killed or injured cyclists or moped riders in the
various collision types as a criterion. But the injury severities that
are the result of the various collision types have to be taken into
consideration too. An attempt for this was made in the Netherlands
where "lethality" was used as an approach for injury severity.
There seem to be some differences in the results of the presented
studies. These differences may partly be caused by sample differences,
especially levels of injury severity. Other differences, such as
infrastructure, modal split etc., may also be present, and may
influence the outcome.
There are some similarities between the results of the various
studies. These similarities are in general as follows:
In most bicycle -to- car accidents the bicycle is impacted at
the (left) side by the front of the car. The collision type front
of car -to- rear of bicycle occurs more often in accidents where the
bicyclist was killed than when he was hospitalised.

Collision types involving the side of the car did not occur often in the more severe bicycle accidents.

In moped-car collisions the two major collision types are front car - (left) side moped and front car - front moped, followed by side car - front moped. The front of the moped therefore plays a more important role than the front of the bicycle.

When lethality was taken into consideration the collision type front car - rear bicycle (moped) seems to be the most severe, followed by the most frequent occurring type front car -to- side of bicycle (or moped).

It seems obvious therefore that the attention of injury prevention should be directed both towards the front of the car (as for pedestrian accidents) and to the side, particularly with respect to moped accidents.

Data of heavy goods vehicle accidents with bicyclists and moped riders from the Netherlands suggest that for the bicycle collisions with the front of heavy goods vehicles happen most often. But collisions with the side of heavy goods vehicles are also relatively frequent.

Accidents with mopeds happen nearly as often with the front, the side as with the rear end of heavy goods vehicles.

Therefore it seems obvious that the attention of injury prevention work should be given to all sides of heavy goods vehicles.

2.4.   Injuries.

2.4.1.   Introduction.

Injury is for the injury prevention research the most important output variable in the accident system.

Injury can be described in terms of place, nature and severity.

In literature all these three dimensions are described, mostly separately.

The place of the injury is reported in most of the studies, sometimes in relation to severity. Severity is mostly scored with the Abbreviated Injury Scale (AIS) system. Injury severity is a complex term.

Probability of death but also temporal or permanent impairment will influence severity. The role of these long term consequences in the AIS is under discussion, in particular for the pedestrian injuries (EEVC [4]).

Whether this is also important for bicyclist or moped rider injuries
cannot be answered at this moment, but for the outcome variable
injury severity, the scaling with the AIS seems to be the most
suitable for injury prevention research at this moment.

There is a wide variety of injury distributions in literature.
As stated in EEVC [4] it is hardly possible to compare the results
of accident studies because of some major differences, for instance:
- differences in levels of injury severity in the samples (e.g.
  fatalities only, fatalities + hospitalised)
- differences with respect to accident type (some studies contain all
  accident types, some only collisions with cars, some only specific
  collision types).
What matters are the main tendencies, common for all studies and the dif-
ferences and similarities within separate studies between injuries of
bicyclists and moped riders (motorized two-wheeler.riders.
It seems quite obvious that injury distributions are dependant on
accident type and collision type because of differences in relative
impact speed and impacted body areas.
Therefore, as already stated, comparisons have to be made carefully.

2.4.2. Description of injury patterns.
When all injuries are considered Pedder [13], Whitaker [15], Otte [12]
and Grattan [5] state that the arms and the legs are the most frequently
injured body areas, followed by the head.
Pedder [13] finds for bicyclists more arm injuries than leg injuries
and the opposite for the motorized two-wheeler riders. The other studies
mentioned do not support this finding.

From Huijbers [9] and Nicholl [11] it follows that the head is the
most frequently injured body area.
The data from the first study are available from the "Stichting
Medische Registratie" (SMR), containing information on 95% of all
Dutch hospitalised casualties. The data of the second study are from a
British hospital.

When the more severe injuries (AIS>2) are taken into consideration
in the studies of Pedder, Whitaker, Otte and Grattan, the head is the
body area most frequently injured.

2.5.   Speed at impact.

Speed at impact seems, like it was with the pedestrian -to- car
accident, one of the more important parameters.
It is better to speak of relative impact speed, since not only the
impact speed of the car but also the impact speed of the two-wheeler,
and the direction of impact (collision type), have a big influence on the
relative impact speed.

In this chapter data on impact speed from the different studies are
presented like in the report of Working Group 7 of EEVC [4].
In some studies it is not quite clear what is meant by impact speed.
There were no impact speed data related to specific collision types.
Therefore the results must be looked at with great care.

Some results (fig. 12):
- Otte [12] indicates that at impact, speeds of cars in collisions
  with motorized two-wheelers are in general lower than those in
  collisions with bicyclists.
- There is a wide variety in impact speeds of cars for the various
  studies:
  50th percentile speed varies from 10 km/h to 50 km/h
  90th percentile speed varies from 37 km/h to 72 km/h
  This variety is larger than for pedestrian accidents (EEVC [4]).

- Gauss [18] found that the speeds at impact depend on the collision
  types, but in general the speed at impact of the two-wheeler was
  remarkable higher than the speed of the heavy goods-vehicle.
  Nearly two out of three two-wheelers collided with a speed between
  31 and 60 km/h.

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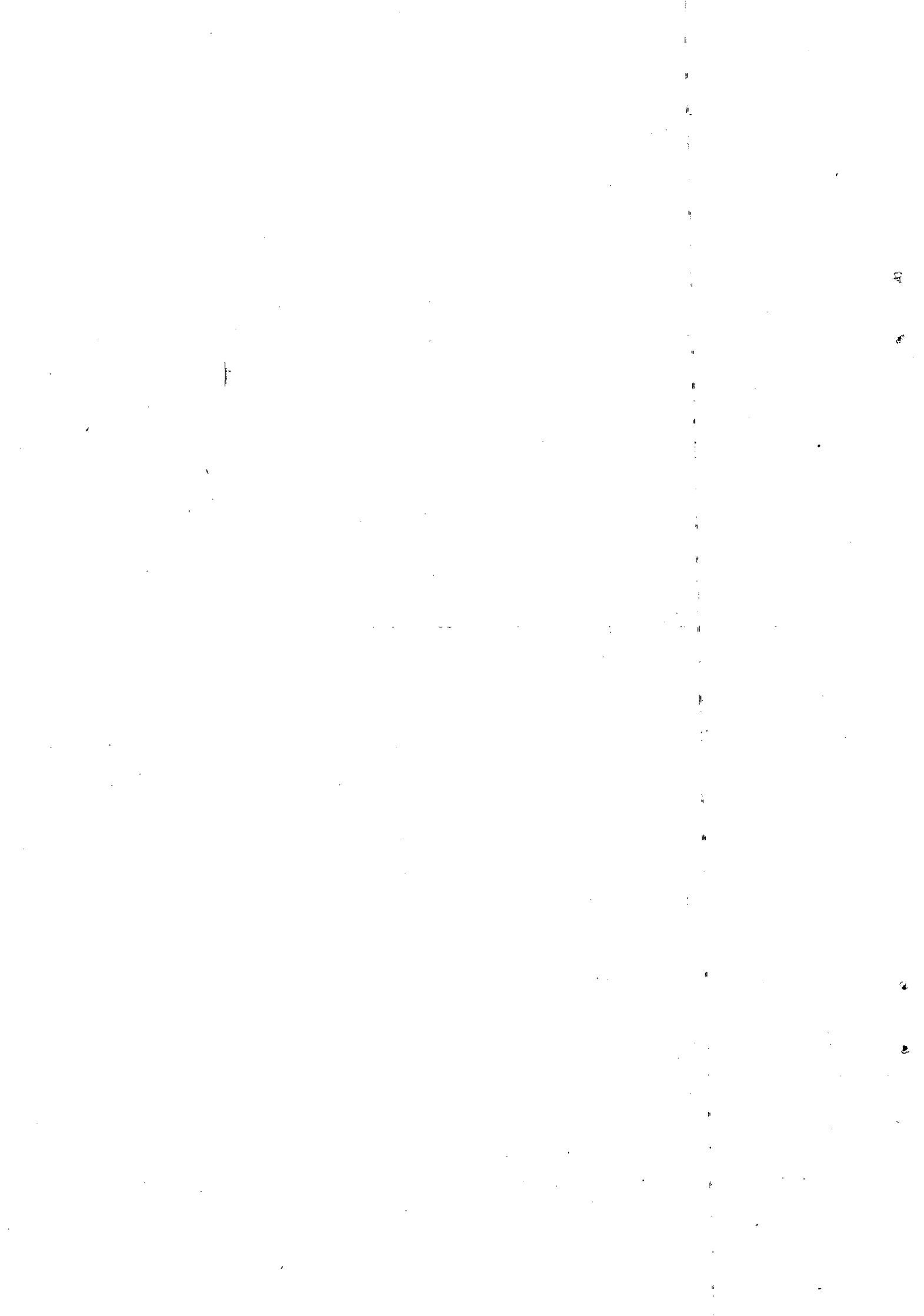
2.7 Figures/tables.

	SINGLE VEHICLE		PEDAL CYCLE	2-WHEELED MOTOR VEHICLE.	CAR	TWO VEHICLE BUS OR COACH	LIGHT GOODS VEHICLE	HEAVY GOODS VEHICLE	TOTAL
	NO PEDE-STRIAN	WITH PEDE-STRIAN							
PEDAL CYCLE USER	1794 (7.7%)	140 (0.6)	229 (1.0)	1411 (6.1)	17013 (73.1)	457 (2.0)	1433 (6.1)	807 (3.5)	23284
TWO WHEELED MOTOR VEHICLE USER	15522 (23.7%)	1950 (3.0)	765 (1.2)	2434 (3.7)	39428 (60.3)	615 (0.9)	3146 (4.8)	1504 (2.3)	65364

* Excludes three or more vehicle accidents and accidents where details are not known.

table 1. Number of two-wheeler casualties (all severeties) reported
to police for different accident types in Great Britain (1980).
Department of Transport [16].

1982	Accidenst with two participants		single vehicle accidents	Total number of killed.
	Car	Vans and HGV's		
BICYCLE	598	127	116	1.085
"Mofa/Moped"	305	57	71	543

Source: BASt

table 2. Number of killed bicyclists and light powered two-wheel riders
for different accident types in Germany (1982).

casualties in collision with	bicyclist			moped rider		
	% killed	% in-patients	"letality"	% killed	% in-patients	"letality"
car	62	69	9,2	48	74	2,6
delivery van	5	4	12,1	8	4	7,3
heavy goods vehicle	23	5	34,2	21	7	11,2
motor/scooter	3	3	9,8	5	1	17,9
train or tram	2	-	100	10	-	100
bicycle	-	6	0,0	-	3	0,0
moped	3	10	3,1	4	7	2,2
other 2 wheelers	-	-	-	-	-	-
pedestrians	-	1	0,0	-	2	7,4
others	2	2	10,1	4	2	-
total	100 %	100 %	-	100 %	100 %	-
N total	349	3.082	-	131	3.169	-

Tab 3 Distribution of accident types resulting in killed and severely injured cyclists and moped riders; Letality of the various accident types (Huijbers[9])
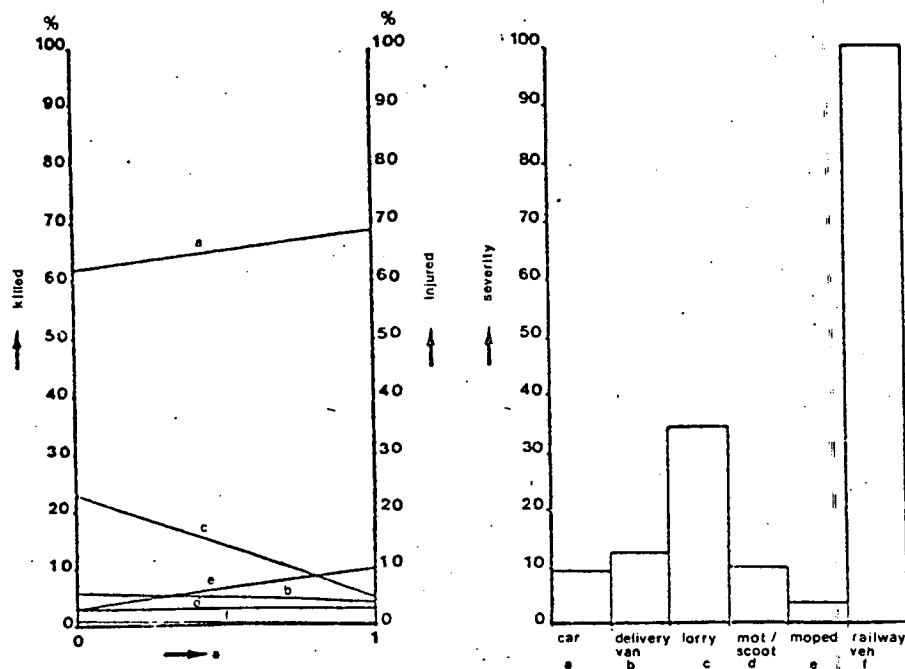
Fig 1 Priorities within the various accident types resulting in killed and severely injured bicyclists. (Huijbers[9])
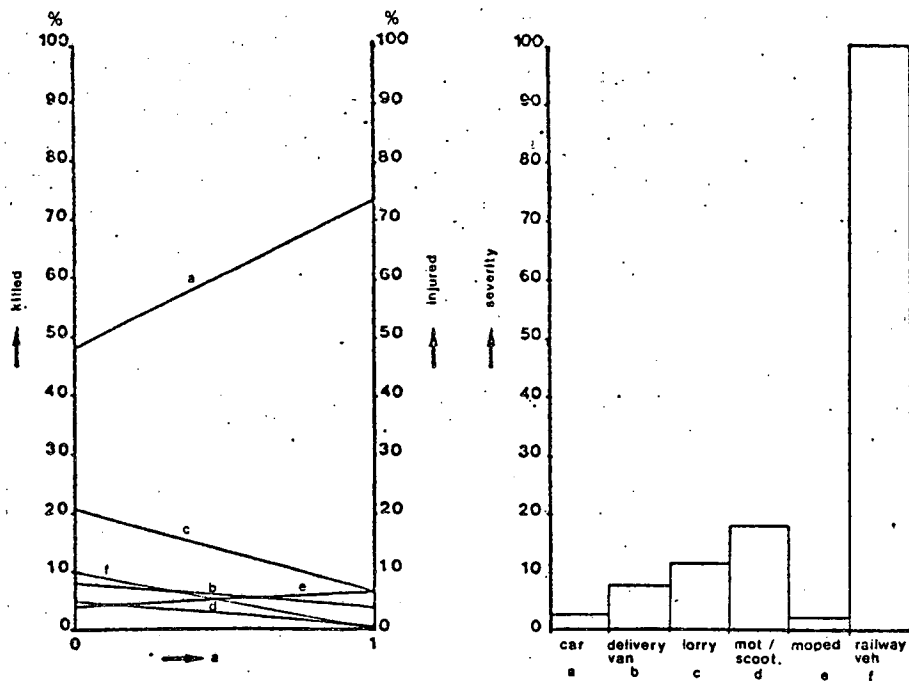
Fig 2 Priorities within the various accident types resulting in killed and
severely injured moped riders. (Huijbers [9])
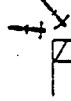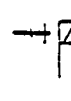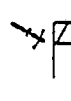
collision type	I	II	III	IV	V	other types
number of accidents	37 (29%)	29 (23%)	22 (17%)	25 (20%)	11 (9%)	3 (2%)
persons involved	43 (28%)	36 (24%)	28 (18%)	32 (21%)	11 (7%)	3 (2%)
VERLETZUNGSSCHWERE GRAD-VERTEILUNG overall AIS [%] Injury severity — 0	0	2,8	7,1	0	9,0	
1	16,7	27,8	17,9	37,5	27,3	
2	23,8	13,9	28,6	31,3	18,2	
3	35,7	25,0	17,9	18,8	18,2	
4	11,9	8,3	1,79	6,2	0	
5	4,8	2,8	0	0	0	
6	7,1	19,4	10,7	6,2	27,3	

Fig. 3. Distribution of two-wheel collision types in motorized crashes. (Otte [12]).
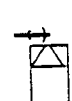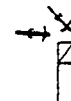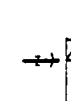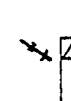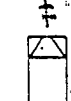
collision type	I	II	III	IV	V	other types
number of accidents	62 (45,6%)	22 (16,2%)	21 (15,4%)		28 (20,6%)	3 (2,2%)
person involved	63 (45,7%)	23 (16,6%)	21 (15,2%)		28 (20,3%)	3 (2,2%)
VERLETZUNGSSCHWERE GRAD-VERTEILUNG overall AIS [%] Injury severity — 0	1,6	4,4	—		—	
1	12,7	13,0	14,3		21,4	
2	34,9	30,4	28,6		42,8	
3	27,0	26,1	19,0		17,9	
4	4,8	4,4	9,5		3,6	
5	12,7	21,7	23,8		3,6	
6	6,3	—	4,8		10,7	

fig. 4. Distribution of two-wheel collision types in bicycle crashes. (Otte [12]).

LIGHT-POWERED TWO-WHEELERS (140 ACCIDENTS)

BICYCLE (168 ACCIDENTS)

TRUCK

27,9%
39,9%
38,1%
27,2%
17,1%
4,2%
10,7%
12,9%

TRAILER

6,4%
5,3%
1,2%
7,1%
0,6%
1,4%
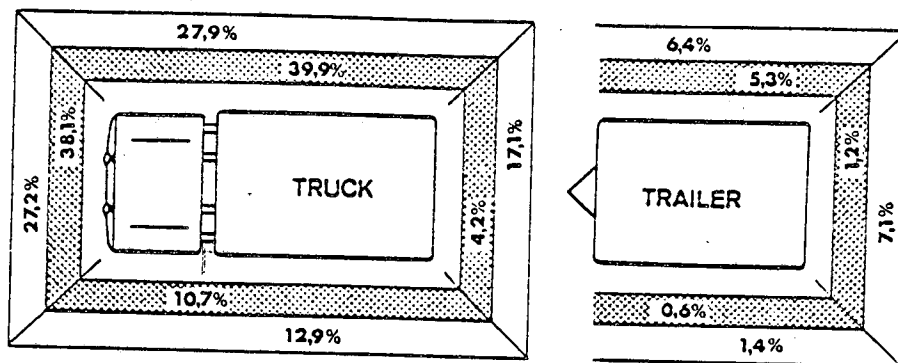
Fig. 4a HEAVY GOODS VEHICLE REGION CONTACTED BY BICYCLE OR LIGHT POWERED TWO-WHEELERS

GAUSS F., LANGWIEDER K., ET AL [19]
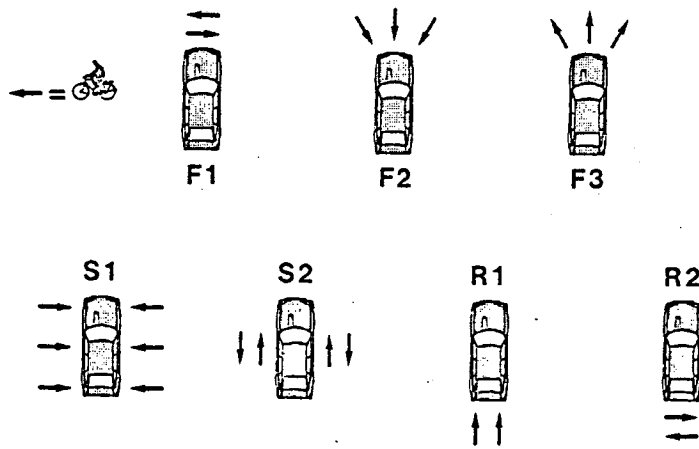
Fig 5 Definition of specific collision types. (Huijbers[9]).

$n_d=493$

$n_g=4475$
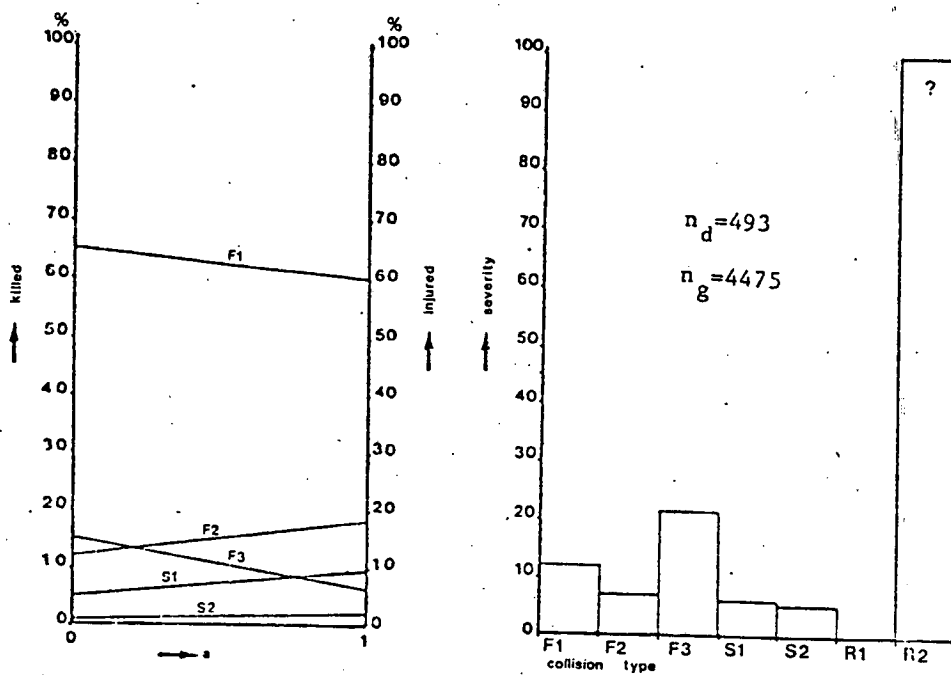
Fig 6 Priorities within the various collision types for bicycle to car collisions. (Huijbers[9]).

a = relative severity

n_d= number of people killed

n_g= number of people injured
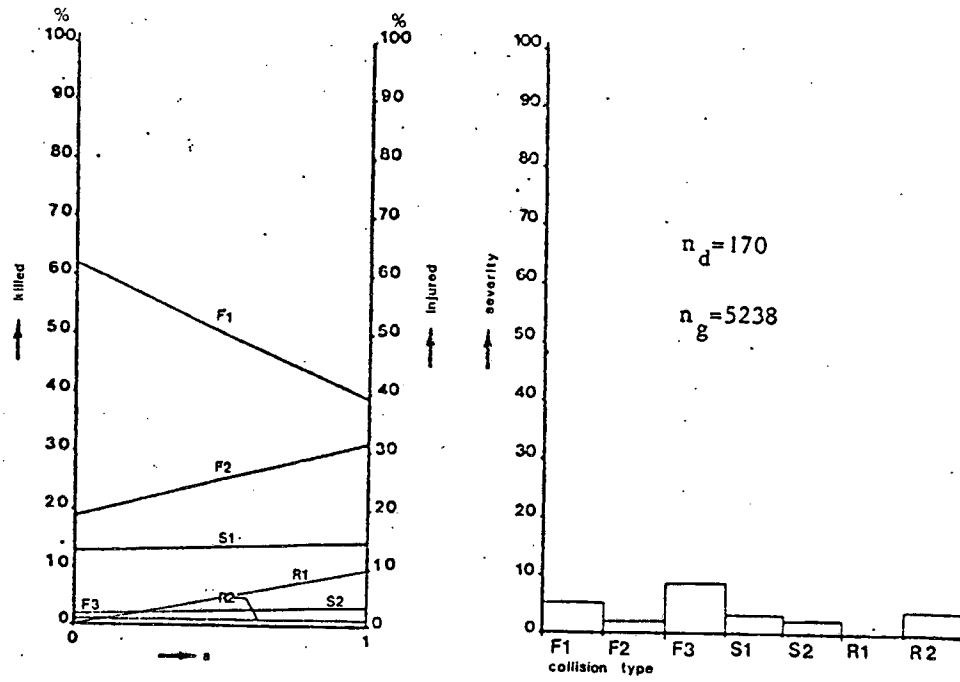
Fig 7 Priorities within the various collision types for bicycle to heavy goods vehicle collisions. (Huijbers [9])
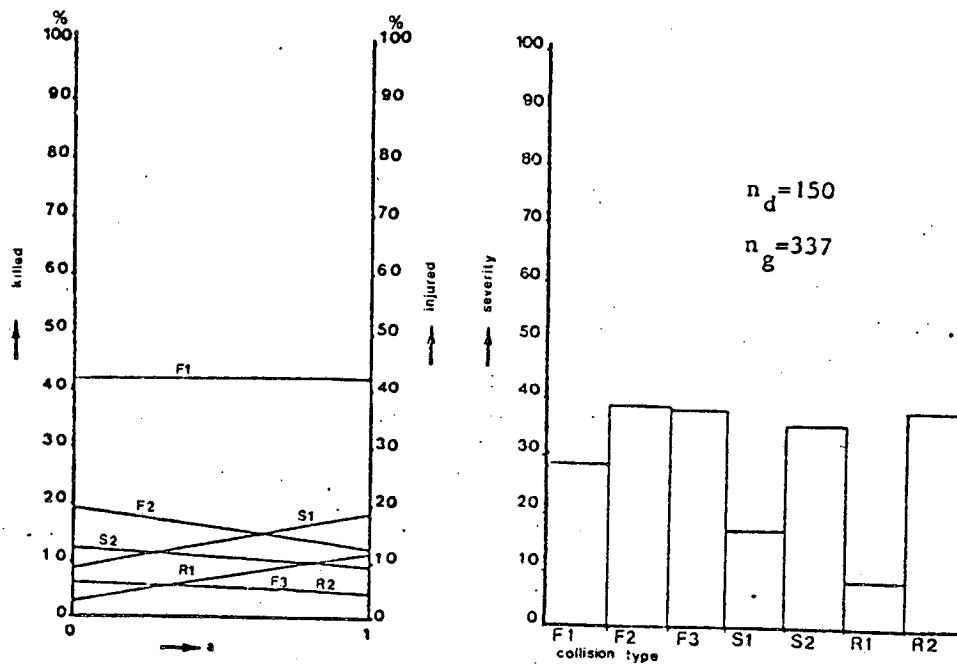
Fig 8 Priorities within the various collision types for moped to car collisions. (Huijbers [9])

a = relative severity

n_d = number of people killed

n_g = number of people injured
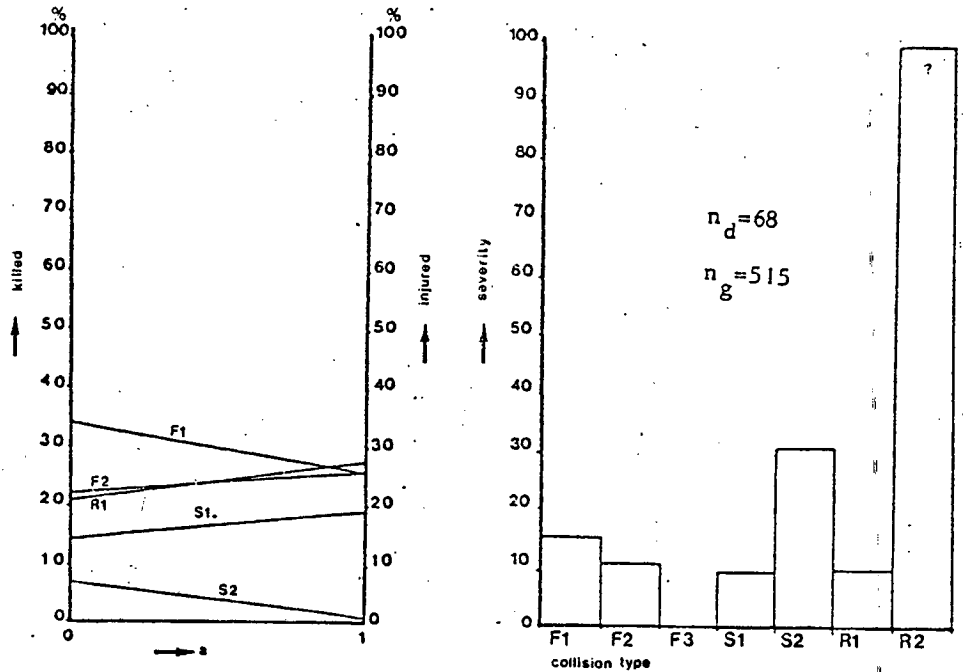
Fig 9 Priorities within the various collision types for moped to heavy goods
vehicle collisions. (Huijbers [9])

a = relative severity

n_d= number of people killed

n_g= number of people injured

Right Side
23.4%
n≈164

Rear
1.9%
n≈13

Front
63.2%
n≈444

Left Side
10.7%
n≈75

Underneath
0.9%
n≈6
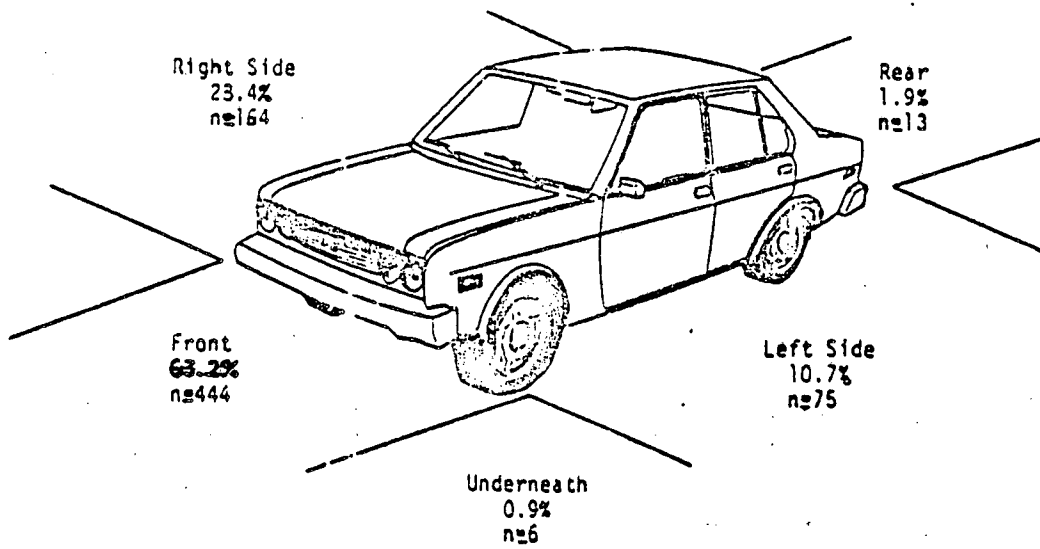
fig. 10. Motor vehicle region contacted by bicycle/bicyclist

(n=702 cases). (Roland [14]).

Right Side
21.2%
n≈149

Rear
3.6%
n≈25

Front
25.6%
n≈180

Left Side
49.6%
n≈348
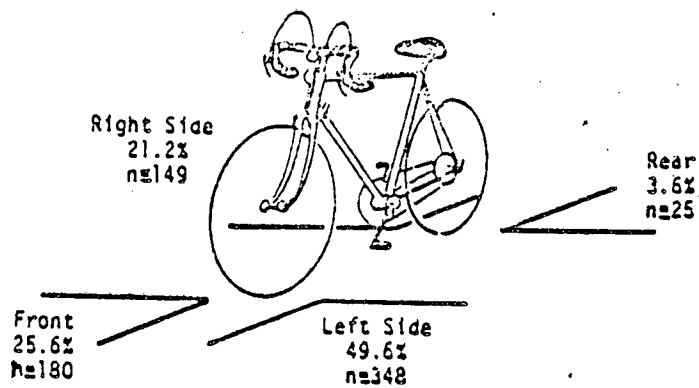
fig. 11. Bicycle region contacted by motor vehicle

(n=702 cases).   (Roland [14]).
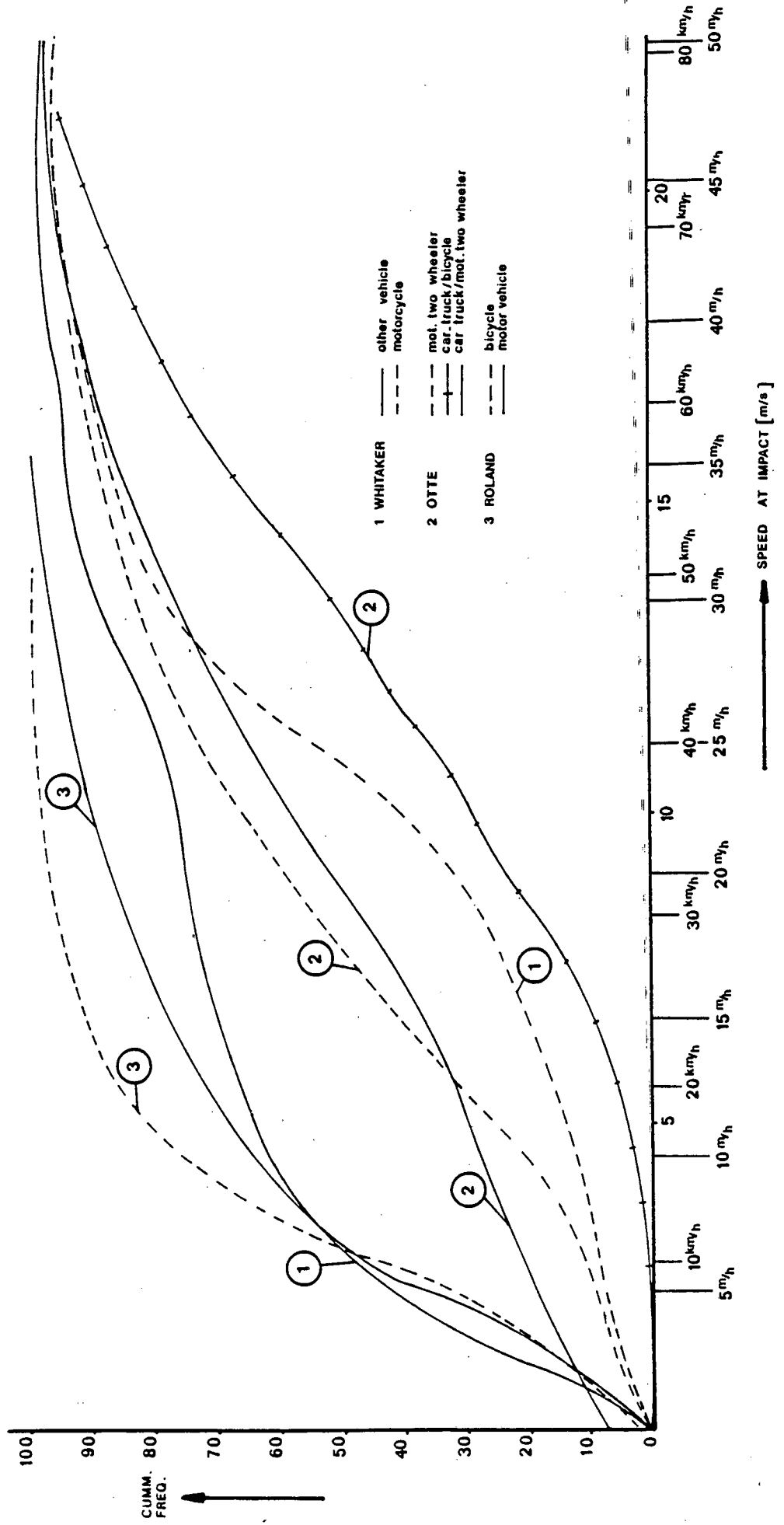
fig. 12. Cumulative distribution of vehicles speeds at impact in two-wheeler/car accidents by several studies.

EEVC WORKING GROUP 8

Bicycle and moped injury accidents.

CHAPTER III

"Injury influencing parameters".

3.   INJURY INFLUENCING PARAMETERS

3.1.   <u>INTRODUCTION</u>

Knowledge of injury influencing parameters in different types
of road traffic accidents is gained through in-depth investigations
at the scene of the accidents combined with detailled reconstruc-
tions and experimental studies.
A large number of reports from this kind of investigations is
found in the literature regarding cars colliding with fixed
obstacles, other cars, motorcycles or pedestrians. Very little
is known about light (motorized) two-wheeler accidents. The
following account of injury influencing parameters in such accidents
is therefore mainly inferrential and rests upon deductions from what
is generally known in this field of research. The main part of
this chapter therefore deals with comparisons with other accident
types and the conclusions drawn from these can of course be disputed.

Nevertheless it was considered desirable to have this kind of a
résumé of factors thought to be of importance for the production
of injuries to two-wheeler riders colliding with cars and heavy
goods vehicles.

The rider is here, if not otherwise stated, generally supposed to
be a teenager or an adult person and the two-wheeler a bicycle or
a moped with an internal combustion engine but otherwise of
essentially the same basic construction as a bicycle. The car is
considered to be an average sized European type sedan.
For children on smaller bicycles the kinematics may be similar to
those of adults although the front stuctures of the car may hit
the child's trunk rather than its lower extremities. In some
cases the child may have a more upright posture than an adult rider
and the kinematics may than be more like that of a child pedestrian.

The kinematics of the two-wheel rider in this kind of accident
depend upon the type of collision, the velocities of the two
vehicles, the rider's posture at the moment of impact and the
construction of the two-wheeler.

While a pedestrian hit by a car is usually upright at the moment
of first contact, the rider of a two-wheeler is thought to be in
a more or less seated position. This implies that his feet are
usually at some distance off the ground, the head may be at
about the same level as that of an upright pedestrian but this
depends very much on the posture of the rider.
The centre of gravity of the rider's body may well be at
approximately the same level above the ground as that of a standing
adult pedestrian.
While the velocity of a pedestrian if often negligible in relation
to that of the car, the two-wheeler travels much faster. His velocity
may sometimes be as high as 50-70 km/h, and has therefore to be
taken into account in may accident situations. However, the parameter
of importance for injury production is of course not the speed of
travel but the relative velocity between the riders body and that of
the car at the time of impact and for each body part.

Another important difference between pedestrians and riders of two-
wheelers is the presence of the two-wheeled vehicle; this presence
may influence the kinematics of the rider.
The inertia of its mass may in some collision types place extra
load on the riders body and his extremities may get entangled in the
main structure of the vehicle during the accident sequence.
A two-wheeler with an engine may also have parts which are hot
enough to cause burns if the rider contacts them during the accident
sequence.

3.2.   COLLISION TYPES

The collision types referred to below are those depicted in figure
5 of chapter two. Due to existing knowledge and the priorities
indicated in chapter II, this paragraph will mainly deal with
the collisions with passenger cars.

PASSENGER CAR.

Type F1

In this type of accident the front of the car impacts the left or
right side of the two-wheeler travelling in a direction perpen-
dicular to that of the car.

This collision type is similar to the most frequent type of car-pedestrian impacts. In both cases the adult victim is hit below the centre of gravity and comes into contact first with the bonnet or windscreen and then with the ground. One obvious difference is the usually higher speed of the two-wheeler at the time of impact. This implies that the rider's upper body will often hit the bonnet at a point further in the direction of his travel than that of a pedestrian would. The ratio between the speeds of the two vehicles will be decisive for where the rider's head and trunk will impact the car structures. In some cases this ratio may of course be such that the upper body of the rider does not impact the car structures at all, but instead he falls directly to the ground.

The seated position of the rider at impact may sometimes induce a rotation of his body about its longitudinal axis. This is particularly the case when the car structures are low relative to the riders torso and the thigh on the struck side is at about a right angle with the rider's torso. The lower leg and to some extent the arms are then accelerated by the car at an earlier moment than the rest of the body. The direction of rotation therefore is such that the back of the rider's trunk and head are turned against the car.

The rider's legs will thus be accelerated by the front structures of the car and may then be loaded also by the inertia of the two-wheeled vehicle's main structure. His torso will usually impact the bonnet or the upper parts of the wings. Where the head impact will take place will depend on the speed of the car and the car configuration parameters (e.g. bumper height bumper lead angle and length of its bonnet). It may be either on the bonnet, the upper parts of the wings, the windscreen or the windscreen frame. The compliance of these car structures varies considerably and is, as has been pointed out in connection with pedestrian-car accidents, an important injury influencing parameter. The speed of the car and the weight and construction of the two-wheeler are also important parameters.

Type F2

The two-wheeler is travelling in the opposite direction to
that of the car and the impact occurs front to front; the
closing speed is the sum of the speeds of the two vehicles.
The mass of the two-wheeler is small compared to that of the
car. This may therefore be the most violet accident situa-
tion. It is also a situation where the rider's body may be
travelling with the head as the leading part of the body.
Even if the trunk is not stooped forward before the impact
the legs may get caught by the handle bar of the two-wheeler
during the accident sequence and this may induce a forward
rotation of the trunk. Should the impact then be head first
into the windscreen area the axial load of the body would often
lead to severe fractures at the base of the skull and in the
cervical spine. This kind of injuries are usually lethal even
at low velocities. In this situation the total velocity change
is the omst important parameter and the compliance of the
impacted structures - or the usage of a helmet by the rider -
can probably influence the outcome only to a minor degree.

Type F3

The direction of travel is the same for both the car and the
two-wheeler; the difference between the speeds of the two
vehicles is a decisive factor.
The position of the rider's upper body then governs his kine-
matics. He may more or less remain in his original position,
slide over the bonnet and impact the windscreen area with
the lower part at his back. Severe back injuries can result
form this type of accident. The main injury influencing para-
meter is again the velocity and the compliance of the structures
is of secondary importance.

Type S1

In this type of accident the two vehicles move perpendicularly
to each other or the car may be stationary but the two-wheeler
impacts either side of the car. Due to the higher speed of the
two-wheeler this type of accident has more similarities with the
corresponding type of motorcycle accident than it has with the
case when a pedestrian walks into the side of a car.

If both vehicles are moving in this configuration the front
of the two-wheeler will be influenced by the moving car
in such a way that the two-wheeler will rotate during the
sequence and the rider will impact the car side in an oblique
way. Usually the rider's head will be at or above the roof
area of the car.

If the impact occurs at the passenger compartment in the
middle of the car the rider's body generally will be stopped
by the car's side structures. The velocity of two-wheeler and
the compliance of the car's side structures will be the injury
influencing parameters and to some extent the structure of the
two-wheeler.

If the impact occurs at the front or the rear of the car,
where the car structures are lower, there is a possibility
that the rider of the two-wheeler will pass over the car and
fall to the ground on the other side. While airborne the rider
may tumble and it is therefore difficult to predict his atti-
tude when impacting the ground.

Types S2 and R2

In the case of a "near miss" or a side sweep only one leg and
possibly one arm and shoulder of the rider may impact a front
corner of the car. Axial or near axial loading of the femur
is then possible and severe leg injuries, at high speed impacts
even traumatic amputations are seen in this type of accident.
Compliant car structures may be of some help but the relative
impact speed is probably more important. The arm and the shoulder
may be injured in a similar way but the direction of force is
probably more favourable.

Type R1

The two-wheeler impacts the rear of a car and the relative velo-
city is likely to be less than in most of the other accident
types. The car structures, other than vertical ones, are there-
fore probably less important but attention should be drawn to
the possible existence of spoilers, which should for this reason
be as compliant as possible.

Oblique impacts

Oblique impact directions may produce a combination of the injury mechanisms mentioned above. When a rider's upper body impacts the top of the bonnet a higher relative velocity may result in a more oblique head impact than is the case for pedestrians. It is not possible to state on the basis of present knowledge whether or not this may lead to more severe head injuries due to angular acceleration of the head.

Accidents involving busses and lorries

In the case of the frontal collision types (F_1, F_2, F_3) the configuration parameters don't seem to have so much influence on the kinematics and injuries of the two-wheel rider. Compliance seems to be important.

The configuration of the sides of the heavy goods vehicles seems to be important for the injuries of the colliding two-wheel rider, due to the large gaps between the wheels of the truck. The two-wheel rider will be hit at head or neck level by the relatively stiff parts of the heavy goods vehicle. The risk of being run over seems to be important too, just as the speed of impact of the two-wheel rider.

3.3   THE STRUCTURES OF THE TWO-WHEELER

When the two-wheeler is hit from the side there is a possibility for the leg of the rider to be squeezed between the two vehicles. The construction and the inertia of the two-wheeler is then of importance for injury production. If the two-wheeler collides in a frontal or oblique direction with another vehicle or an obstacle it is possible that the rider is caught by the handle-bar in the groin area. This may sometimes lead to vascular and/or nerve injuries and may change the kinematics of the rider. Any other protruding detail on the two-wheeler may cause injuries if the rider hits it during the accident sequence.

A special type of injuries occur when children are carried
as passengers on two-wheelers without adequate protection
for the child's legs. If the child's foot gets caught in
the wheel it will be squeezed between a spoke and the
frame and the resulting injury usually requires hospita-
lization.

3.4 THE GROUND

For pedestrians it is now believed that the ground is of
little importance in relation to the car for injury produc-
tion. The same is probably to some extent the case for two-
wheelers. At higher speeds there may be a more substantial
influence by the ground. The oblique impact of the head to
the ground and possible kerbstone impacts may then become
important for the severity of brain injuries. Another im-
portant factor is the dirt on the road surface. Open wounds
caused by the primary impact to the car or resulting from the
sliding of the rider on the ground after impact may be smeard
with dirt. This prolongs the healing process and may lead
to complicating infections. Normal cloths are of little use
for protection since they are easily torn under these circum-
stances.

3.5 OBSTACLES

In the streets there are several obstacles which a two-wheeler
can contact violently after loss of control. Street appertu-
nances are sometimes designed to break away or yield when hit
by cars in order to mimimize the risk of injuries to car occu-
pants.Because of their low mass, two-wheelers will normally
not be capable of deforming these structures to any appreci-
able degree. Hence, the risk of having an injury is much greater
for these categories. In country roads trees and fences can also
cause injuries if violently contacted by the rider of a two-
wheeler.

Particularly children and teenagers sometimes use their
vehicles also in playing grounds, parks and other places
outside the roads where there are several possibilities
for contacting fixed obstacles. The types and severities
of the resulting injuries from such contacts depend upon
many variables, such as type of accident which determines
the kinematics and attitude of the body at impact, the
velocity, the object struck etc.

Children seem to more prone then adults in overturning to
fall on the end of the handlebar in such a way that abdo-
minal injuries occur. Due to the very low tolerance of the
child abdomen to the high level of loading resulting from
this kind of impact very little can be done with the bi-
cycle to prevent these injuries.
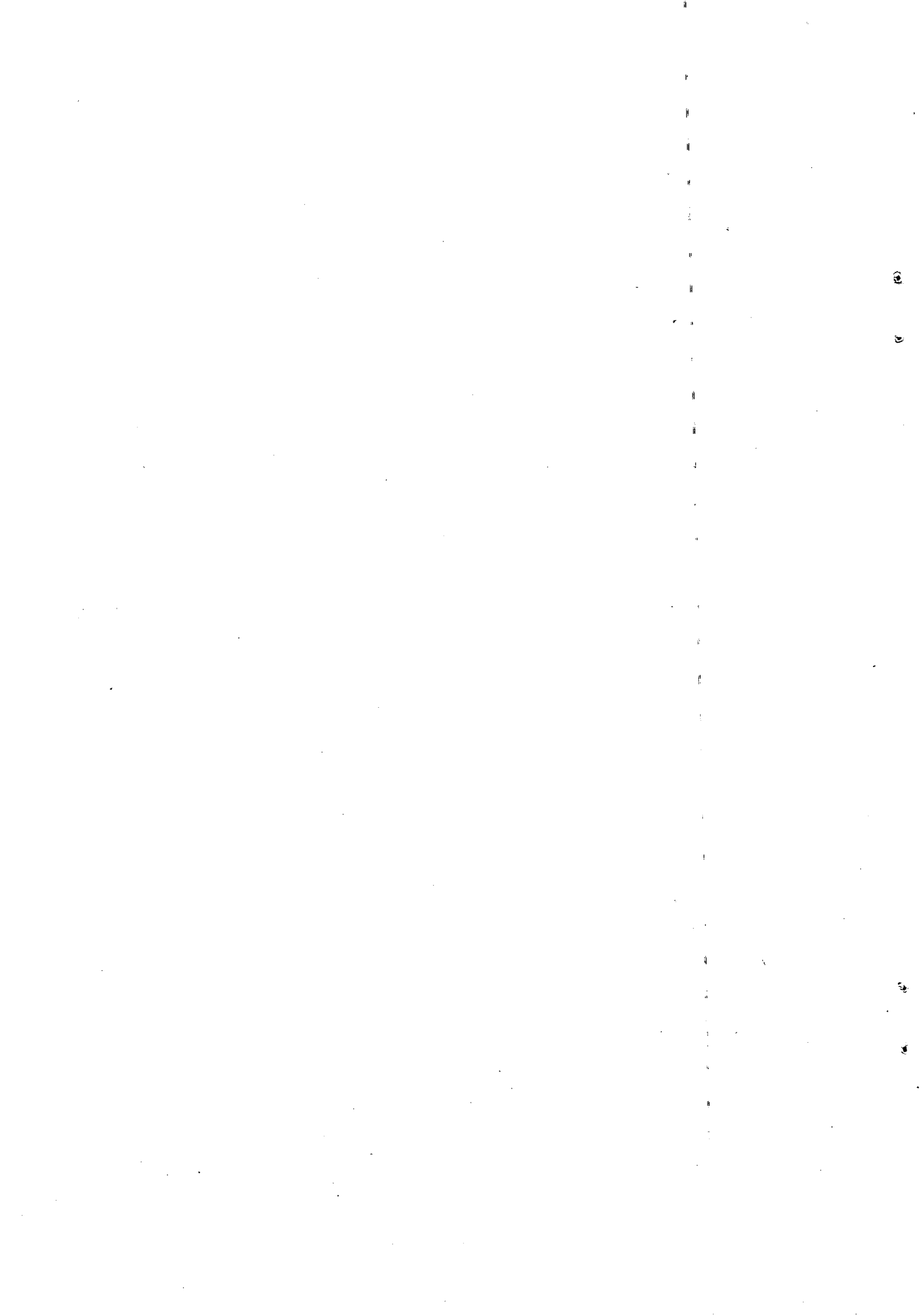
Chapter IV - Research methods and results.

4.1. INTRODUCTION.

Injury prevention research for two-wheel riders got less
attention than injury prevention research for pedestrians.
The accident process of the two-wheel rider is even more
complex than that of the pedestrian because of the contri-
bution of the two-wheeler itself to the injury producing
proces. Also the speed of the two-wheeler and its position
in traffic situations lead to other collision types and speeds
at impact.
There are several ways to study two-wheeler injury protection:
One is analysis of accident data and another is experimental
research.

4.2. ACCIDENT STUDIES.

4.2.1. Accident studies give samples of reality in order to estimate
the size of the problem, defining priorities within this problem
and developing hypothesis in which relations between injury
influencing parameters and injury severity are postulated.
Accident studies also give results with regard to the
quantification of these relations. The study of the effect
of a specific (legal) measure is a special application of
this type of accident investigation.

4.2.2. One might distinguish at last three levels of depth of
accident studies:
   1) accident statistics (police data level)
   2) intermediate level studies
   3) in-depth studies.
To describe the size of the problem, the relative proportions of
collision types etc. level 1 and 2 data are needed.
These data may also form the basis for experimental studies under
laboratory conditions. In chapter I and II, level 1 and part of
level 2 are described.
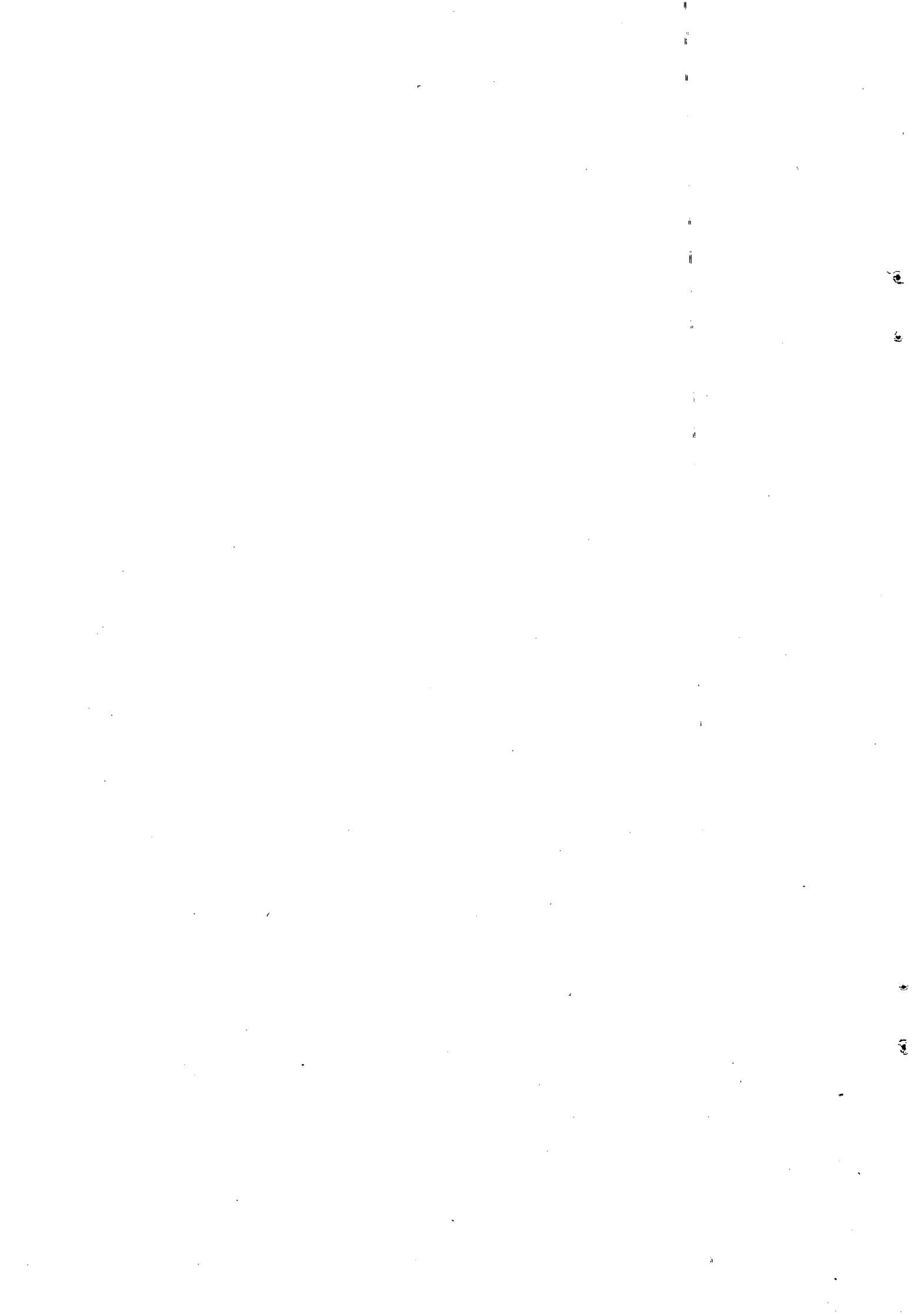
The difference between level 2 and level 3 data is normally that in level 3 far more detailed data are gathered including data on scene for each accident.
Emphasis with level 2 data is on the statistical side, which means that sample size, sampling method and detail of information are balanced with respect to representativeness and statistical analysis. For both levels investigators of more than one discipline are often used (i.e. technical, medical etc.)

Since accidents involving two-wheelers are complicated with respect to the exact cause of injury (for instance contribution of vehicle and road factors) the in-depth level of data gathering is often used.

Level 3 in-depth data may provide for each case:
- data form observation on scene, soon after the accident, helping to understand the sequences of the collision phases.
- data on the vehicles or obstacles involved, with emphasis on vehicle types, damage, marks for reconstructing the collision type, collision severity and if possible injury mechanisms.
- general data on two-wheel riders, especially their position on the two-wheeler, their means of protection etc.
- detailed injury description for every casualty, if possible by direct observation or through hospital records.

Level 2 data may also contain valuable information on injuries and the accident in general and since emphasis is on representativeness, a far more reliable picture of all occurring crashes is acquired than by means of police data (level 1).

Level 2 studies may be based on insurance data, hospital data (though these will be restricted to only part of the injury population),tow-away accidents or any other starting point.
As in level 3 studies, both damage, accident and injury information will be gathered, often on a statistical basis (e.g. by a written enquiry to car owners, occupants, hospitals or police). Visiting the scene of the accident is not part of this method, since this would take too much time and effort.
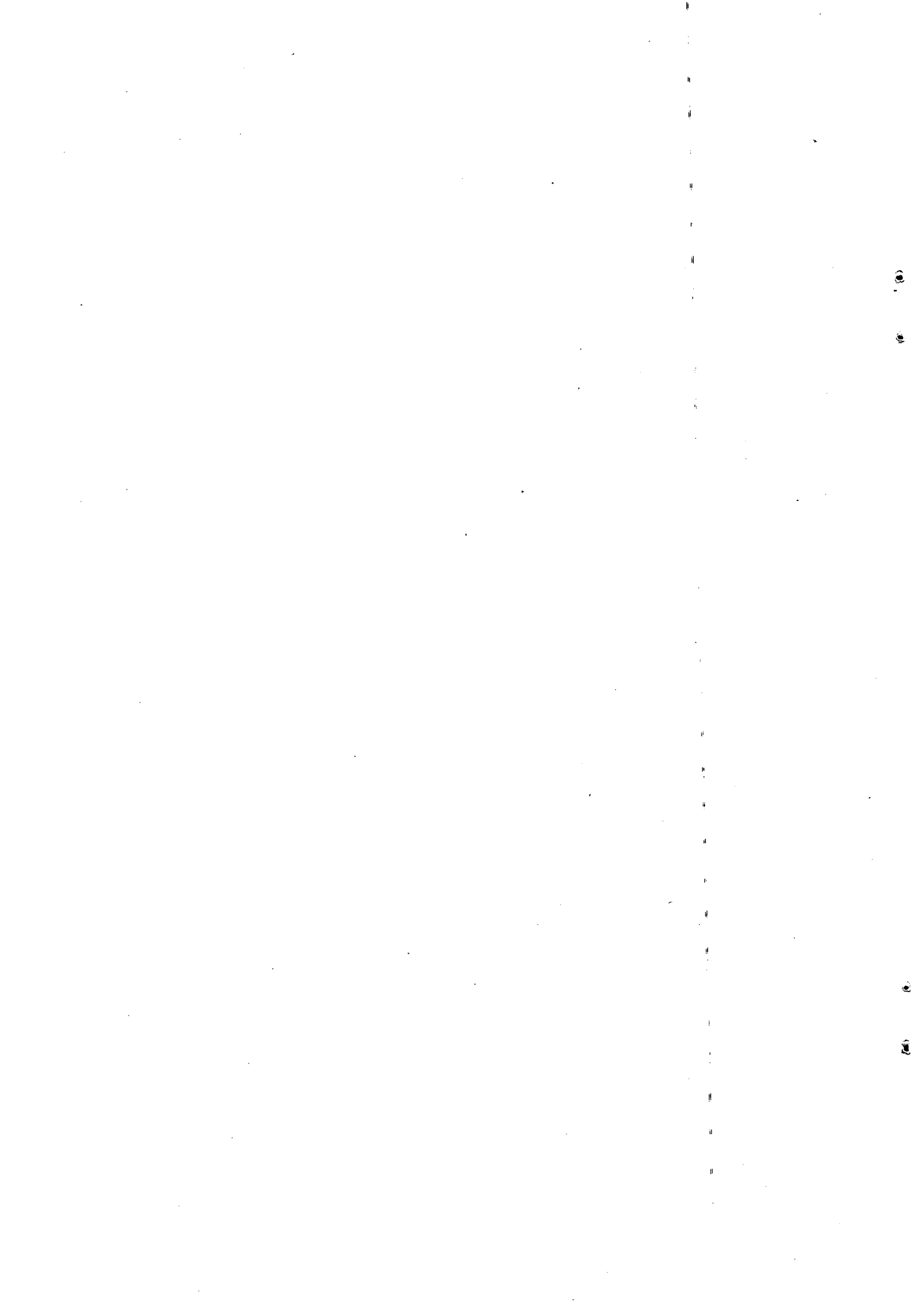
For two-wheeler accidents a visit to the scene and a full
investigation of the surroundings and the vehicles involved
seems necessary if all injury causing factors are to be known.
However the in-depth approach limits the quantity of cases
to be studied in a given period of time.
Therefore level 2 data are needed to get view on the problem
and its relevant distributions as part of reality, especially
if level 1 data is not available or incomplete, as is the case
in many countries.

4.2.3. Some results:

Cross [4] studied 753 non-fatal and 166 fatal bicycle casualties
in collisions with motorvehicles (level 3).
From the non-fatal group only 17,5% remained in hospital longer
than one day. Contact with the road surface seemed to be the
cause of injury in 60% of the cases.
Contact with the motorvehicle in 23% and contact with the
bicycle in 6,2%.
The conclusion from Roland [5], after examining 700 motor-
vehicle-to-bicycle accidents (level 3), is in agreement with
this last statement as far as the injury causation of the
bicycle is concerned.
Roland [5] concluded that the bicycle did not seem to be a
major source of severe injuries.
There were only four injuries resulting from a contact with
that bicycle the produced an AIS rating greater than one.
There is a significant overrepresentation of the motor
vehicle as the source of injury rather than the environment.
For all the defined speed categories more severe injuries
tend to result when the contact source was the motorvehicle
as opposed to the bicycle or the environment. This does
indicate that the injuries are being produced in the initial
contacts rather than from secondary contacts with the environ-
ment.
No significant influence on injury severity was found for:
estimated speed of bicycle prior to impact, bicyclist's age,
handle-bar type, bicycle region contacted.
Significant influence of the following motorvehicle variables was
found: estimated speed at impact, vehicle manoeuvre prior to impact.
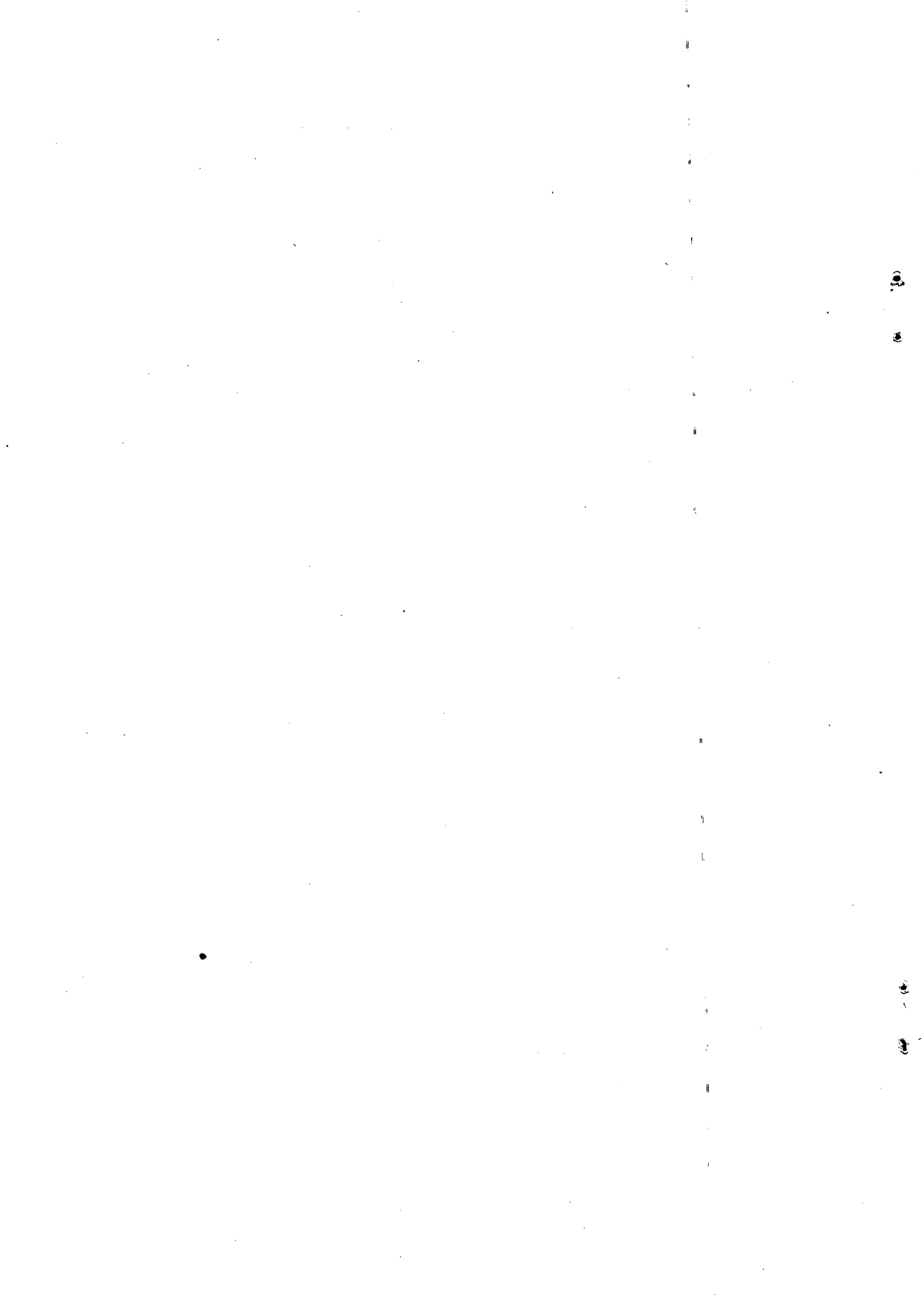
Some studies described specific injuries:
The influence of the bicycle on intra-abdominal injuries
(Esterer [21], Aldman [19]). These injuries are usually
caused by falling on the free end of the handle-bar.
Bicycle spoke injuries (Juhl [20]): these lesions
occur if the (child) passenger's foot is caught in the
wheel of the bicycle.

4.2.4. Some advantages and disadvantages of accident studies in
relation to experimental research:
advantages:
● The only way to establish the size of the problem.
● The only method that gives insight in the injury influen-
cing parameters in the real accident situation.

disadvantages:
● Approximation of some of the accident data (e.g. speed at impact,
contactplaces).
● Only the influence of the values of the parameters, as they
exist in real traffic, can be studied.

4.3.   EXPERIMENTAL RESEARCH METHODS.

In a collision between a two-wheeler and a car, type and
severity of injuries sustained by the two-wheeler user may
depend on its kinematics but also on the relative speeds of
the two vehicles. (chapter III). The two-wheeled vehicle may have
an important speed. Moreover the crash configuration can differ
from one case to another in a large range (chapter II).
The main collision types are: F1, F2, S1 (chapter II).
Experimental research on bicycle and moped collisions is mosty
focused on type F1. Type S1 is dealth with in motorcycle
collision experiments.
The posture seems to have a small influence on the kinematics
and one can imagine that differences in height would also have
minor influence, as most of the two-wheeler users are adults.

Three main methods are available for research in two-wheeler
safety:
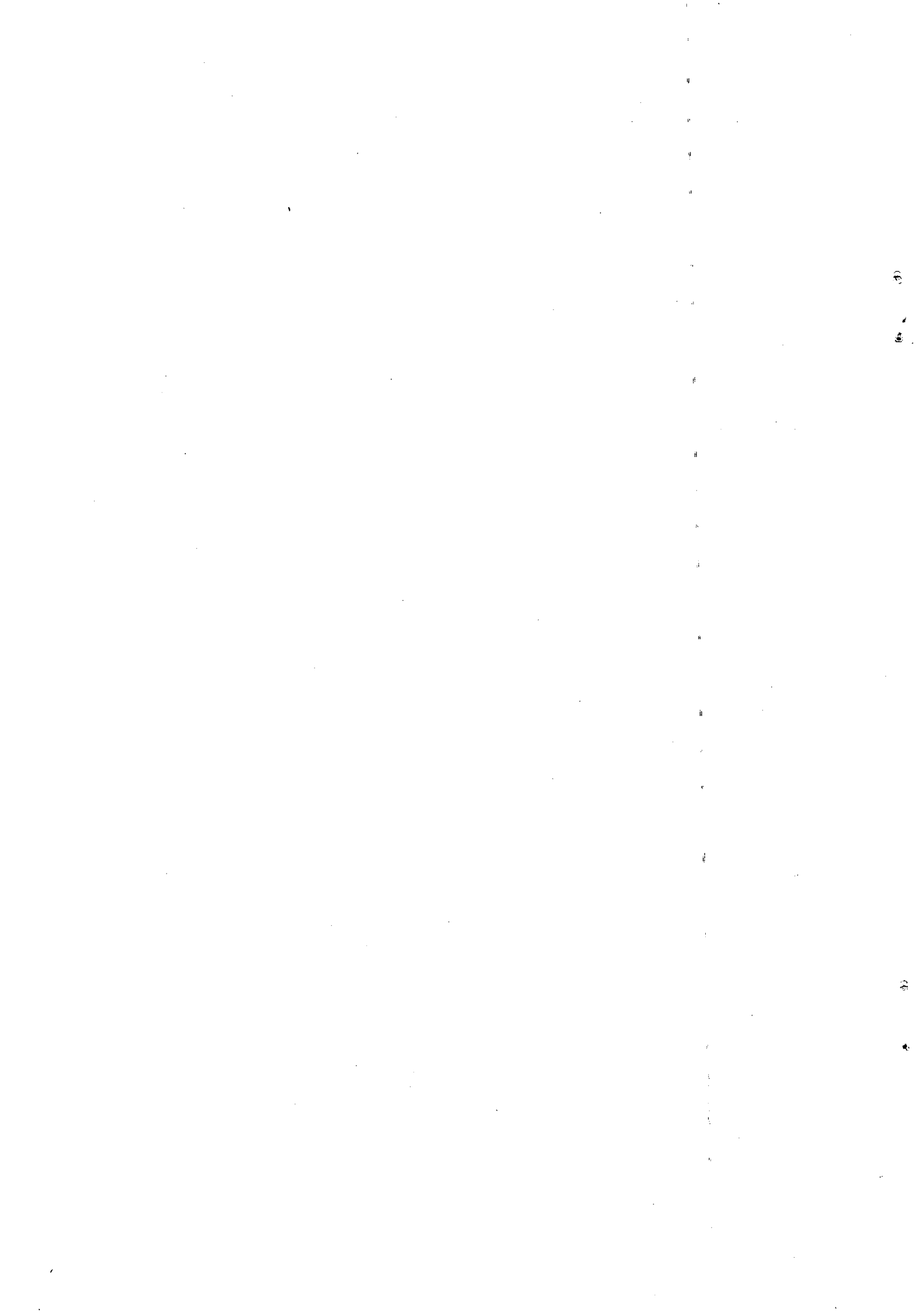
1. The full scale test between a two-wheeler and a car (or a
   mobile barrier), the two-wheeler rider being a dummy or a
   cadaver.
   Even if they have the advantage of being realistic, for car/
   two-wheeler collisions they will have to be performed in a
   large number of configurations as the potential collision
   types are numerous and the impact speed can vary in a large
   range. The problem of impact "with escape" may be difficult
   to reconstruct.

2. The body segment test (or component test) in which the safety
   problems involving a specific body area are investigated.
   They would not be fundamentally different from research made
   on pedestrian safety, as the same body segments are concerned.
   Moreover, specific research dealing with two-wheeler safety
   concerns head injury protection with crash helmets, as well as
   some other parts of cars, trucks etc.

3. The mathematical model: this can be used as a general tool
   to evaluate and predict two-wheel rider kinematics and
   dynamics. Mathematical models are especially usefull in para-
   meter variation studies. As a result, mathematical modelling
   has the advantage (and may be the only practical tool capable)
   of determining generalised output for complete populations.
   The use of mathematical models in two-wheeler safety research
   is relatively recent. The method is promising for the near
   future. Mathematical models have to be validated with test-
   results and/or accident investigation output.

4.3.1. FULL SCALE APPROACH OF TWO-WHEELER SAFETY RESEARCH.

This approach generally consists inreconstructing a collision
between a car and a two-wheeled vehicle on which a model of
a human being is seated (Sacreste [8], Taneda [9]).
The impacts sustained by the two-wheeler rider ejected from
his vehicle can be analyzed in relation to car/two-wheeler
collisions or to impacts against objects in the surroundings
(Chretien [10]).
Two main research projects used this car/two-wheel full scale
approach to study two-wheeler protection.
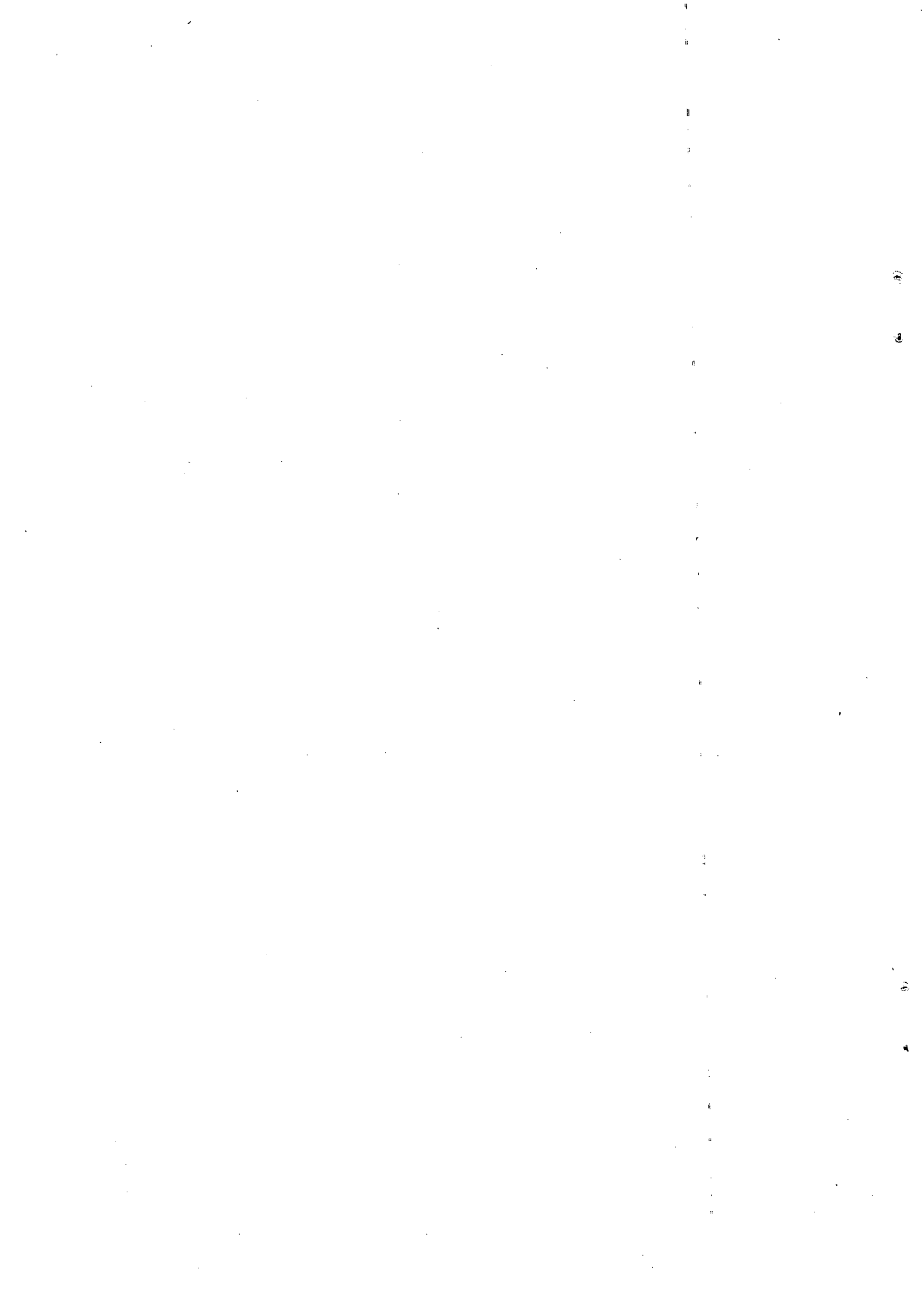
For the <u>first</u> one (Kraus [2]) 22 collisions between a passenger
car and a moped were reconstructed. These tests were made in 6
different configurations, most of the tests representing a road
crossing collision, the moped being either striking or struck.
All the tests, except 2, were performed with a 50th percentile
dummy; the other 2 used cadavers.
In 13 tests, the two-wheeler user was helmeted whereas in the
other 9 his head was not protected.

Main results:
this research found that, in the case of struck moped, the
two-wheeler user kinematics can be compared with pedestrian
kinematics.
From this point of view, the car modifications made to protect
a pedestrian can be favorable for two-wheeler users too.
The head-ground impact gave higher HIC values than the head-
car impact. The helmet ensures a certain measure of head protec-
tion; it is less effective in the temporo-parietal area. Finally,
an interaction between the moped and the dummy pelvis has been
found in several cases.

The <u>second</u> study (Taneda [9]) was made in Japan. For this research
10 collisions were performed, in which a standing motorcycle was
struck laterally by a car or a rigid mobile barrier. The aim of
this research is to study lower limb protection of motorcyclists,
so the tests were made with a 50th percentile dummy equiped
with frangible legs.

Main results:
the modifications of cars in order to optimize energy absorbtion
would allow to ensure a better protection of the rider against
leg injuries. It seems possible to protect from leg injuries at
a speed up to 40 km/h and the authors think that the other
injuries are acceptable in this range of speed.
The protecting device tested in lateral collisions would have a
beneficial effect in other crash configurations, especially
avoiding leg crush under the motorcycle in case of rollover and
underide of the motorcycle under a car.
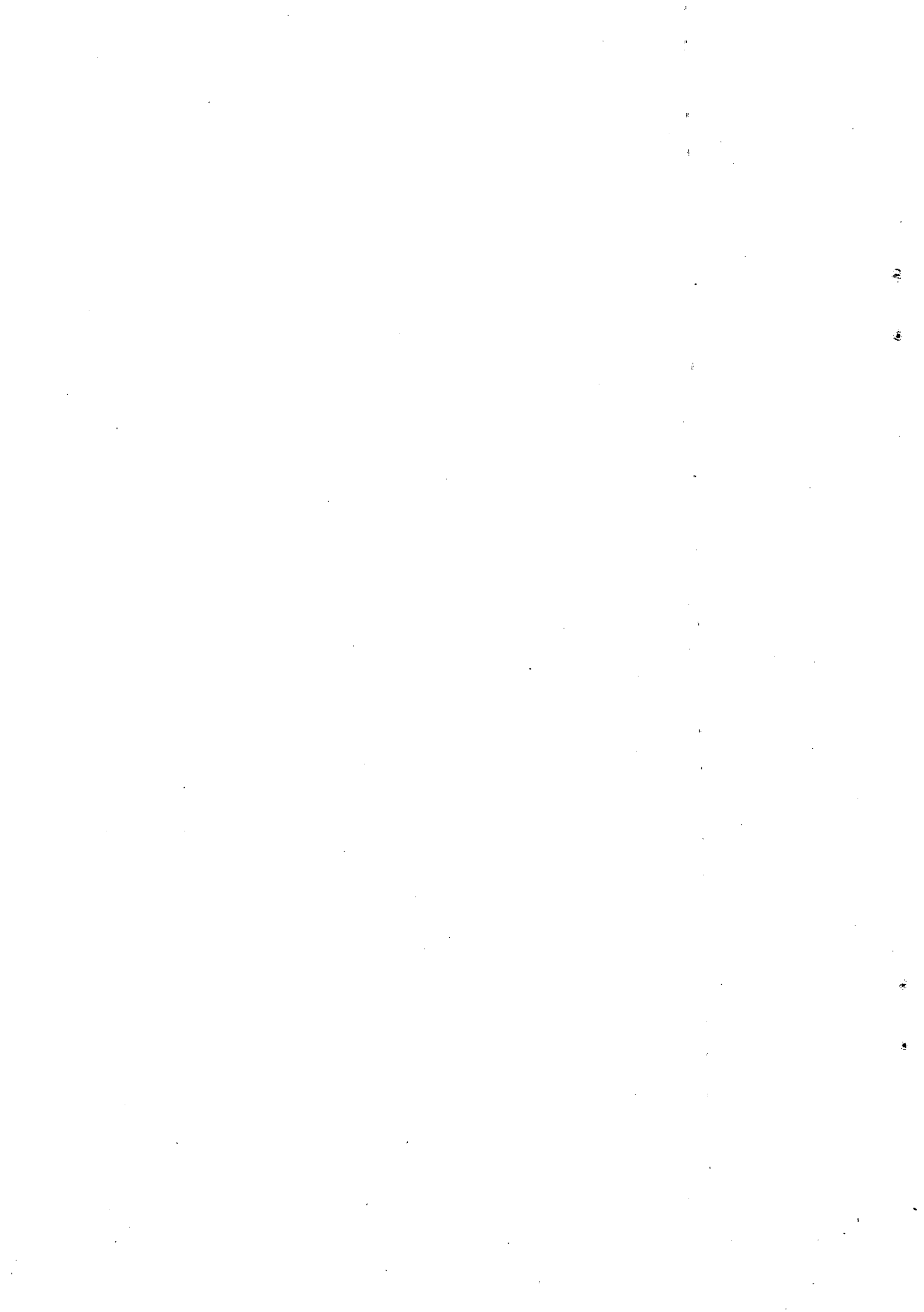
The effect of the rider ejected from his motorcycle and impacting a guardrail has been studied experimentally (Chretien [10]), with tests in which a dummy is laid down on the back, the head forward, on a mobile platform which is suddenly stopped: the dummy is projected forward and hits a guardrail, the head first and under a chosen angle.
This research has shown that it is possible to design deformable shields avoiding the direct impact between the two-wheeler rider and the rigid and sharp parts of the guardrail (posts and rails).

The third study is done at TNO (Janssen [17]).
Dummy tests were executed (type F1) as a first step to validate the MADYMO mathematical model.
The first results indicate that the kinematics of the bicyclist resembles that of a pedestrian but that the impact places of the bicyclist-head on the car is somewght higher.
Futher results will be presented at IRCOBI 1984 in Delft.

Advantages and disadvantages of the full scale approach for two-wheeler protection research.
This approach would give generally a realistic view of the two-wheeled vehicle/car collision but the realism of the reconstruction is limited by the behaviour of the dummies and by the selection of crash configurations.
Especially making tests with a standing vehicle decreases the interest of this approach.
These tests do not have a good repeatability and each test can only allow a safety evaluation in one specific configuration, whereas the accidentology shows an important diversity of real crash configurations.
The two-wheeled vehicle type has a big influence on the results of the tests; thus these results can not be applied to all two-wheeled vehicles (e.g. mopeds versus motorcycles).

4.3.2. COMPONENT TESTS USED IN RESEARCH FOR TWO-WHEELER SAFETY.

Many researches using the component test approach, dealing with two-wheeler protection have been performed: most of them concerned head protection, i.e. study of crash helmet protection.
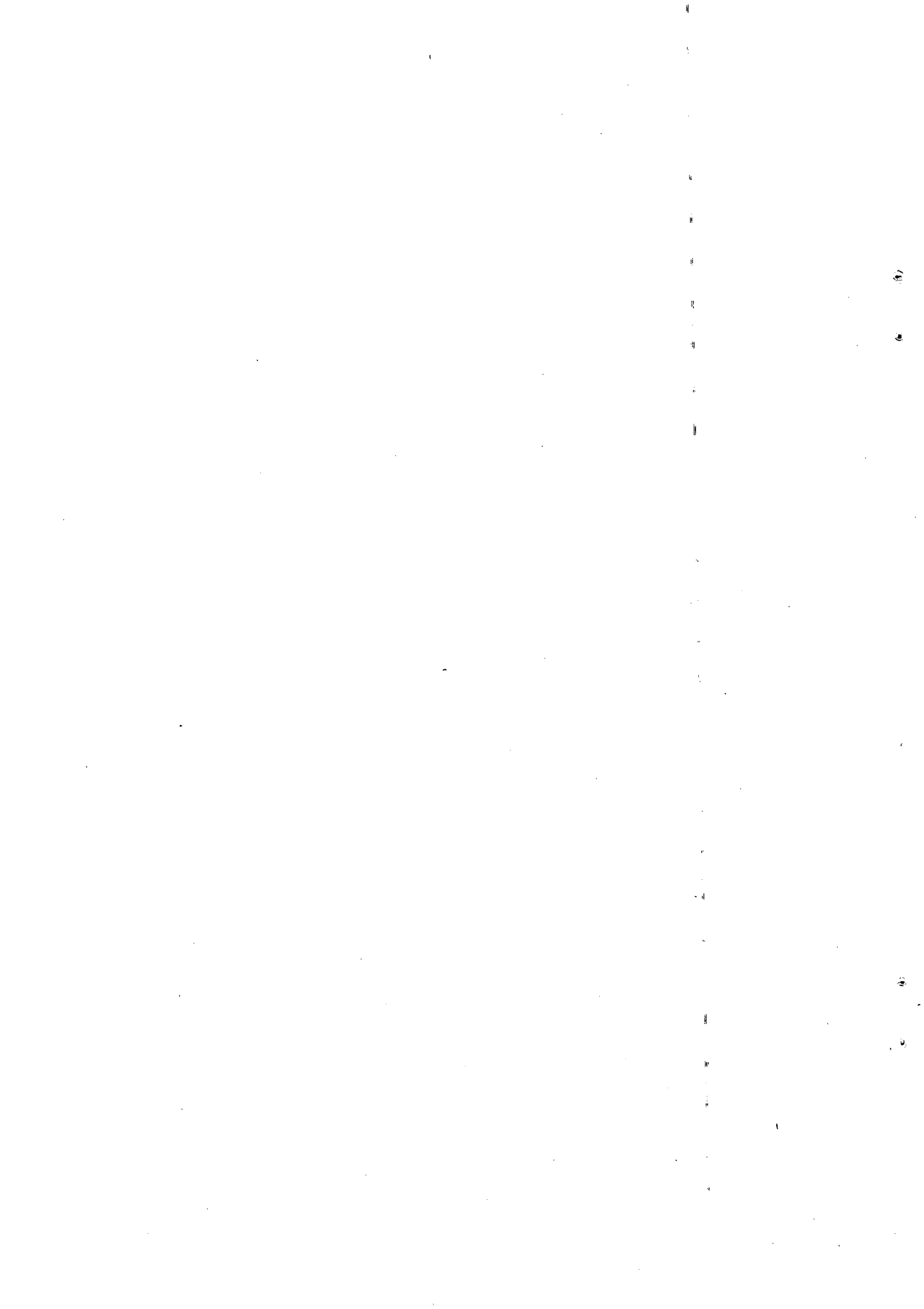
Some of these studies are limited to the verification of
helmet performance in tests similar to standard tests
(Taneda [9], Chretien [10]).

Other more fundamental studies allow to better know the
mechanisms which govern the head protected with a helmet and
then to increase the performance of these devices.

One biomechanical research project (Fayon [13]) investigated
injury mechanisms and head protection possibilities on the basis
of drop tests. 11 tests have been performed with cadavers, 9 of
them were helmeted: the drop height was 1.83 m or 2.50 m.
The subject was inclined at 30° downwards, the head first
hitting a rigid flat surface.

These tests were completed by some tests using only the helmeted
head of a Hybrid II dummy or a helmeted metallic head model.
In this study the HIC values are very high even in tests
performed at 1.83 m, but the measures were not obtained at
the center of gravity of the head.

Tests performed with a head only (dummy head or metallic form)
gave HIC values lower than those obtained in tests using whole
bodies.

An other research (Aldman [14]) studied the influence of horizontal
velocity of the head when it hit the ground, on the kinematics
and the linear and angular accelerations sustained by the head.
Helmeted head an neck of a dummy, attached by a lever arm to
a rail guided carriage, sustained free falls on a ring simula-
ting the road surface. The horizontal ring rotated in order to
simulate the horizontal component of the head speed related to
the ground.

These tests showed that in these conditions the head sustained
important angular accelerations and speeds while the HIC value,
which takes into account only the linear acceleration components,
staid generally below 1000.

This study concludes that some helmets have a shell made of
material which is too soft to provide a desirable low friction
between helmet and road surface.

An other study (Bastiaanse [15]) compared the energy absorbtion
characteristics of a protective helmet and a coconut shell, and
showed on the basis of experimental tests, that the coconut has
greater energy absorbtion capacity than the foam used for
helmets. The author proposed to design helmets without rigid
external shell.
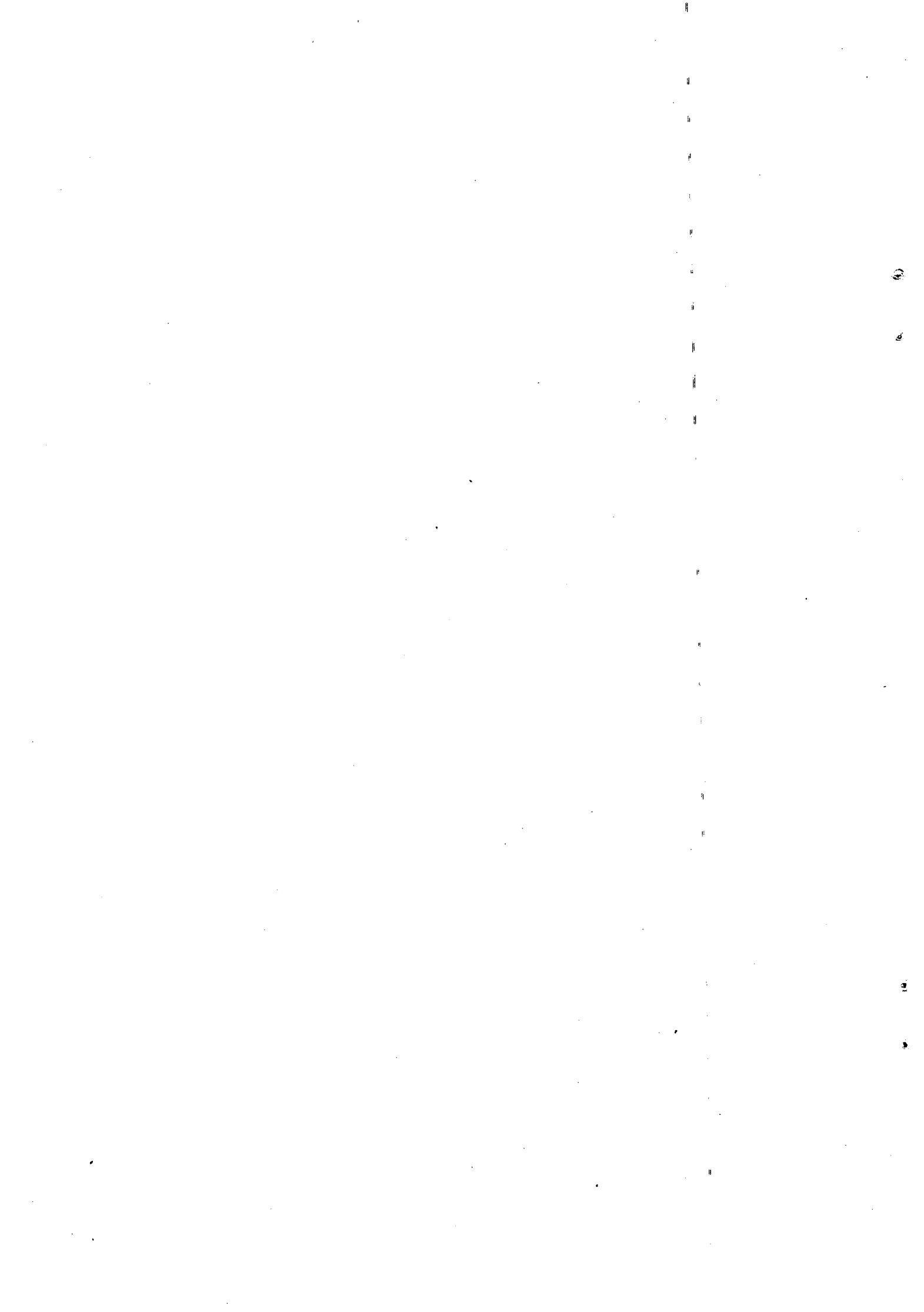
<u>Advantages and disadvantages</u> of component tests as a basis of
two-wheeler rider protection research:

Component test methods allow to make researches based on a large
number of tests, having a good repeatability at relatively low cost.
But these tests are notable to give only a global view
of the two-wheeler accidents as they reproduce just one phase
of the accident.
Moreover, the conditions in which they are performed are
simplified (2D motions) and so their realism is limited.
From this point of view, the conclusions found in researches
using the component tests approach should be validated through
full scale tests.

## 4.3.3. MATHEMATICAL MODELS FOR RESEARCH IN TWO-WHEELER PROTECTION.

It seems that there is no mathematical model which is
especially designed for bicycle and light powered two-wheeler
safety research. Existing models of car occupants or pedestrians
could be used for two-wheelers but their adaptation and validation
would need a sufficient number of test results.
The three dimensional CVS 3 Calspan model has been adapted by the
Denver Research Institute to study the behaviour of crash victims
in motorcycle accidents (Fleck [16]). In the Netherlands, SWOV
and IW-TNO are working on a program that is set up to produce
a validated mathematical model for two-wheeler accidents with cars.
At this moment dummy-tests have taken place as a first step to
validation (Janssen [17]).
In Germany a mathematical model exists which simulates the
impact of a motorcycle in the side of a standing car (Sporner [18]).
In fact, it seems that up to today there are practically no results
of light powered two-wheeler safety research using mathematical
modelling.

<u>Advantages and disadvantages</u>.

Mathematical models have potentially many advantages as they allow
to investigate a large number of situations in a short time at low
cost, without repeating experimental tests. For that reason they
can generalise output for (complete) populations involved in
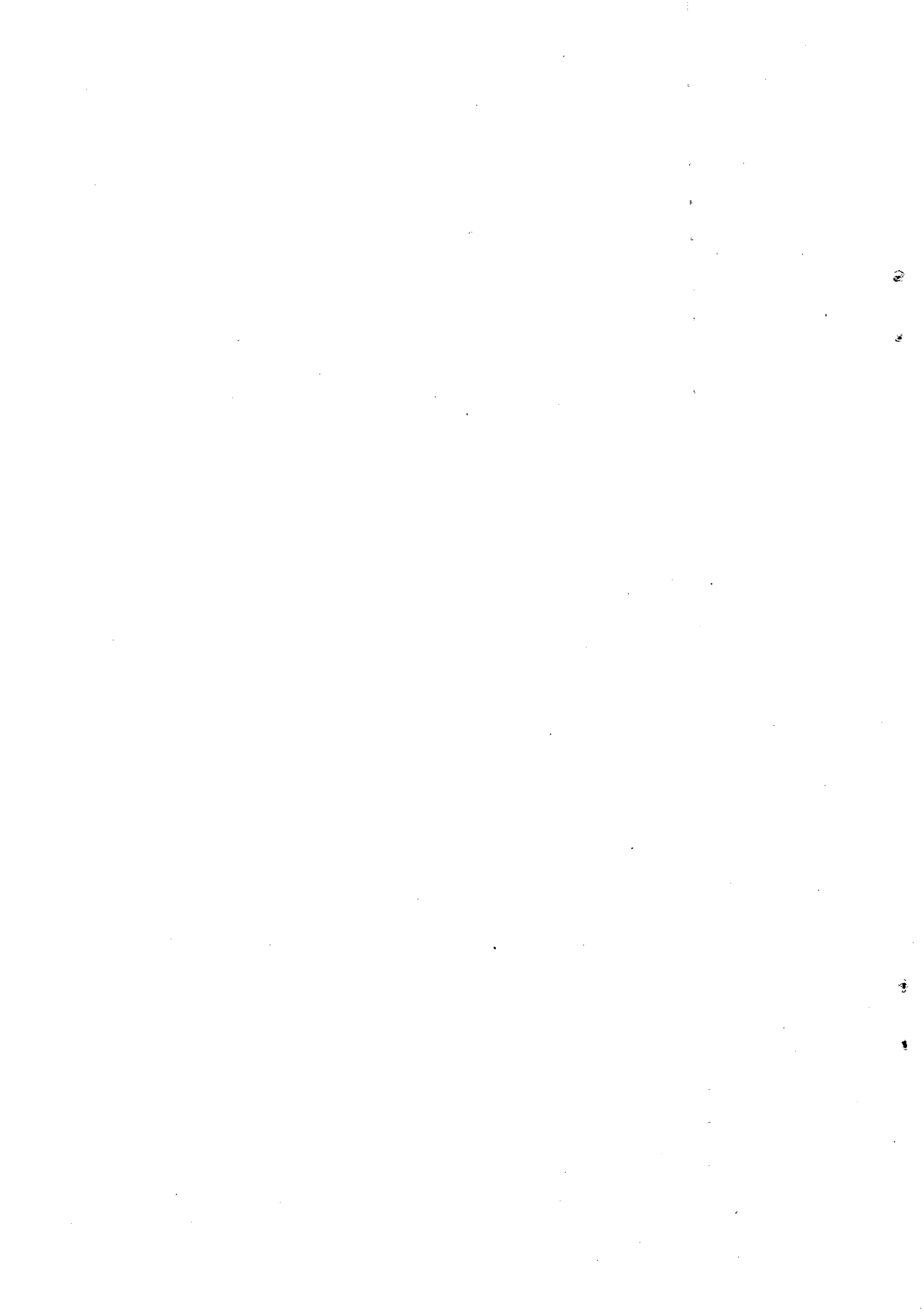
certain (or all) crash configurations. The accuracy of the results
of mathematical model studies are largely depending on the
quality of the validation of the model. For validation not only
full-scale test results must be used, but also results from
(in-depth) accident investigations and specially developed vali-
dation test results can be used.

Compared with full-scale tests, the results of mathematical
models can be stated to be at least as realistic.

The condition of the representation of the real situation
with dummies or cadavers is somewhat questionable.
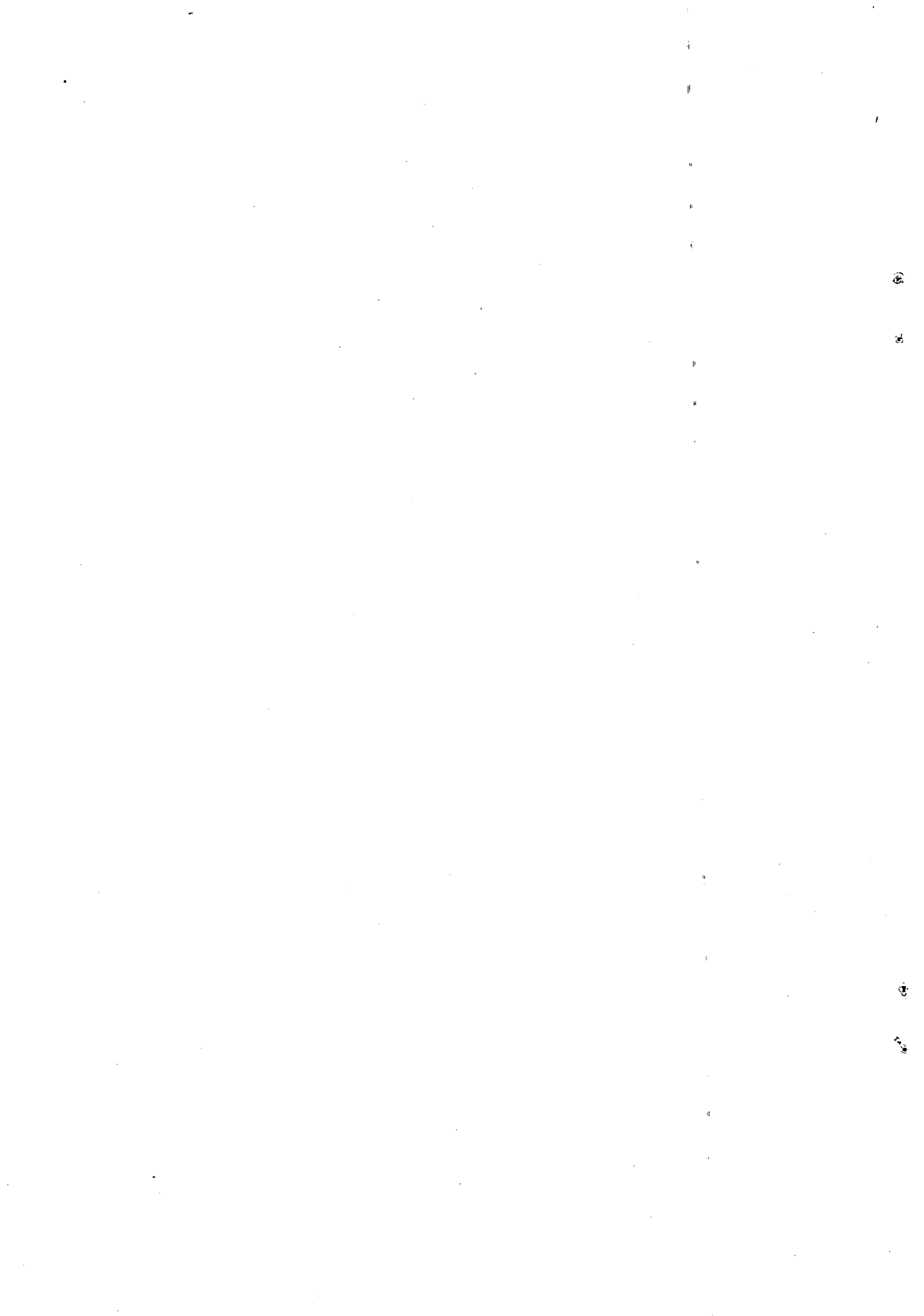
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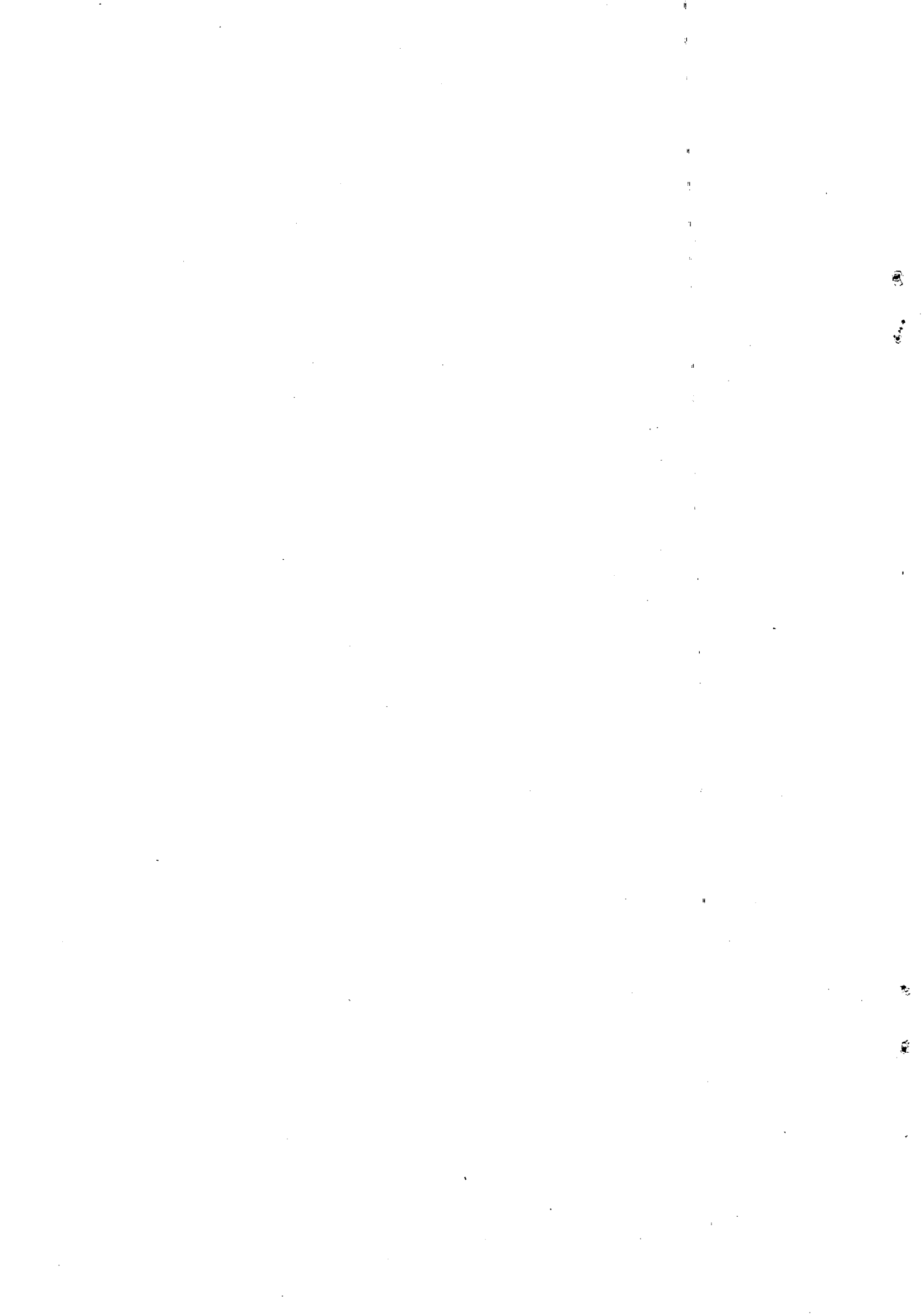
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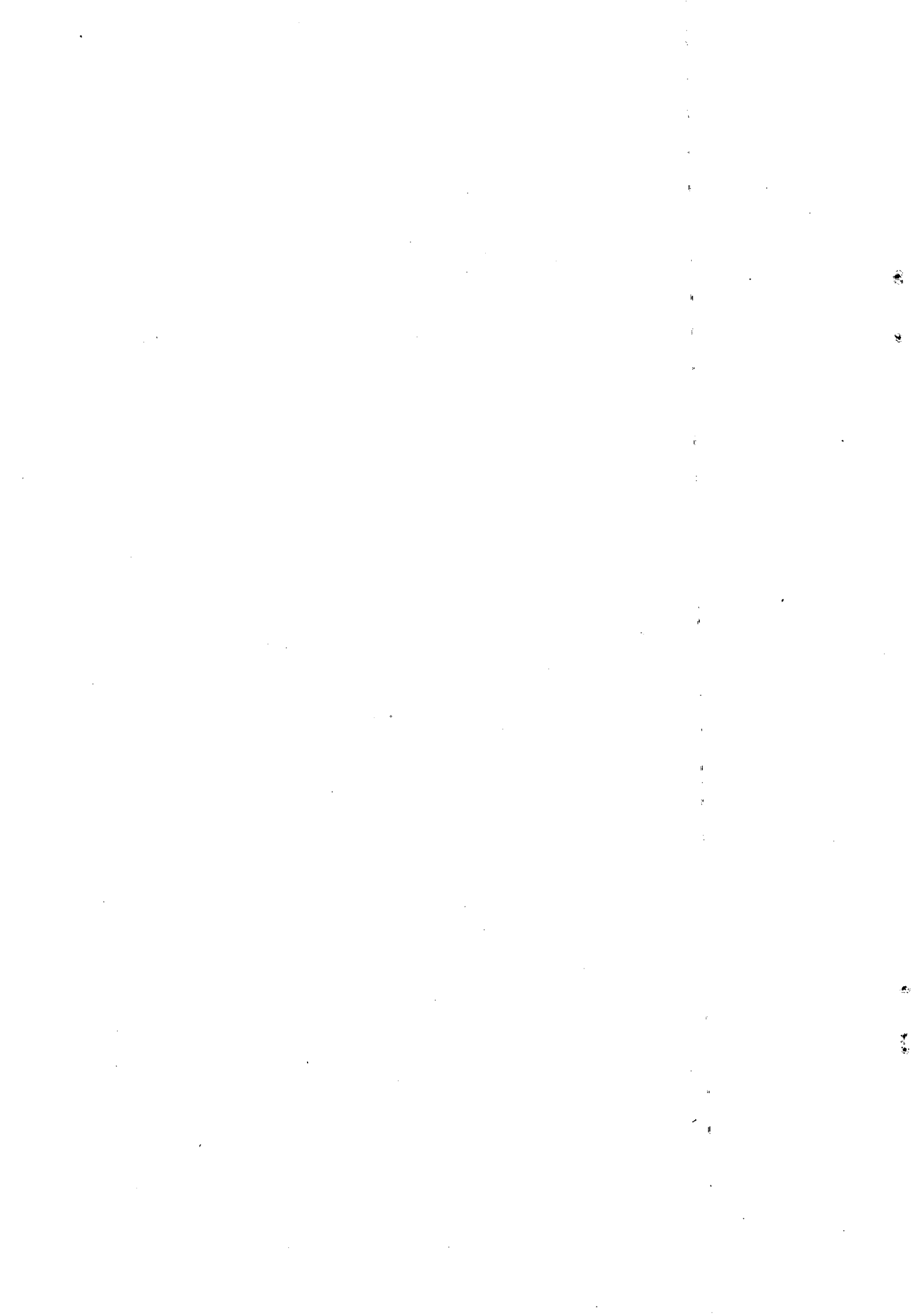
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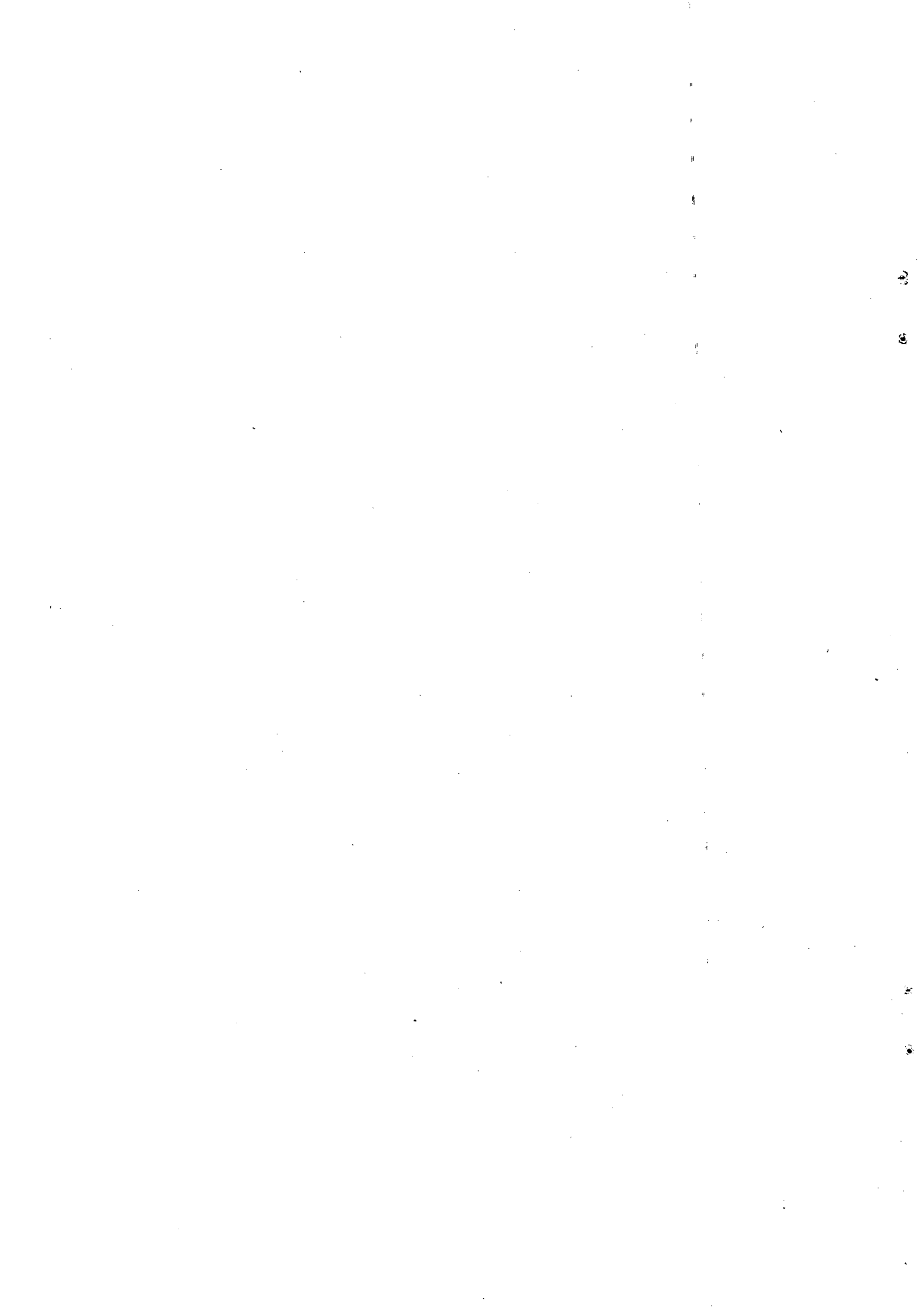
CHAPTER V - CURRENT KNOWLEDGE IN HUMAN TOLERANCES

Accidents involving bicyclists and moped users can occur in various situations, and contrary to pedestrians, mechanisms producing two-wheeler users injuries are numerous and can be very different from on case to the others.

For this reason, it is not possible to describe a typical kinematic of a two-wheeler user involved in a traffic accident.

The human tolerance can also vary according to the loading process: (age, diseases, conditions, anthropometry impact speed ...).

Tolerance can be considered in terms of severity: injuries sustained in real world accidents can have several degrees of severity, as simple bone fracture or severe internal organs contusions which are corresponding to AIS 2 or 3, are considered as tolerable.

There are few studies conducted to determine human tolerance of two-wheeler users involved in traffic accident. Nevertheless some of the studies dealing with pedestrians or car occupants can be taken into account.

1.   HEAD TOLERANCE

Concerning head tolerance, it is necessary to investigate separately cranial and/of facial head injuries and brain injuries.

1.1   BONE INJURIES

The tolerance of skull to fracture depends mainly from the dimensions of the impacting structure. The main values published by the litterature are reported in table 5.1.

Impacted area	Small		Large	
frontal	5	(1)	7	(2)
temporal	1.8	(3)	8.3	(4)
parietal	3.4	(1)	8.5	(2)
occipital	?		9.6	(4)

Table 5.1 : Tolerance of skull to fracture in KN
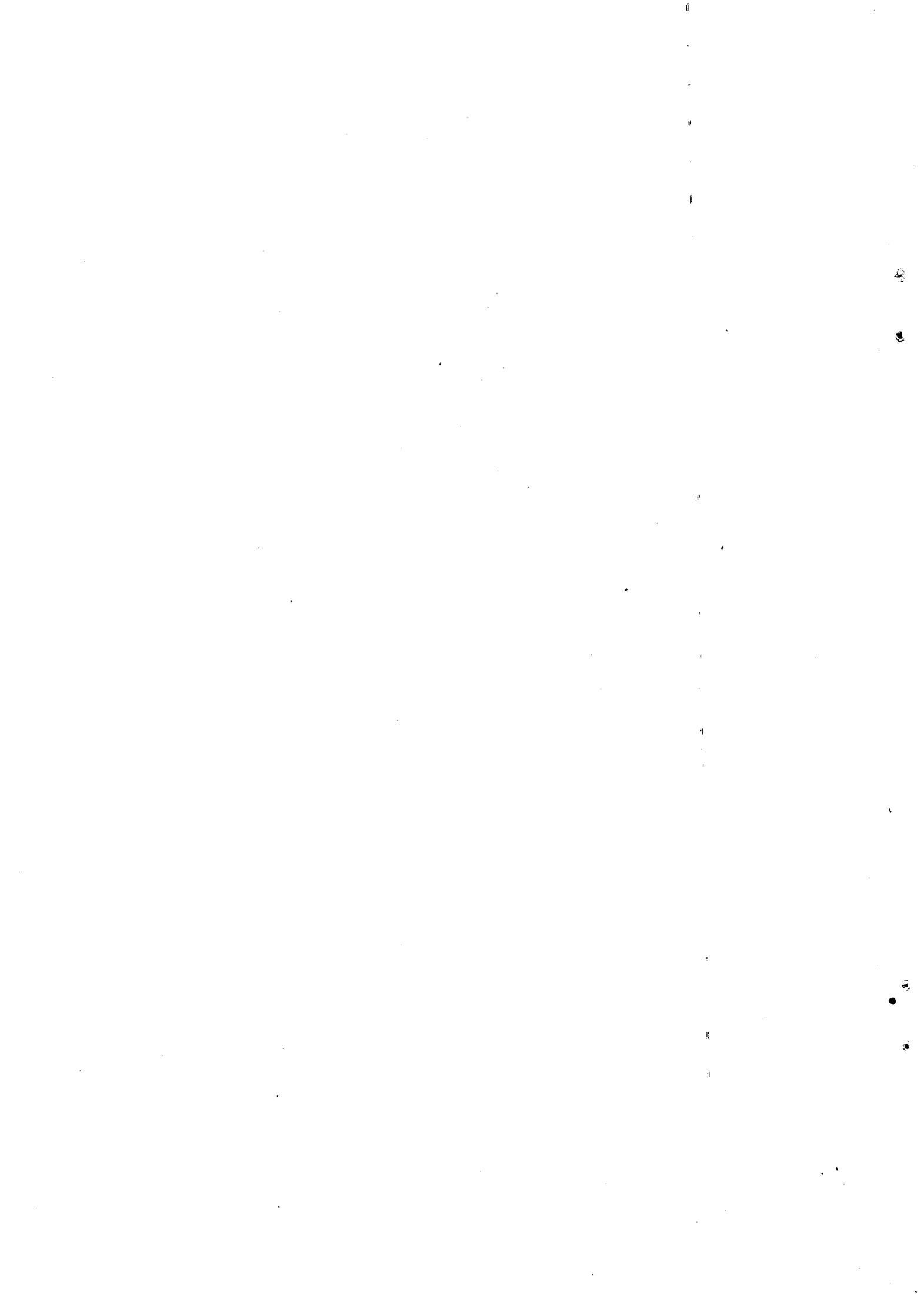
The tolerance of the facial bones is lower than the tolerance
of the skull.
Table 5.2 summarizes the main results found in the literature.

Tolerance force

zygóma	800 to 1800 (5)
maxilla	650 to 1000 (4,5)
mandible	800 to 3000* (5)
nose	1300 (6)

*depending on impact direction

Table 5.2 : Tolerance of facil bones to fracture in N

This two tables show the potential effect of helmet in avoiding
small impacts which correspond to the lowest skull tolerance,
and in protection facial bones from direct impact.

1.2   TOLERANCE OF THE BRAIN (brain concussion)

The brain tolerance is not well established, and brain injuries
have no evident correlation with skull fractures. Tolerance of
head as a function of pulse duration has been established by
Lissner (7) and is called "Wayne State Curve". The corresponding
parameter to this curve is the GSI (Gadd Severity Index) which
is defined by:

$$GSI = \int_0^t a^{2,5} \, dt$$

in which a is head acceleration in g's and the value of 1000 is
considered as the tolerable limit.

A more recent index called HIC has been developed more recently
and is used for car occupant frontal impacts. The HIC is defined
by the maximum value of:

$$HIC : \left[\frac{1}{t2 - t1} \int_{t1}^{t2} a(t) \, dt \right]^{2.5} (t2 - t1) \Bigg|_{max}$$
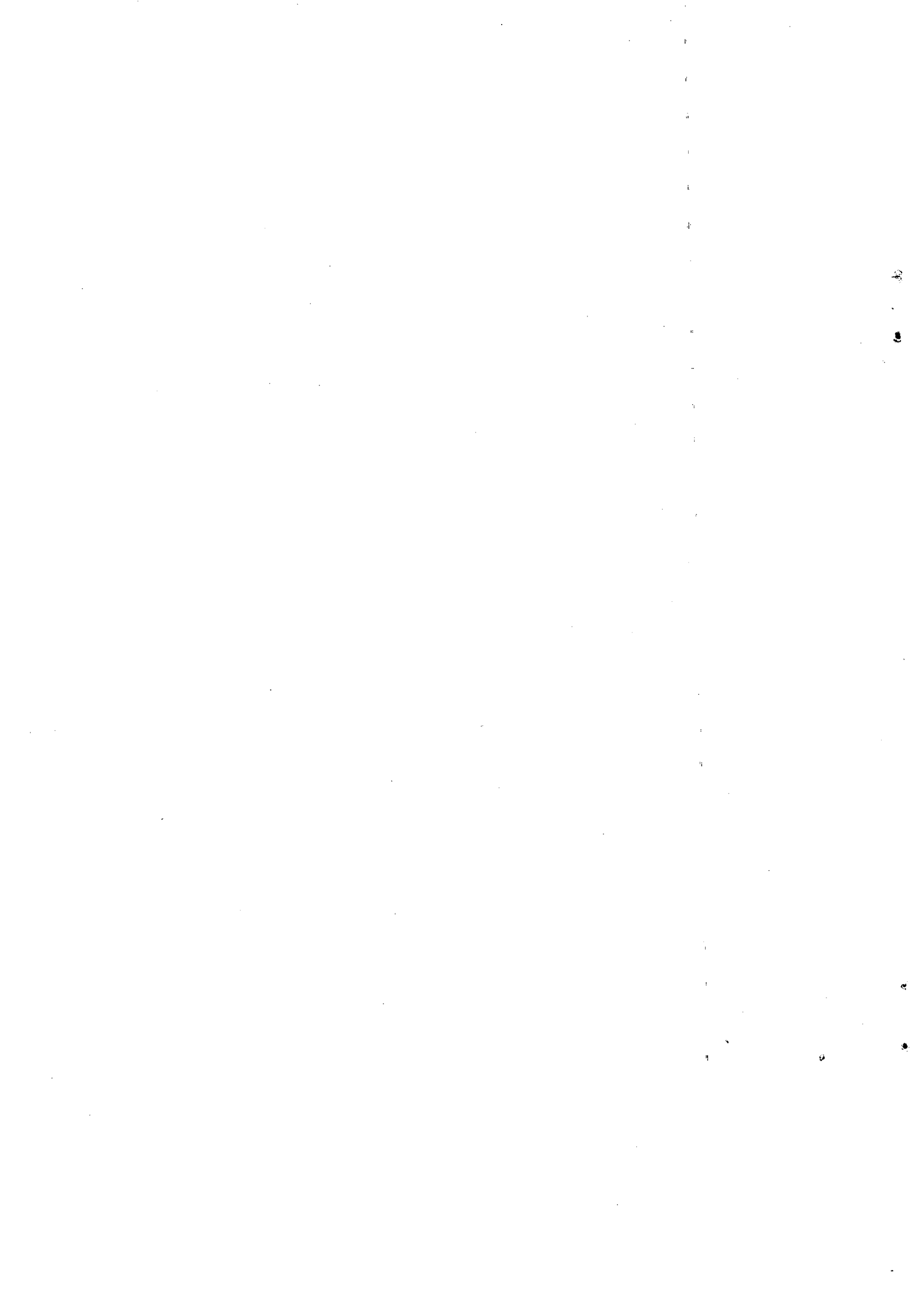
The proposed limit of tolerance for HIC is 1000 or 1500, but recent studies have shown that this criterion is not very pertinent to predict head injuries. Some other criteria have been proposed but none were widely accepted. However in the absence of a more pertinent criterion, the HIC can be accepted in dummy tests.

Two-wheeler accidents can correspond to large body motion and the wearing of a safety helmet could increase the amplitude of head motion.

For these reasons the rotational acceleration which has been proposed to be correlated with brain injury would be considered as a tolerance parameter.

Theorical analysis using the mechanics of similitude seems to indicate that children have a higher brain tolerance than adult (Dejeammes [8]), either if we consider translational acceleration or rotational one; this is confirmed by the higher breaking strenght of arterial tissues of children found by Yamada [9].

2.   THORACIC TOLERANCE

Recent studies on thoracic tolerance indicate that the tolerance to rib fractures is more correlated to thoracic deflexion than to thoracic acceleration, either in frontal or in lateral impact (Verriest [10], Walfish [11]). However the tolerance is not the same for frontal and for lateral loadings. The proposed value of tolerance is 30 35 % of the half thorax width in lateral impact.

Comparison of rib characteristics between children and adults seems to indicate that children can sustain higher thoracic deflexion without rib fracture but in this case internal thoracic injuries can occur. In general way, increasing the number of rib fractures enlarge the risk of thoracic internal organs injuries.

3.   ABOMINAL TOLERANCE

The tolerance if the abdomen has been studied with cadaver free falls hitting laterally an arm rest model (Walfish [12]).
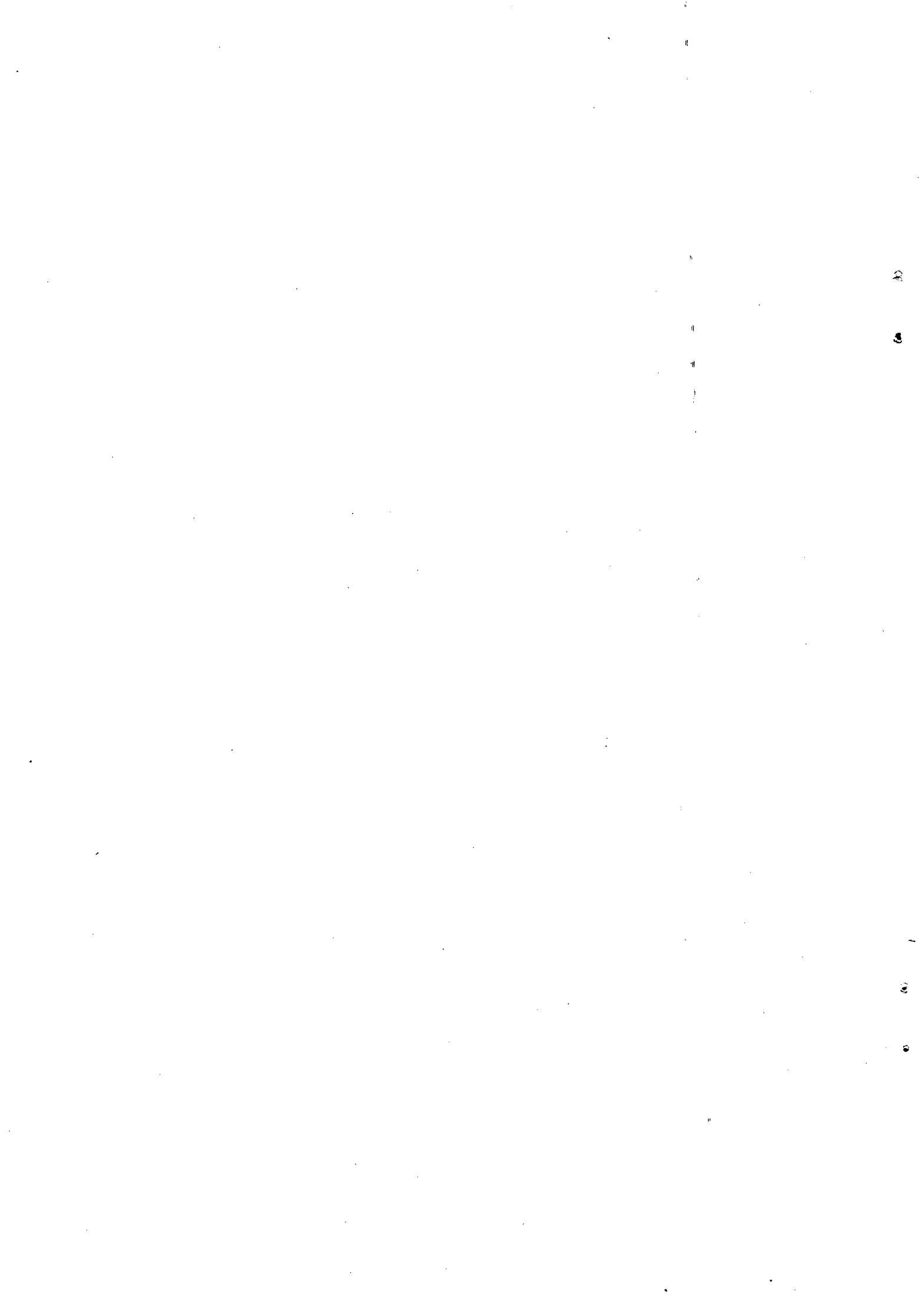
This study proposes a limit of 28 % of abdomen width corres-
ponding to 4.5 N impact force, as a human tolerance. These
tolerance data concern mainly liver injuries.

4. PELVIS TOLERANCE

The tolerance of the pelvic bones has been studied for car
occupants either in frontal or in lateral impacts.
In frontal impact the pelvis is loaded through the femur, when
knees are impacted this mechanism can be found as well in car
occupants as in some two-wheeler accidents. The proposed tole-
rance in this case is close to 10 KN (Evans [13]).

In side impact the pelvis can be loaded either through the hip
or directly on the iliac wing. These mechanisms can occur in
some two-wheeler accidents, as for example when a two-wheeler
is hit laterally by the front of another vehicle. The proposed
tolerance in this case is 10 to 12 KN impact force (Cesari [14]).

5. LOWER LIMB TOLERANCE TO FRACTURE

Several studies dealing with leg tolerance have been made
either for car occupants or for pedestrians.
The tolerance of the femur in bending fracture depends from
the point of impact, the lower tolerance corresponding to the
mid-shaft impact. In this case the tolerance seems to be close
to 10 KN.

Tibia tolerance to horizontal loading seems to be between 3000 N
and 9800 N depending on the impacted area with an average value
of 5000 N (15).
However a recent study conducted in Sweden[(*)] (Bunketorp [16])
has found a much lower value of lower limb tolerance. The value
of the momentum corresponding to the fracture is about 200 Nm
(Ashton [17]). However these values are related to a small sur-
face impact and the tolerance in a bumper-like impact is pro-
bably higher.
In general the child seems to have a tolerable bone strength
higher than the adults (Dejeammes [8]).

(*) dealing with pedestrian safety
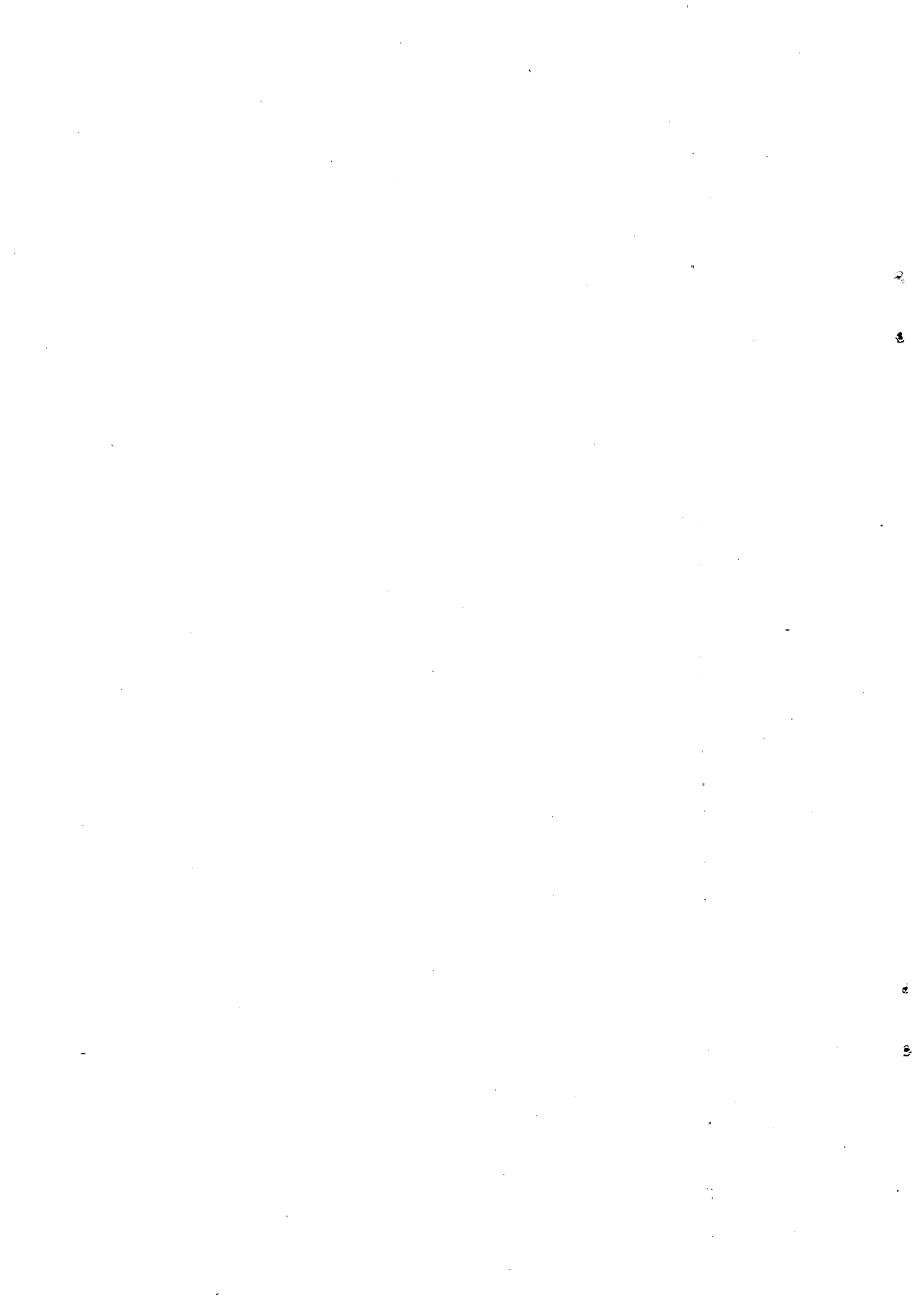
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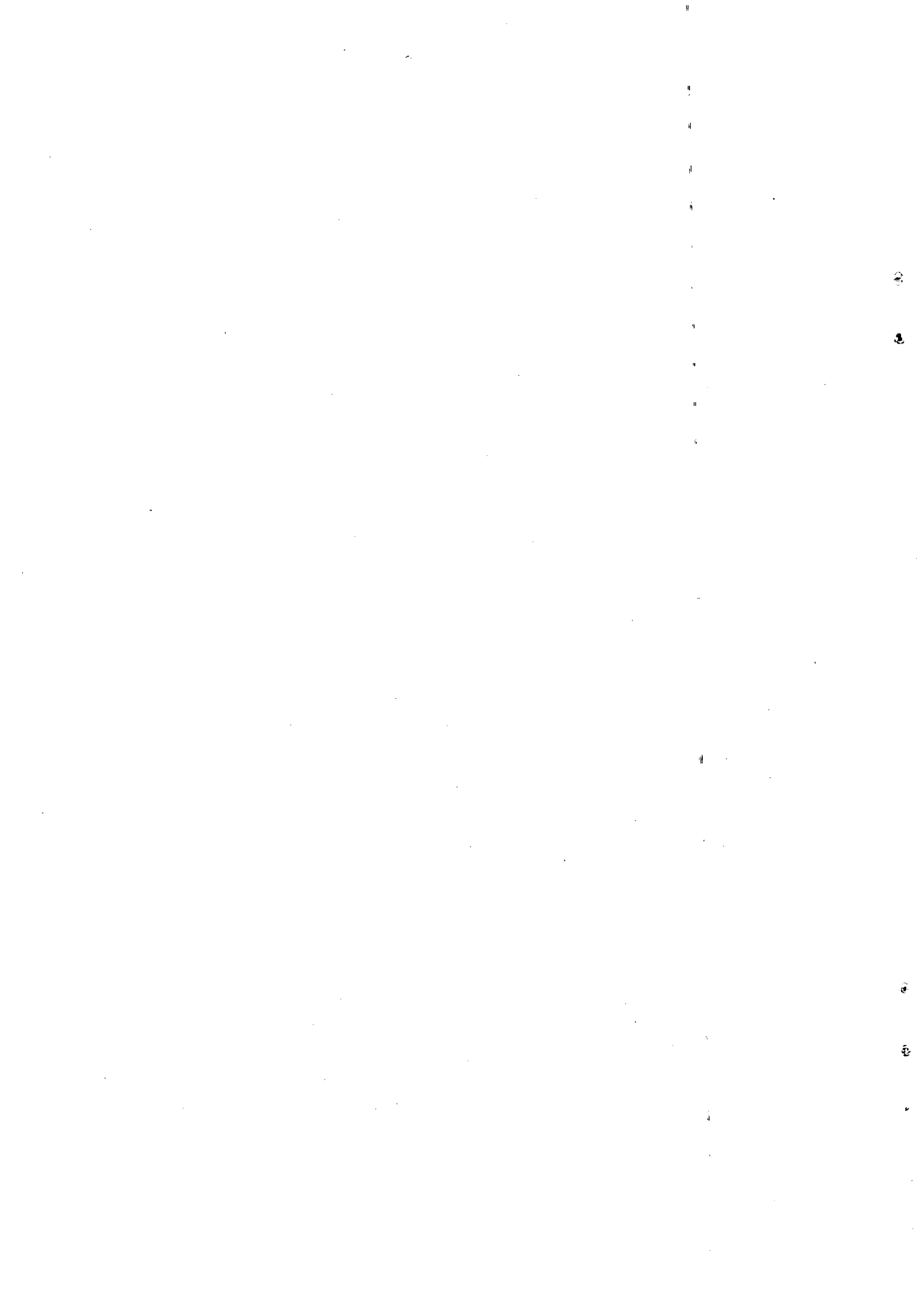
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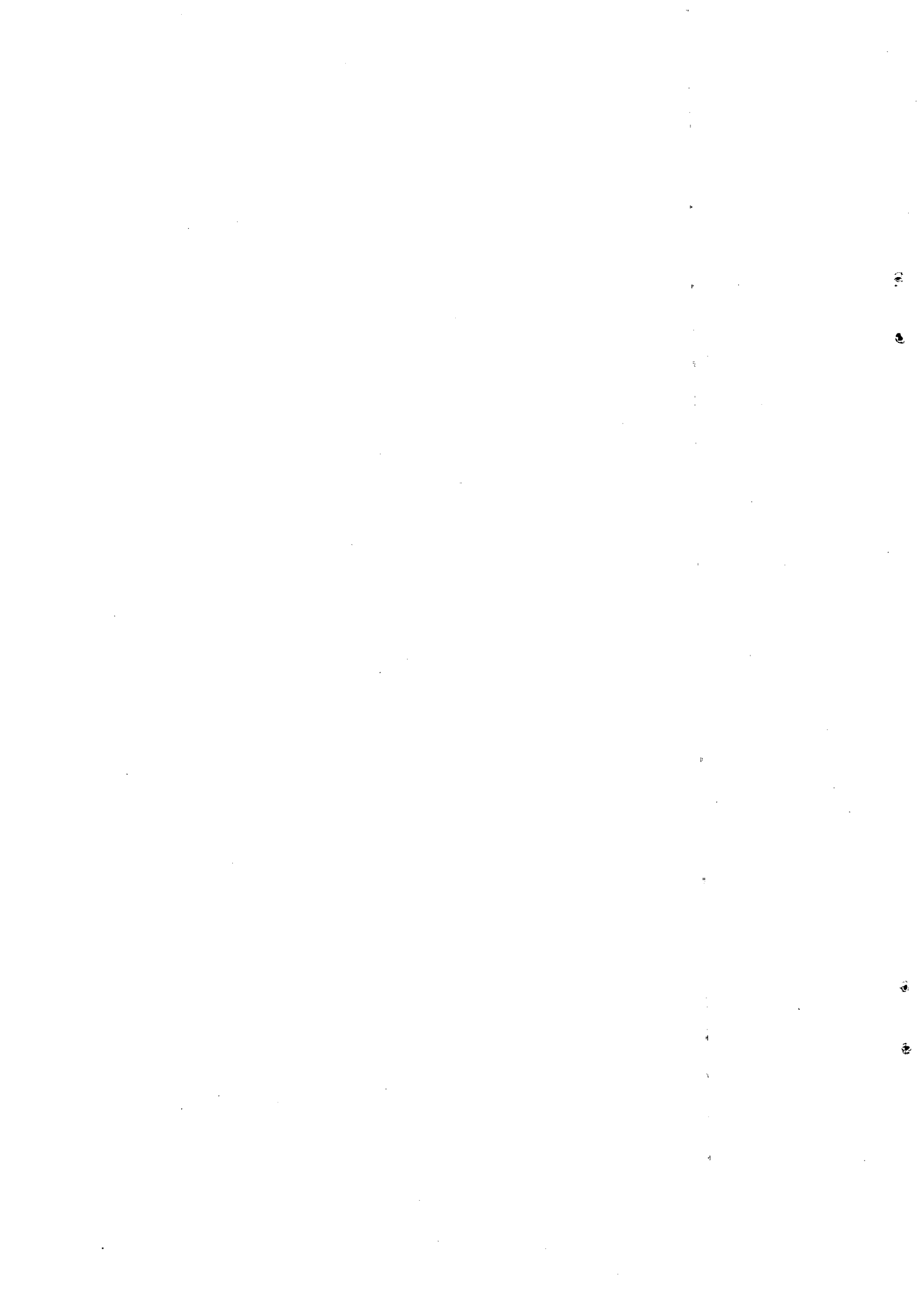
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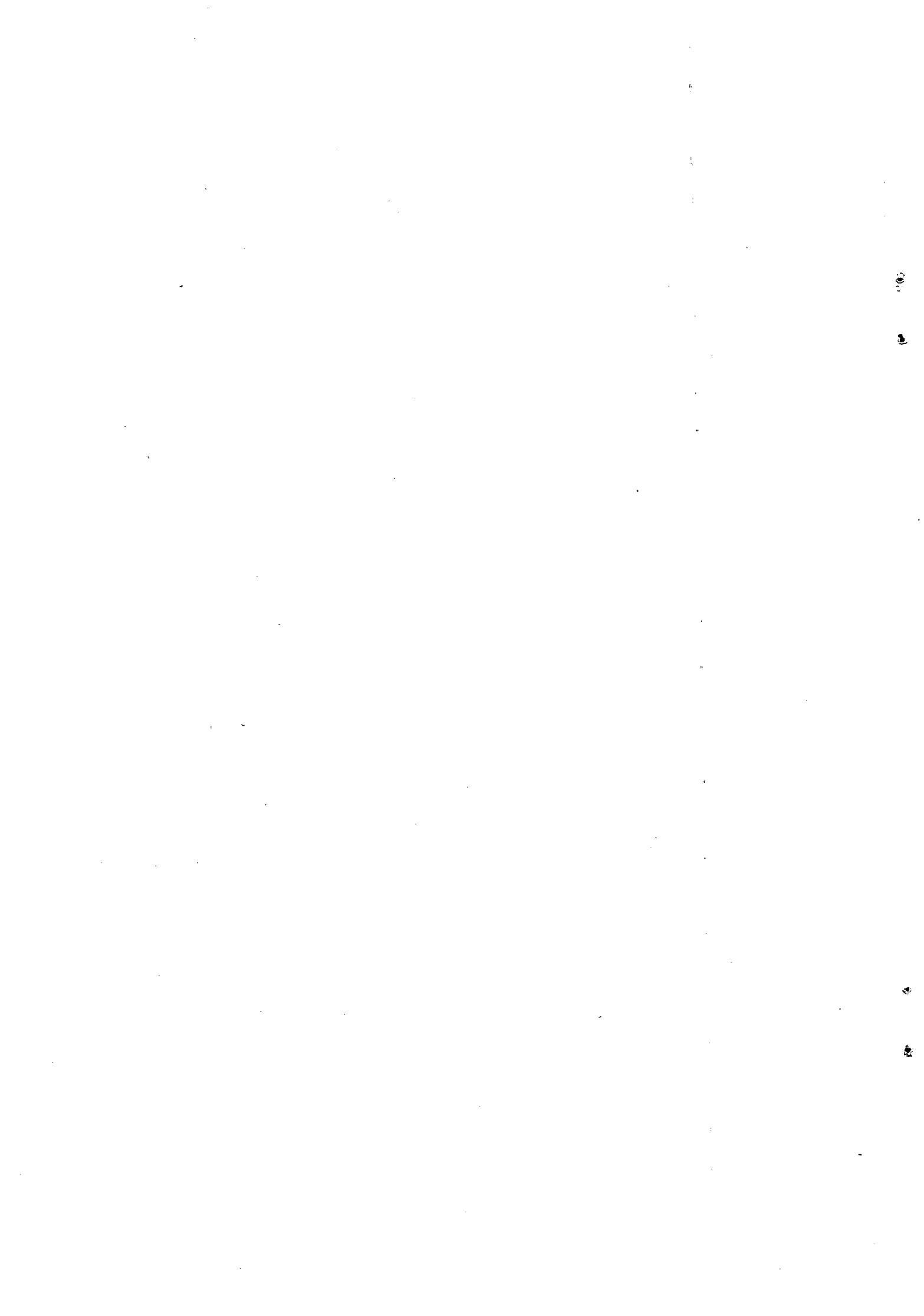
CHAPTER VI

EEVC W.G. 8

INJURY PREVENTION MEASURES FOR BICYCLIST AND LIGHT POWERED

TWO-WHEELER RIDERS

(in relation to other injury prevention measures).

Chapter VI - Injury prevention measures.

6.1   INTRODUCTION

This chapter will deal with:

1. Proposals for injury prevention of two-wheeler riders.
2. Consequences of these proposals for other groups of
   road users.
3. Consequences of (proposed) legal requirements for injury
   reduction of other groups of road users to the injuries of
   bicyclists and light prowered two-wheeler riders.
   The philosophy of the integral approach of the "safety
   Vehicle" will take a central place; at the same time it will
   be quite obvious that the amount of concrete proposals is
   limited due to just starting research activities in this area.

As stated in chapters II and III this chapter will deal with
the proposals as a function of the different relevant colli-
sion types. The proposals made in this chapter are mainly
based on information from literature.

6.2   PROPOSALS FOR INJURY PREVENTION OF TWO-WHEELER RIDERS

From chapter IV it follows that the contact with the car is the
leading cause of injury. Therefore efforts concerning the in-
jury prevention have to be directed to these contacts.

The proposals can be distinguished in proposals concerning:
-    the car
-    the heavy goods vehicle
-    the two-wheeler
-    the two-wheeler rider

In general:
the aim of these proposals in to influence kinematics and to
minimize the loads to the struck body parts.

CHAPTER VI

EEVC W.G. 8

INJURY PREVENTION MEASURES FOR BICYCLIST AND LIGHT POWERED
TWO-WHEELER RIDERS

(in relation to other injury prevention measures).

A. CAR - TWO-WHEELER COLLISION

CAR

The collision types F1, F2 en F3 (fig. 5, chapter II) for
bicyclist collisions and F1 and F2 for moped rider collisions
seem to be the most important (chapter II); in these colli-
sions the front of the car is hit.
Changing the stiffness of some parts of the car will probably
have the same positive effect on the injury minimization for
two-wheeler riders and pedestrians.
The optimum values for the stiffness from a view point of
biomechanical tolerance cannot be answered at this moment.
The parts of the car that have to be taken into consideration
depend on the collision types but vary from bumper to the upper
side of the windshield frame.

For shape the same variables as for pedestrian impacts seem to
be important but no concrete proposals can be made for this
moment, but it seems obvious that sharp protrusions and "popping
up" headlamps should probably have a negative effect.

Two-wheeler

F1: Side protection devices for motorcycles are proposed by
Bourret [3], Rau [6] and Taneda [9] (fig. 1 and 2).
According to Bourret the leg injury severity in a F1 type of
collision is strongly related to the mass of the two-wheeler.
Whether these side protection devices are realistic for mopeds
(or even bicycles) cannot be answered at this moment.
F2: The question whether the two-wheeler rider has to be ejected
over the colliding object (if possible) or has to be tightened
to his two-wheeler cannot be answered either at this moment.
Knee paddings were first proposed by Langwieder [12] (fig. 3).
The aim is to avoid contact with the colliding object. Whether
this can be effective in a frontal impact (F2) is doubtful.
If a rider is launched with his head first and he contacts the
motorvehicle, this will probably lead to brain stem injuries.
The helmet cannot protect against this kind of injury. Filler caps
or expander pins on handle bars are the cause of (minor) in-
juries (chapter IV), therefore sunken caps are applied on motor-
cycles and sunken pins on bicycles.

B. HEAVY GOODS VEHICLE - TWO-WHEELER

Chapter II indicates that the collision types F1, F2, S1, S2 and R1 are the most important.

Heavy goods vehicle

For F1 and F2 the same remarks as for the passenger car about stiffness and shape apply.

For S1, S2 and R1 side and rear- end underrun guards seem to be the most convrete proposals at this moment (Volvo [11]; Riley [7]; Gauss [13]; fig. 4, 5 and 6).

The use of better or additional side mirrors, will be benefi- cial, to give the truck driver a better overview. (par. 8.3)

Two-wheeler

F1, S1 and R1: The knee padding proposal made by Langwieder [12] does not seem to be so effective due to the dimensions of the heavy goods vehicle.

F2: Whether the suggested side protection will be effective for this accident type is an open question because the first impact point will probably take place at a higher level then for collisions with a passenger car.

S2: No protection proposals known.

C. TWO-WHEELER INJURIES

Adequately designed child seats and/or a simple dress-quard can prevent bicycle spoke injuries.

D. TWO-WHEELER RIDERS

Helmets and protective clothing can prevent injuries. The posi- tive effect of crash helmets in motorcycle accidents is well documented. The effect of moped helmets is not so well known. In a Dutch study made by SWOV it is described as "a decrease in the chance of getting fatally injured of 40% and a saving of 500-600 lives for the years 1975 until 1977". (SWOV [8]).

The proportional share of head injuries differs considerably
for the (not helmeted) bicyclists and the helmet wearing moped
riders for the different studies:

		bicyclists	moped riders
Grattan	[14]	48 %	╱ 26 % *
Huijbers	[15]	51 %	36 %
Nicholl	[16]	75 %	52 % *
Otte	[17]	85 %	60 % *

(* including motorcycle riders)

The wearing of helmets seems to be an obvious explanation for
these differences, but differences in accident type and colli-
sion type for bicycles and mopeds may also contribute.
Adequate protection against head injuries may be achieved by
the use of helmets. For bicyclists this kind of protection is
still not very widely accepted.
The reason for this is to some extent that existing bicycle
helmets tend to become uncomfortable due to inadequate venti-
lation.
For moped or motorcycle helmets there is amongst others an
European set of requirements (ECE Regulation number 22); some countries
already have requirements for bicycle rider helmets (Technisearch
[10], Gilies [4]).
According to the studies of Otte [17], Appel [19], Pedder [20],
and Ramet [21] some of the crash-helmets came off during accidents.
The wearing of protective clothing by motorcyclists has some
positive effect on the minimazation of injury severity, accor-
ding to Hunt [6] and Aldman [1]. The question is whether this
is a practical solution for riders of lighter two-wheelers?

E. SPEED AT IMPACT

Speed at impact will probably be strongly related to injury
severity, especially for the impacts with the fronts of motor
vehicles.
Lowering the speeds at impact, in any way, will therefore be
favourable.

2. CONSEQUENCES OF THESE PROPOSALS FOR OTHER GROUPS OF ROAD USERS

A. CAR

As far as stiffness is concerned the consequences may be a (small) reduction of the decelerations for e.g. car-to-car collisions.
Because there are no concrete proposals for shape at the moment there are no consequences either, but contradictions may occur.

B. HEAVY GOODS VEHICLE

If dimensions of the side and rear-end underrun guard are properly chosen, a positive effect for other accident types may be expected.
Rear view mirrors mounted on the sides of vans and small trucks may extend beyond the sides of the vehicles and pose a hazard to other road users, e.g. two-wheeler riders (Fife [18]).

C/D. TWO-WHEELER

The proposed knee-paddings may have a negative effect. If the attempt is not so succesfull the two-wheeler rider might fly into the interior of the car and hit the driver or a passenger, just as in other cases without knee-padding.

E. TWO-WHEELER RIDER

Contact between a helmeted two-wheeler rider and a not-helmeted victim may be a hazard for the unprotected one.

3. CONSEQUENCES OF (PROPOSED) LEGAL REQUIREMENTS FOR INJURY REDUCTION OF OTHER GROUPS OF ROAD USERS TO THE INJURIES OF BICYCLISTS AND LIGHT POWERED TWO-WHEELER RIDERS

As far as bumperheight is concerned, there is some doubt whether the required value is benificial for pedestrians. (e.g. ECE Reg. 42).
Considering two-wheeler accidents the effects are even less predictable as yet.

The other requirements, as e.g. for front-front of front-side impacts, do not seem to have so much effect on the injuries of two-wheeler riders due to the differences in the amount of energy to be dissipated.

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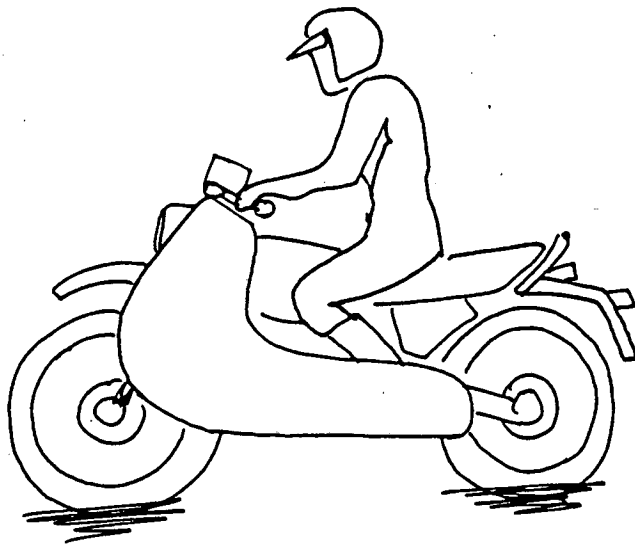
fig. 1 Side protection device proposed by Bourret [3].

SH-O 350 SS FRONT WHEEL, SHOCK,
& HANDLEBAR ASSY.

H-O 350 SS FRONT WHEEL
AND SHOCK ASSY.

H-O 350 SS REAR WHEEL, SHOCK,
& MODIFIED SWING ARM ASSY.
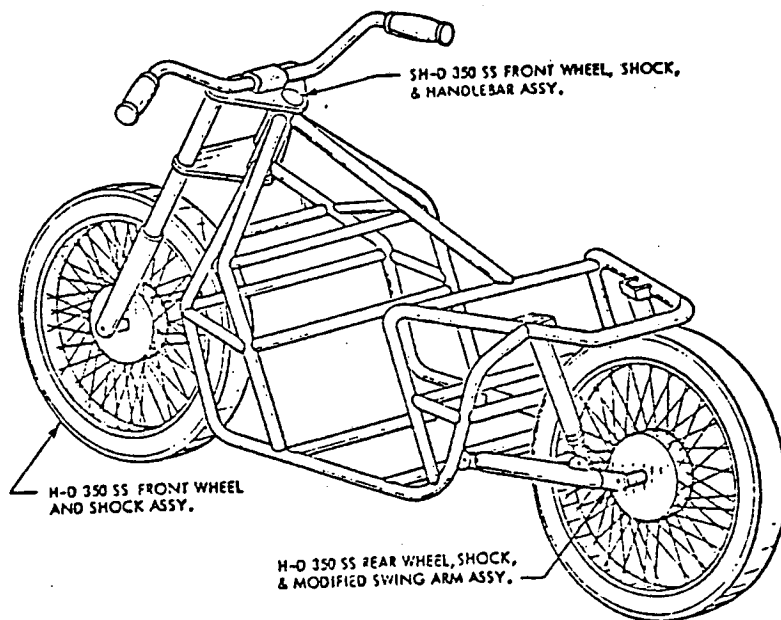
fig. 2 Side protection device proposed by Rau [6].
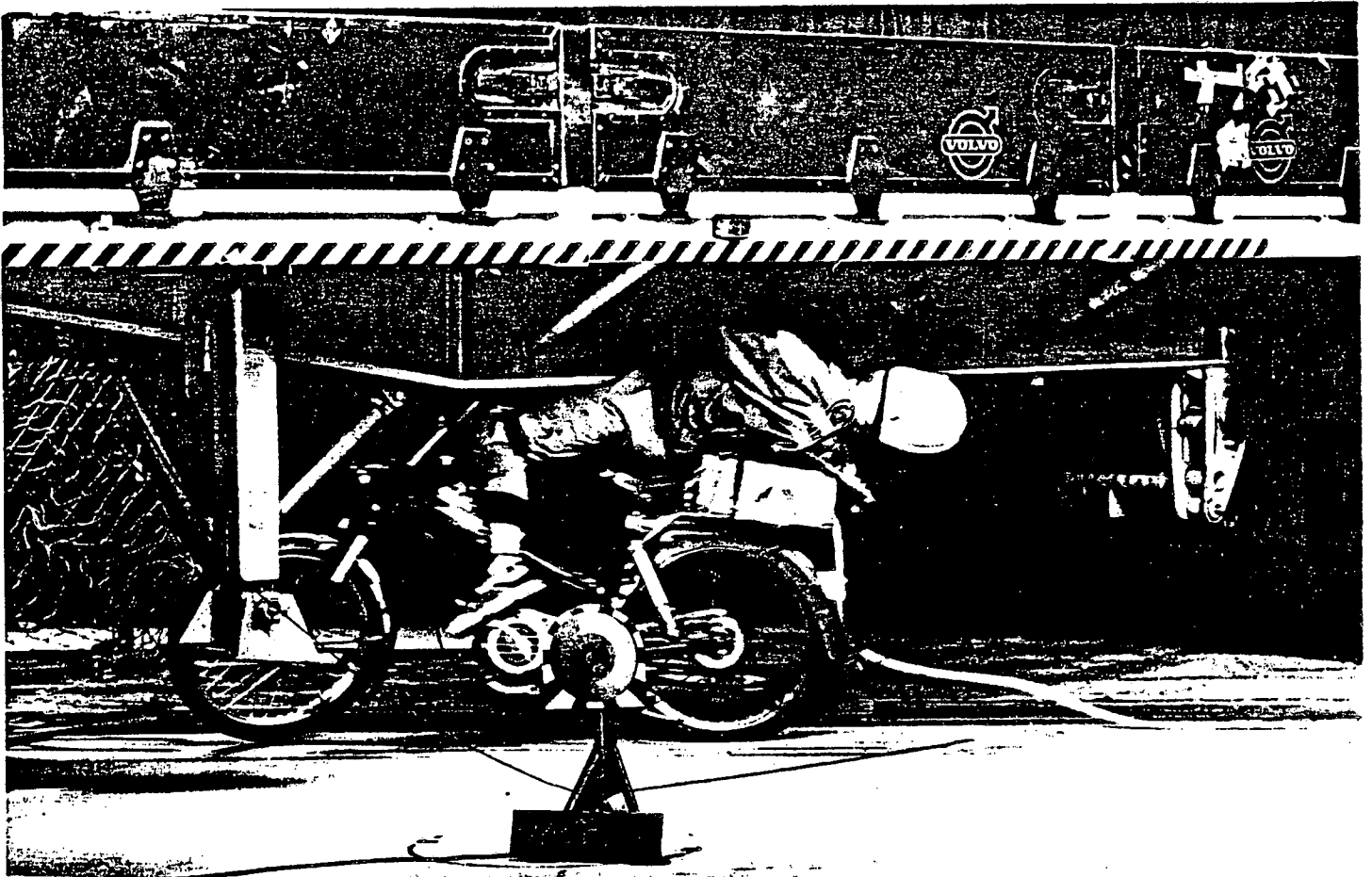
fig. 4 Moped-heavy goods vehicle collision simulation (type S₁)
Volvo [11].

fig. 6 Side protection device for
heavy goods vehicle.
Automotive Engineer [2].

fig. 5 Side protection device
for heavy goods vehicle.
Volvo [11].

Knie-Abstützung

möglichst hohe Sitzflache

möglichst großer Radstand

HUK Verband	Vorschlag einer Sicherheits- konzeption für Motorräder / Moped	Bild 13

fig. 3 "knee-padding" ejection device proposed by Langwieder [12].

C H A P T E R VII

TEST PROCEDURES

1. INTRODUCTION

The test procedures examined in this chapter are aimed at
ensuring conformity of the vehicle (bicycle, moped car and
truck) and/or safety device (helmet, underride protection,
etc.) to bicycle and moped rider protection requirements.
As said in the previous chapters accident case history for
bicycle and moped riders is ample and cannot be reduced to
a single standard situation.
Doubts also exist (see chapter II) about the possibility of
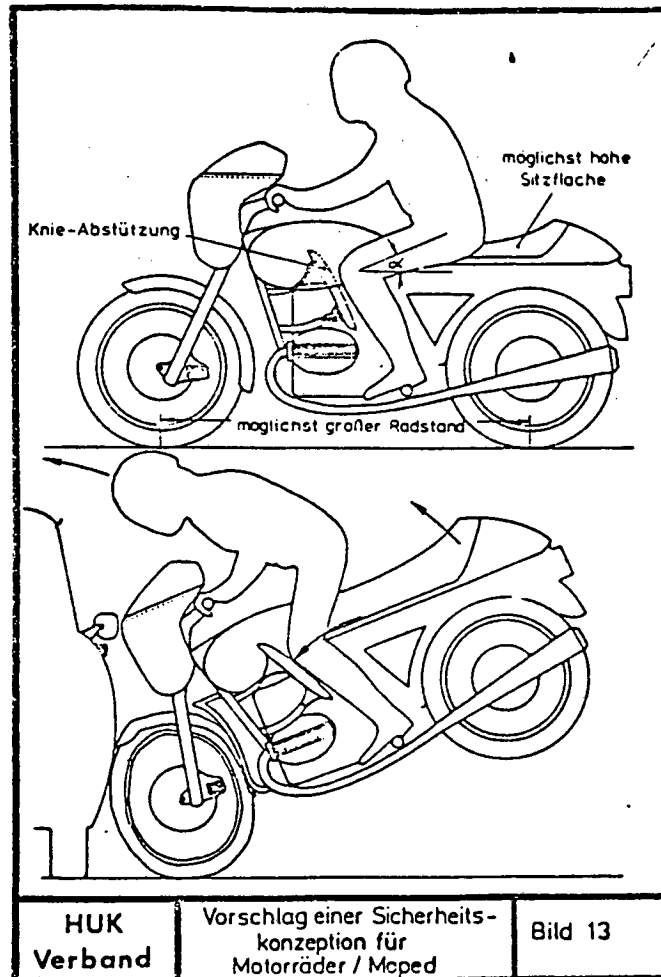considering the bicycle and moped together for studying any
countermeasures.
It seems, in fact, that the two vehicles give rise to two
different types of accidents.
Because of this complexity, proposals on test procedures for
bicycle and moped rider safety are practically nonexistent or
incomplete.
To conclude, it is evident that, as far as test procedures
for the protection of bicycle and moped riders are concerned,
there are no exhaustive proposals.
It is therefore necessary to draw from the experience acquired
in other areas of safety and to extrapolate the methods that
must obviously be verified experimentally to make sure that
they are feasible and meet the objectives.

2. DISCUSSION ON POSSIBLE TEST METHODS

The test methods which can be adopted are as follows:
- Component tests
- Full-scale tests
- Sub-system tests
- Validation tests by mathematical models

Each of these methods has advantages and disavantages and,
depending on the situation, it may be more convenient to adopt
one method rather than another, or even use them together.

It is, however, important to point out that the degree of knowledge of the phenomenon and the devices available determine the test method to be developed.

For example, it is impossible to develop a test method based on a full-scale test if the accident mode is unknown (impossibility of obtaining "the test conditions" scientifically) or of a reliable dummy is not available (impossibility of having a "reliable conformity response").

2.1 COMPONENT TESTS:

are tests performed on a single component or on a single safety device. Requirements are either design (geometrical and/or stiffness) or, in the more sophisticated cases, biomechanical.

Included in this category are some of the first regulations developed for vehicle safety; it is, in general, a primitive approach whereby the result on a single component is often taken to represent overall safety provided by the vehicle.

When component tests belong to a series of tests whose wider scope is to cover the various aspects of safety, there is a shift towards methods based on "sub-system tests".

Component tests are still valid today in those cases in which it is demonstrated that the objective is attained with a specific solution (e.g. if the objective is protection of the cyclists head wherever it will strike, the "helmet" solution can be accepted and this component can be submitted to various tests).

By applying the above to the specific case of the bicycle and moped rider it is possible to state that a method based on component tests has the following advantages and drawbacks:

- It is relatively easy to define, in the sense that a single aspect of the phenomenon can be examined (e.g. impact of the head) and that requirements can be provided even with very little knowledge of the overall phenomenon

- Method efficiency is low and the method itself can prove to be inadequate because influence of the vehicle shape on bicycle and moped rider is not taken into account.

In this case, design requirements would prove particu-
larly detrimental because they would be applied to all
vehicles (even where not needed) and limit design.
The result would be a poor quality product and a high
cost for the user, but upgrading of safety would not be
ensured (e.g. when a bonnet is specified).
- This method can be applied correctly only to tests on
particular safety devices developed for a specific pur-
pose such as helmets.

2.2 FULL-SCALE TESTS

A full-scale test reproduces the conditions of a typical road
accident.
This method poses many problems, the most important point being,
however, the definition of test conditions. It is, in fact,
necessary that the full-scale test be equivalent to the actual
accident. In the case of the bicycle and moped rider (see
chapter II) more than one test condition must be defined and this
poses a few serious economic problems when a new model is devel-
oped and approved.
The situation with regard to the test equipment to be set up is,
instead, more complicated. In particular, no reliable dummies
representative of cyclist's are available today and may be that
the physical parameters traditionally recorded on dummies are
inadequate for this type of accident.
Moreover, for full-scale tests aimed at evaluating the effec-
tiveness of a modification to the bicycle or moped, there would
also be the problem of designing one or more standard impactors.
As to this method, it is possible to conclude that its adoption
for rider protection is more difficult than for other types of
accidents. Because of the need to conduct more than one full-
scale test and the lack of reliable dummies, other methods
should be adopted.

2.3 SUB-SYSTEM TESTS

Are those "series of tests on different components" whose results
permit an assessment of the overall degree of protection provi-
ded to the rider in a specific accident.

The difficulty of developing sub-system tests, as defined
is due to the need to know the phenomenon perfectly and to
the required capability to shear it into many single tests;
this taking into account the interaction between the impacts
of the various components and body segments (e.g. for a
given impact speed the shape of a vehicle can determine par-
ticular data on speed, area and direction of impact of the
cyclist's pelvis against the bonnet; the type of impact of
the pelvis and vehicle shape affect the head speed, area and
direction of impact; etc.).

2.4 VALIDATION TESTS BY MATHEMATICAL MODELS

Development of a test method based on mathematical models will
not be feasible for many years, because the use of mathemati-
cal models in two-wheeler safety research is relatively recent.
It should also be noted that the use of mathematical models for
type approval on different computers and at different Test Centers
poses the problem of issuing such procedure standards as to
ensure response identity. This is a field of activity for which
the existing Technical Services are probably not yet prepared.
But it enables a simulated vehicle to be assessed before it is
actually produced.

3. CONCLUSIONS

None of the methods examined is capable today to verify the
degree of protection that can be provided to a struck cycle
or moped rider. There are no proper validated mathematical
models of cyclists colliding with cars or heavy goods vehicles
at this moment and, above all, problems for transforming a
model in a type approval instrument would arise.
The full-scale test approach is likewise unfeasible. There is
no single equivalent test.
Several full-scale tests should have to be carried out and the
test device (dummy) is not reliable, component tests neglect
the effect of vehicle shape on the kinematics of the cycle and
moped rider.

Knowledge of rider collision is insufficient to permit the
development of a method based on sub-system tests.
The only approach feasible, in which it is desirable to carry
out reasearch, studies and design of adequate devices is the
development of a hybrid method based on the use of a bicycle
and moped rider elementary mathematical model to determine the
impact conditions of each body segment and on tests of the
corresponding elements.
The elementary model is not used to evaluate impact severity
but only to determine the initial conditions for testing the
parts struck by the pelvis, chest and head. Moreover, this
model defines the angle, direction and impact velocity for each
body segment.
It is, in practice, a sub-system test method integrated with an
elementary mathematical model.
An approach of this type can only be feasible when the approach
for protection of the pedestrian is also of the same type. In
fact, both pedestrians and cyclists are unprotected road users
for which similar countermeasures should be developed.

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CHAPTER VIII

"ACCIDENT PREVENTION"

8. ACCIDENT PREVENTION

Accident prevention or primary safety measures can make important contributions to the safety of the cyclist or moped rider. Accident studies suggest that conspicuity is a factor in accidents involving the two-wheeler and another vehicle. The parameters influencing conspicuity are related to the two-wheeler and its rider (active lighting, retroreflective materials and the riders clothing), to the other vehicle (optimal head-lamps, good view) and the surroundings (other light sources).

In the overtaking situation the gap left by the driver when overtaking the two-wheeler is critical and experiments show that the percentage of vehicles passing very close can be substantially reduced by 'spacers' and conspicuity aids.

Better brakes will reduce injuries by avoiding accidents or reducing speed at impact, specially in rainy conditions.

Test results are given showing that with the correct combinatin of rim and brake block significant improvements are possible. The state of maintenance of the two-wheeler has been found to be an important factor in many accidents and results of a survey are given. Studies on bicycle stability and manoeuvrability are also reported which show significant differences between different styles of bicycles and mopeds.

8.1 CONSPICUITY

8.1.1 Introduction

The conspicuity of bicycles and mopeds is an important factor for the prevention of accidents. The conspicuity presupposes an observer for which the different objects must be conspicuous: this observer obviously is in many cases the driver of a car. A number of factors may influence, hamper or even obstruct the visual observations to be made by those drivers. Concpicuity will be described for daytime and for nighttime.

8.1.2   DAYTIME CONSPICUITY

8.1.2.1 Accident Studies.

From accidents studies described in Chapter II it follows
that two-thirds of the injury accidents involving a pedal
cyclist occur at junctions, when in most cases the collision
partners were travelling on a different road before collision.
In another study interviews with involved drivers who had not
given way when emerging from junctions into the major road
indicated a lack of awareness of the presence or movement of
the cyclist [4]. Cyclists often wear dark clothing and in
one survey only about 10 per cent of cyclists were wearing
high visibility aids.

In addition a two-wheeler rider presents a relatively small
area to other road users, the frontal area being only a third
that of an averaged sizes car. The rider is also readily ob-
scured by roadside objects, other vehicles, windscreen pillars
etc. The rider is often near the edge of the road and may be
overlooked if a driver carelessly directs his attention only
at heavier faster vehicles closer to the centre of the road.
In cases where the driver fails to give way the conspicuity
of the frontal aspect of the rider is likely to be most impor-
tant and since most accidents occur during daytime, initial
studies at TRRL concentrated on comparisons of frontal con-
spicuity in daylight. From the accident analysis in Chapter
II it is not possible to determine the number of cases where
the driver failed to give way to the cyclists or moped rider.
Where the rider is at fault the importance of conspicuity
may be less although in instances where he is highly visible
the driver may see the rider sooner and appreciate his speed
and direction more accurately allowing more effective avoi-
ding action to be taken.

8.1.2.3 TESTS AND SURVEYS.

In a TRRL-study it was decided to use a peripheral detection
technique similar to that used by Horberg and Rumar [5] to
evaluate high visibility aids for cyclists because the expe-
rimental conditions resembled a cycle accident situation
that is common at junctions.

The test conditions are shown in Figure 1.
Under constraint of an operational task (subjects were required
to fixate a visual display and repeat random numbers that
appeared), the driver had to signal when he first became aware of
the cyclist. The detection distances were used a measure of
conspicuity.
Initial tests [6] indicated that bicycle attachments were
not as effective as clothing items in making the cyclists
detectable and that the brightest materials (highest lumi-
nance factor) performed best against commonly encountered
backgrounds. Colour was found to be a less significant
factor than brightness.

Further tests [7] were therefore aimed at establishing the
most effective clothing styles all made from one type of
bright material. This was a fluorescent greenish yellow woven
nylon material with luminance factor of 74 per cent. (CIE
chromaticity coordinates were $x = 0.36$, $y = 0.51$). This cloth
was used to make five types of visibility aid which were tested
against a natural background of trees and shrubs using the
peripheral vision detection method. The items were worn over a
black jacket of near zero luminance factor. This jacket worn
alone was also used as a controle. Eighteen observers took part.
They were selected on age and sex to be representative of the
motoring population. For each observer there were eight trials
per option, the order of presentation being balanced to reduce
the effects of time dependent factors such as fatigue and ambient
illumination.
The average detection distances for each option are given in
Table 1.
Testing between means it was shown that the jacket was most
effective having a significantly longer average detection distance
thant the other items.

The effectiveness of conspicuity aids in the overtaking situa-
tion where the visibility of the back is likely to be important
was assessed by measuring the gaps left by overtaking vehicles.
It was considered that an effective aid would be one that signifi-
cantly reduced the number of close passing vehicles i.e. those
passing within 0.8 m of the cyclist's elbow on the off-side.

An ultrasonic device attached to a front carrier of a bicycle was
used which when actuated by the test cyclist automatically recorded
the closest passing distance between the bicycle and nearside of
the overtaking vehicle. It measured the gap to within a few centi-
metres and automatically recorded the distance in one of eight
passing distance bands. The clothing items described above were
tested in turn in daylight on four straight sections of road. The average
results are given in Table 2. It can be seen that the jacket had
the largest effect.
The number of close passing vehicles was more than halved compa-
red with the controle. The effect of brightness of fabric was
established by making a number of jackets of similar colour
(greenish-yellow) but of widely different luminance factor.
Results are given in Table 3.
Tests were also carried out on white, yellow and orange colou-
red jackets of similar brightnesses and as expected their
effects on passing vehicles were not significantly different.
In addition to providing effective conspicuity aids for the rider
there are other measures that may prove effective. A number of factors
may influence the visual observation made by drivers. The visual scene
could be structured so there is less demand on drivers limited attention
span, thus irrelevant objects that could distract or hamper the obser-
vation of the cyclist could be removed or repositioned.
Glare from the sun can be annoying and dangerous and signalling lights
should have adequate luminous intensities to ensure a conspicuous signal
under most of these conditions.

8.1.2.4. DISCUSSION AND CONCLUSIONS

There was good agreement between the results from daytime detec-
tion and public road experiments indicating that a jacket was
more effective than all the other aids tested. A waistcoat styled
aid was the second most effective in both studies.
When viewing from the rear it is likely that the arms of the
jacket contribute only a small amount to the overall conspicuity
because the backs of the arms were poorly illuminated. From the
front, however, the tops of the arms were visible and these were
relatively well illuminated, receiving the direct light from the

sky and therefore they contributed significantly to the visibility of the cyclist. In this study and in a previous pilot experiment [6] a jacket was shown to be more effective than a waistcoat when viewed from the front. Drivers' increased awareness of the presence of the rider and earlier detection when approaching are possible for the larger gaps left by overtaking vehicles.

The relatively small and statistically non-significant effects of the armbands and belt are probably due to their small total area. For its size the hat performed well and this is probably due to its relatively high illumination receiving direct light from the sky. Its domed shape resulted in high luminance or brightness levels when viewed from most directions. The jacket is preferable to the other aids for the additional reasons that arm signals are more conspicuous and the sides of the rider are likely to be more visible. Tests on the roads with jackets of various reflectances and colours indicate the importance of brightness rather than colour in determining the conspicuity of clothing. However there are likely to be a number of situations where colour contrast may aid detection because luminance contrast is low. For example where the rider is viewed against a bright desaturated background such as a concrete façade or cloudy sky.
To offer maximum visibility a conspicuous garment should be made from material having both high luminance factor and highly saturated colour.

Finally a conspicuous garment must be attractively styled and be comfortable to wear as well a retailing at a reasonable price if its use is to be encouraged.

8.1.3. NIGHT-TIME CONSPICUITY

8.1.3.1 ACCIDENT STUDIES
A comparison of accidents in Belgium, Denmark, Spain, Germany and Ireland [1] showed that the percentage of casualties occurring in darkness ranged from 18 to 33 per cent for bicycles and from 26 to 38 per cent for mopeds. In the Netherlands recent data [8] has shown that 21 per cent of severe injuries to cyclists involved in collisions with other vehicles and 24 per

cent of severe injuries to moped riders occur at dusk or at
night. It was found that accidents after dark were more serious
and the cyclists concerned were usually older and more fre-
quently struck from behind. In Great Britain a total of 4,549
(18 per cent) pedal cyclists were reported as killed or injured
on the roads during the hours of darkness in 1980 [9]. A study
in the Netherlands [10] has shown that the risk/of a fatal
collision between a cyclist and a travelling motor vehicle is
nearly four times greater under dark conditions.
It is not known to what extent the poor conspicuity of the
pedal cycle or cyclist is a factor in night time accidents
but obviously cyclists riding without adequate lights are likely
to incur considerable additional accident risk.

8.1.3.2 TESTS AND SURVEYS

Cyclists in Great Britain as in most other countries
are legally required to show a white light to the front and a
red light to the rear when riding after dark. Observations were
made in four towns in England to determine the extent
to which cyclists comply with these lighting regulations [11].
Details relating to over 2,500 bicycles were collected in a two
week period during December 1980.
Observations were made after darkness and it was shown
overall that approximately 25 per cent did not have complete
lighting and 9 per cent had no visible lights at all. Where
lamps were fitted 9 per cent were off and nearly a quarter were
either dim or gave an unsteady output. Three-quarters of the
lamps observed were battery powered. It therefore appears that
many cyclists at night will be inconspiciuous and therefore
at increased risk. Interviews with over 600 cyclists revealed
some reasons for this state of affairs. Many only replaced
batteries when they were exhausted and important reasons given
for the poor performance of lamps were damage and poor connec-
tions.

The observations showed that dim lamps were common and in
order to establish the importance of bicycle reflectors for
safety tests were carried out on the TRRL test-track after dark
to compare the detectability of two reflectors (25 mm and 75 mm
dia) and a common type of battery lamp modified to give two

levels of light output [11]. These levels were low and corres-
ponded to dim lamps where the batteries were close to being
exhausted. To ensure realistic viewing conditions observers
drove a test vehicle towards the various options in turn down
a 650 m long range on the Laboratory's test-track after dark.
Glare was produced by mounting a set of Anglo-American type
sealed beam head-lamp units 0.65 m above the track surface
and set 1 or 3 m to the right of a stationary cycle. The rear
of the bicycle faced the observer (Figure 2).

The glare source, simulating dipped opposing head-lamps, gave
a luminous intensity of 1,100 cd at the observer's eye 200 m
up the range. The luminous intensity of the observer's dipped
head-lamps in the direction of the test bicycle was found to
be 2,260 cd at this point. The observer drove towards the
bicycle at about 35 km/h and on detection of the lamp or reflec-
tor released the accelerator, stopping a distance measuring device
on the car which had previously been started by the experimenter
at the beginning of the range.
For each observer two detection distances were recorded for
each test condition and a total of ten observers were employed.
The average detection distance for the reflectors and two
levels of light output against the glare source are given in
Table 4.

Not only is early detection of the rider by the approaching
driver important but also recognition at an early stage. Early
recognition of the rider can be important since for safety the
driver needs to know the likely behaviour of the road user he
is about to overtake. In further tests the distances at which
observers were certain that a cyclist was present were used as
a measure of effectiveness. Since the motion of the cyclist
on the cycle was thougt to provide important cues to recogni-
tion a test cyclist rode the bicycle on rollers. The rollers
were positioned 3 m to the side of the opposing head-lamps so
the rear of the bicycle was facing the observer on the range.
The control was the test bicycle and rider wearing a dark
jacket with a bright lamp (giving a steady output of 11 cd)
and a small mudguard reflector attached to the bicycle. The
glare source was identical to the one described above. The
options were a commercially available flashing amber lamp

designed to be attached to the cyclist's clothing, a reflective jacket, a reflective shoulder and waistbelt, a reflective spacer and a set of pedal reflectors. Each of the options was tested in turn in conjunction with the control, i.e. rear light and mudguard reflector. To obtain the detection distance the observer indicated when he had first detected the conspicuity aid while driving down the range and then released the accelerator (so stopping the distance counter) when he or she felt confident that a cyclist and no other road user or object was being observed. The average detection and recognition distances based on results from six subjects are given in Table 5.

A survey in the Netherlands [12] has shown that 4 per cent of front lamps and 4 per cent of rear lamps were missing. It was also shown that 7 per cent of the front lamps were defective in some way. The legally required large rear reflector was present in 93 per cent of cases.
Some indication of the effectiveness of this large rear reflector and pedal reflectors in reducing accidents can be judged from another Dutch report [13] which details the change in accident rate to cyclists following their legal requirement in November 1979. This preliminary report using only "one year's after" data, records a drop in casualties. As accident data accumulates it may be possible to precisely quantify their contribution to the reduction in accident risk.

The Institute of Road Safety Research SWOV [8] has carried out an analysis of accidents and has concluded that a small reduction in casualties will result from the mandatory use in the Netherlands of spoke reflectors or reflective tyres.

In the USA Burg and Hulbert conducted a series of tests on bicycle spoke reflectors and reflective tyres [14]. Using dipped head-lamps it was found that spoke reflectors were detected at a greater distance than reflective tyres, when viewing the side of the bicycle. The average detection distance for the most effective spoke reflector was 354 m while for the most effective reflective tyre it was 297 m.

However in static viewing tests the reflecting tyres were
easier to recognise. In dynamic trials where observers had
to correctly determine the direction, the reflective tyres
were more effective at indicating direction of travel.

In West Germany viewing trials were held to assess the con-
tribution to conspicuity of various types of reflector [15].
Spoke reflectors were judged to be superior to reflective
tyres.

The international Federation of Senior Police Officers
(FIFSP), after a study of safety equipment for bicycles [16],
concluded that a large rear reflector would be beneficial
and that dynamo lighting systems should be provided which
should automatically switch to battery power when the bi-
cycle is stationary.
They also attached special importance to flank protec-
tion of the bicycle rider and recommended the use of
retro-reflective tyres [16, 17].
In addition to ensuring that two-wheeler lighting and reflectioni-
sation is adequate, there are other vehicle factors that are
important for adequate visibility. The transmission of light through
motor vehicle windscreens is of obvious importance since modern
cars have windscreens that usually make an angle of 35° to 40°
to the horizontal plane. These small angles seem to be unfavourable
for the transmission of the incident light coming from the traffic
scene especially where dim.lamps naer the threshold of perception
are being viewed.
A dirty, scratched, tinted or highly raked windscreen will limit
transmission of light or reduce contrast and could cause a poorly
lit cyclist to be missed. Poorly aligned vehicle headlamps are a
problem in that they can cause high levels of glare which can
interfere with the detection of lights and can cause distraction.

8.1.3.3 DISCUSSION AND CONCLUSIONS.

It has been demonstrated that a reflector having a coeffi-
cient of luminous intensity of 1450 mcd/lx (75 mm dia reflec-
tor measured at zero entrance angle and 0° 12' observation
angle) can perform reasonably well when compared with a dim

rear lamp. In fact under the worst conditions of glare (bi-
cycle positioned 1 m from glare source) the detection dis-
tance of the large reflector was similar to that of the
dimmest lamp. Without reflector or rear light of any descrip-
tion visibility distances are dangerously low (41-64 m) when
it is considered that at a speed of 110 km/h a driver may need
a distance of up to 200 m to stop after an unexpected object
becomes visible. The light output from a dim front or rear
lamp when viewed from the side can be very low indeed and the
provision of side reflectors in this case can substabtially
improve conspicuity. The obvious disadvantage of a reflector
is that its visibility depends on the illumination it receives
from the driver's head-lamps. If the head-lamps are dim or
misaligned or the two-wheeler is not directly ahead of the
vehicle then the reflectors may prove ineffective. In addi-
tion the performance of most reflectors decreases with in-
creasing entrance angle although 'wide angle' reflectors are
available and these significantly decrease the reduction in
reflected light at large entrance angles.

In Great Britain and to a lesser extent in the Netherlands,
it has been shown many bicycles are not equipped with ade-
quate lights at night even though they are legally required.
The widespread use of a good quality bicycle reflectors might
make a worthwhile contribution to safety in these and other
countries where such problems exist.
Should the lights flicker, dim or go out completely a bicycle
equipped with good reflectors should be visible in a number
(but by no means all) of accident situations.
It is of course desirable that bicycle lighting performance
should improve to a point where reflectors are needed only
very rarely for the purpose of ensuring the bicycle is
visible. Bicycle reflectors are useful for the purposes of
not only aiding detection but also improving recognition.

After the rear light of a bicycle has been detected by an
approaching driver early recognition that a cyclist is ahead
is probably important on many occasions. Pedal reflectors

proved most effective at increasing recognition distance as
they more than doubled the distance at which a cycle equipped
with a rear lamp and mudguard reflector could be recognised.
The reflective jacket was also effective; observers quickly
recognised the cyclist by the side to side motion and outline of the
cyclist. In addition both these aids should give the driver a
useful indication of the distance to the cycle. For example
the amplitude of the pedal motion can be clearly seen soon
after the pedal reflectors have been detected and this is
likely to be a useful cue in judging distance. Tests have
shown that large errors in judging distance can result when
only a single red light is visible and this could be a possi-
ble cause of accidents. Reflective tyres have been shown to
indicate the presence and direction of travel of a two-wheeler
when viewed from the side. Spoke reflectors are more effective
at improving detection distance in this situation but are less
efficient at improving recognition.

The need for adequate bicycle reflectors has been recognised.
In the Netherlands a high performance rear reflector and pedal
reflectors have been required on a bicycle since 1979. The
international Federation of Senior Police Officers has recom-
mended the use of a large rear reflectors and retro reflective
tyres on bicycles.

The British Standards Institution [19] has published a stan-
dard specifying minimum requirements for bicycle reflectori-
sation. This standard is based on the work of the Internatio-
nal Organisation for Standardisation and specifies high grade
reflectors at the front, rear and side of the bicycle as well
as for the pedals.
The British government has been considering the possibility
of ensuring that all bicycles offered for sale should meet
these and other safety requirements.

8.2   BICYCLE SPACERS

8.2.1   INTRODUCTION

Because of the inherent instability of two-wheeled vehicles,
cycle and moped riders need to be given sufficient clearance
by the overtaking driver to take account of possible course
deviations. Experimental studies of course holding by cycle
and moped riders under a range of conditions [20] show that
riders need a road width in excess of 1 m; an additional
safety margin is necessary.

A spacer is a device attached to the bicycle to discourage
drivers from passing too close to the cyclist when overtaking.
Commercially available spacers usually consist of a plastic
rod with either a flag or disc attached at the end, the overall
length being about 400 mm. It is to be mounted horizontally
on the rear off-side of the bicycle so it projects into the
road.
They have been widely used in Scandinavia but have only re-
cently gained acceptance in Great Britain.

8.2.2   ACCIDENT STATISTICS

In Great Britain national accident data for 1980 indicate that
about 30 per cent of fatal pedal cycle casualties occur in
situations where the other road users collides with the cyclist
while overtaking or strikes the rear of the bicycle, both
vehicles initially travelling in the same direction and going
ahead. French and Danish accident studies show that the domi-
nant manoeuvre type involving cycles and mopeds in rural areas
is that of the overtaking situation [1]. In Chapter 2 it has
been shown that when 'lethality' was calculated for bicycle-
car accidents the collision front of car-rear end of bicycle
or moped appeared to be most severe. Clearly attention should
be given to reducing the risks in this particular accident
situation.

8.2.3   EVALUATION OF SPACERS

Previous studies in Great Britain, Finland, Sweden and
France [21, 22, 23, 24] of the effects of spacers on the
gaps left by overtaking drivers (used as a measure of the
accident risk) have shown a range of effects from none up
to an increase in average passing distance of 220 mm.
Differences in road conditions, driver behaviour and
measurement technique could account for these differences.
At TRRL the ultrasonic range finding technique described
above was used to measure the effect of spacers of various
lengths during day and night time [25].
Because of the ease of measurement and subsequent analysis
it was possible to quantify for the first time the effects of
spacers of various types in reducing the percentage of
drivers passing very close.

For determining the effects of spacer lenght a red reflective
disc shape* 9000 mm² in area was employed. The shaft of the
spacer was 8 mm in diameter and white in colour. The overall
lengths of the spacers tested were 0.35, 0.40, 0.45 and 0.50 m.
These lengths covered the range of those commercially available
and produced estimated projections beyond the rider's elbow of
25, 75, 125 and 175 mm. The rider's elbow was the part closest
to overtaking vehicles. For comparison purposes the cyclist wore
a black jacket of near zero luminance factor and this acted as
the control when testing without a spacer present. Four sites
were chosen for test purposes. Road width varied from 5.1. to
6.3 m and speed limits from 48 to 96 km/h. Broken centreline
markings were present along all sections. Each spacer was
tested several times at each site in a balanced order to reduce
the effects of time dependent factors. ·

* The material had a luminous factor of 0.51 and its colour
  specification in CIE coordinates was x = 0.58, y = 0.36.
  Its coefficient of luminous intensity under typical viewing
  conditions (0° 12' observation angle and zero entrance angle)
  was approximately 1,200 mcd/lx.

Data collected at the four test sites were combined as
there were no substantial differences between the results.
Table 6 gives the averagd results for daylight and night-
time tests. Statistically significant differences at the
0.1 per cent level were found under both lighting condi-
tions.

Further tests were carried out to compare the effects of the
longest spacer (0.5 m) and the yellow jacket used in the
detection distance studies described in Section 8.1.1.2.
Table 7 gives the results.

8.2.4   DISCUSSION AND CONCLUSIONS

The effects produced by spacers in increasing median overtaking
distances and decreasing the percentages of vehicles passing
very close are probably due to the increase in the effective
width of the bicycle and rider although some of the effect
may be due to increased conspicuity. In most cases the increase
in effective width is not quite matched by a corresponding in-
crease in median passing distance. This could be a result of the
knowledge that the consequences of striking the end of the
spacer when overtaking are not as severe as hitting the cyclist.
The results show that using a spacer 0.5 m in length the per-
centage of overtaking vehicles passing less than 0.8 m from the
cyclist was approximately half that recorded when no spacer was
present. This spacer had a similar effect on overtaking be-
haviour across a wide range of road and traffic conditions.
Results obtained in the day were similar to those recorded at
night. As the length of the spacer decreased, effectiveness was
reduced such that a spacer of length 0.35 was only about half
as effective as a spacer 0.50 m long.
The effects on overtaking drivers of the long spacer were very
similar to those of a fluorescent yellow jacket across a range
of daytime road conditions. The fluorescent jacket would ob-
viously confer extra benefits on the cyclist by increasing
overall conspicuity. However the cost of a spacer is low and
if of sufficient length offers good value.

8.3   FIELD OF VIEW OF TRUCK DRIVERS

From a Dutch study [37] it followed that most of the
accidents, in which a two-wheel-rider collided with the
side of a heavy goods vehicle,happened when the heavy
goods vehicle turned to the right.
From a analysis of the EEC directives on rear view
mirrors it appeared that certain areas could not be
seen when the vehicle was only equiped with mirrors
according to these requirements (fig. 5).
Therefore additional requirements need to be recommended.

8.4   BRAKING

8.4.1   OUTLINE OF THE PROBLEM

The rim brake has been fitted to bicycles for many years in
some countries and is widely used on all types of bicycle.
On applying the brake lever the rubber block is forced against
the metal wheel rim. The latter is normally chrome plated
steel and often gives a very low coefficient of friction when
wet resulting in poor braking performance [26, 27]. In dry
conditions the braking force can be high and there exists the
possibility of the rider going over the handlebars during
emergency braking. Hub (both internal-expanding and back-pedal-
ling) and disc brakes have generally superior performance in
wet weather because the braking surfaces are not so exposed
to water. However they are more expensive, heavier and can make
wheel removal difficult. This is perhaps the reason for many
new lightweight bicycles being equipped with rim brakes.

It is difficult to obtain reliable estimates of the number of
injury accidents due to inefficient brakes but bicycle accident
reports received by the Consumer Product Safety Commission of
the USA [28] show that many injuries to children result from
the inability of the bicycle to stop quickly in emergency situa-
tions. In West Germany, Wobben [27] refers to the complaints
of many cyclists concerning the inadequate braking efficiency
of rim brakes in the wet.

Currently the British government is considering setting
minimum permitted wet and dry braking efficiencies for
new bicycles based on the recent British Standard for
cycles [19]. TRRL has been involved in preparing this
Standard and has conducted a series of tests on rim brakes.

8.4.2 BRAKING STUDIES AT TRRL

In one study the size of the problem was established by allo-
wing children to carry out emergency braking tests under wet
conditions [29]. In addition road tests were carried out to
determine the performance of a common type of caliper brake,
using a number of different brake blocks and wheel rims to
determine whether or not one or more combinations would prove
satisfactory in both dry and wet conditions. Recently manu-
facturers have produced new types of brake blocks which are
claimed to be effective in wet conditions.
Nine commercially available brake blocks sets were tested:
three synthetic blocks, five rubber blocks of various hard-
nesses and patterning and one leather block. All nine sets
of blocks were tested on plain chrome plated and light alloy
rims and three sets, representing the three types of material,
were further tested on dimpled and grooved chrome plated rims.
The test bicycle was a standard touring model with 686 mm dia-
meter wheels and fitted with a side pull caliper brake. To
reduce variation between tests one adult rider was used. The
bicycle was equipped with a water reservoir and jets to each
wheel which applied 4 ml/s at each rim and brake force was
controlled by attaching brake lever stops to the ends of the
handlebars. These were adjusted so that loads of 180 N were
effectively applied 25 mm from the lever ends when the brake
levers were pulled up to the stops. (Tests have shown that
loads of this magnitude are possible to achieve by male adults
under emergency braking conditions. However many children and
adults females would not be expected to exert these forces).
The braking distance were measured form a speed of approxi-
mately 16 km/h for each combination of block and rim.

The rims were tested both dry and when continuously wetted. Table 8 gives the average deceleration achieved for each set of brake blocks under dry and wet conditions together with the expected braking distance from a speed of exactly 16 km/h. Figure 3 illustrates the relative effectiveness of the various types of block.

Nineteen children whose ages ranged from 6 to 11 also took part in further tests. In this case a small bicycle was used (457 mm dia wheels) equipped with chromed rims and rubber blocks. They each made 4 runs under wet conditions similar to those described above. The average braking performance was 0.08 g corresponding to an expected braking distance of 12.6 m from a speed of exactly 16 km/h. The lowest rate of 0.047 g (equivalent to a braking distance of 21.4 from 16 km/h) was achieved by the youngest child and the highest rate of 0.113 by the eldest.

8.4.3   DISCUSSION OF RESULTS AND CONCLUSIONS

The results of the tests involving children illustrate well the very poor performance that may result in wet conditions where rubber brake blocks are used on chromed rims. This is in agreement with a previous study [30]. The youngest child would have travelled over 20 m in braking to a halt from the modest speed of 16 km/h. This level of performance may result in an inexperienced rider failing to give way at a road junction and emerging dangerously into the major road. On hill descents very much longer stopping distances may result. Under controlled tests, braking distances were about 4 1/2 times those measured under dry conditions. Neither hardness nor patterning of the rubber blocks or the use of dimpled and grooved rims significantly affected stopping distances. By contrast leather blocks on chromed rims produced a statistically significant improvement and adequate braking was achieved in the wet.

With wet alloy rims adequate levels of braking perfor-
mance were achieved with the synthetic blocks. The leather
and rubber blocks (e) and (g) (see _Table 8_) were slightly
less effective and the other rubber blocks were less effec-
tive still.

In the dry, braking efficiencies with any of the combina-
tions of block and rim were good, however very high levels
of braking were found with synthetic blocks on the plain
chromed rims. This is potentially dangerous since the longi-
tudinal stability of the bicycle is poor compared with other
road vehicles. Calculations for the rider and bicycle employed
showed that the rear wheel would be expected to lift at a
deceleration of 0.56 g. This is in reasonable accord with
the observation that consistent rear wheel lift occurred where
average decelerations were significantly greater than this
value.

The reduction of accident risk in both wet and dry is likely
if the correct combination of brake block and rim is selected.
Even if a collision is unavoidable the relative velocity at
impact may be reduced with better brakes. This can lead to less
severe injury.
Leather blocks are now available in Great Britain and one major
manufacturer fits them to all their bicycles equipped with
chromed rims. British Standard BS 6102 part 1 specifies a maxi-
mum wet braking distance of 7.5 m from 16 km/h which would ex-
clude the fitment of the worst combinations of brake block and
rim. (This is a significant improvement on the ISO standard (ISO
4210) on which it is based, which specifies a braking distance
twice as long (15 m)). As mentioned above the British government
is considering making the standard mandatory for all bicycles
sold.

8.5   DEFECTS AND MAINTENANCE

8.5.1   OUTLINE OF THE PROBLEM

The two-wheeler rider will have less chance of avoiding an acci-
dent if his machine is not maintained in good condition.

Defects in brakes, transmission and tyres, for example, may delay or otherwise reduce the effectiveness of accident avoidance manoeuvres. Obviously direct failure of frame or parts can be the prime cause of accidents; for example, failure of pedal crank or forks can easily lead to loss of control. Lighting that flickers, dims or goes out completely can lead to virtual invisibility in poorly lit areas.

8.5.2   ACCIDENT STUDIES

TRRL carried out on-the-spot investigation of 183 accidents involving two-wheelers from 1970 to 1972 [31]. They considered that 14.5 per cent of bicycles and 4.7 per cent of the motorcycles involved had defects which contributed to the accident. A Finnish study on 74 bicycle fatalities [32] indicated that defects were a contributory factor in 4 per cent of cases.

8.5.3   MAINTENANCE SURVEY

In order to get an estimate of the size and nature of the problem a survey was carried out by TRRL into the state of maintenance of bicycles ridden to primary and middle schools [33].

It was found that of the 439 bicycles examined over a third (151) were categorised as in a 'dangerous' condition and only 36 per cent were regarded by the examiners as being in good condition. A fault was categorised as 'dangerous' if it was possible for it to be a contributory factor in an accident. The component showing the largest number of dangerous faults was the rear brake. Twelve per cent were in a dangerous condition and nine per cent of front brakes were similarly categorised.

No firm conclusion can be drawn from the existing data on the direct contribution of defects to accidents but they do indicate the need for remedial action. This could take the form of vehicle inspection schemes and instruction on regular maintenance especially for younger riders.

The standard BS 6102 referred to above has minimum require-
ments for the strength of essentional parts such as brake
system, frame and fork assembly, wheels, pedals and chain.
It also   includes requirements on sizes of protrusions
and sharp edges that may come into contact with the rider
during normal use. In addition it contains a requirement that
instructions be provided with each bicycle. These include,
among many items, instructions on brake adjustment and recom-
mendations for replacement of brake blocks, correct chain
tension, lubrication and recommended tightening of fasteners
related to handlebar, saddle and pillar and wheels. Also it
contains recommendations on safe riding,e.g.regular checks on
brakes, tyres, steering and lighting. The design of the bicycle
to aid adjustment or eliminate it would be advantageous. For
example it is often difficult to adjust brakes; yet self-
adjusting brakes are already on the market [34].

8.6   STABILITY AND MANOEUVRABILITY

8.6.1   THE NATURE OF THE PROBLEM

A certain degree of skill is required to ride any two-wheeler.
To become proficient there is a learning process and the rider
must aquire sufficient experience in a range of traffic and
road conditions. To reduce accident risks the two-wheeler must
be easy to manoeuvre so obstacles can be avoided quickly and
must also be stable so that it follows the intended course
when for example the cyclist is signalling or is caught in a
cross wing. The extent to which bicycle design affects rider
performance has been examined in a number of experimental
situations.

8.6.2   STUDIES OF STABILITY AND MANOEUVRABILITY

In an early study at TRRL [35] an attempt was made to assess
manoeuvrability of cycles and motor assisted cycles by the
number of faults committed on an obstacle course and on a slow
riding test.

Similar tests were carried out using school children [30] on
a number of bicycles both on smooth and bumpy surfaces. These
tests showed that there were large differences between the
performances of riders and small differences between diffe-
rent cycles.
A Swedish study [36] tested cyclists attempting to hold a
straight course while looking behind which was intended to
simulate a common turning manoeuvre involving crossing the
traffic stream. With three types of bicycle investigated
(small-wheeled, standard touring and rodeo type) the proba-
bility of making errors in following the course and asses-
sing the situation behind ranged from 10 to 50 per cent.

A Dutch study [20] also found differences between different
machines. In one of several tests the riders had to follow a
track consisting of a sloping road section immediately follo-
wed by a sharp left turn. The riders attempted to stay within
two lines 0.15 m apart. The percentage of time spent outside
the prescribed course was used as a measure of performance.
When riding down the slope speed increased which made the bend
more difficult to negotiate and so both good stability and
manoeuvrability were important for course holding. Figure 4
shows the average percentage of time outside the prescribed
course when negotiating the curve with one and two hands. It
can be seen that differences between the bicycles and mopeds
are comparatively slight. However the performance of the racing
bicycle and standard model with high handlebars differs signi-
ficantly from that of the other two bicycles. With these other
models, path deviation (averaged over conditions) occurred
for about 25 per cent of the time. For the racing bicycle
this was nearly 50 per cent while for the bicycle with high
handlebars this was 40 per cent.

It appears from these studies that bicycle design has an in-
fuence on stability and manoeuvrability although it is not yet
possible to quantify the contribution of a particular design
feature to the accident risk.

8.7.   Recommendations concerning accident prevention measures

When compared with motor vehicles, bicycles generally have
inferior lighting and braking systems and are poorly maintained.
In the case of bicycle lighting, surveys and observations have
demonstrated that a large problem exists. Better lighting systems
are required not only to provide more reliable lighting in order
that the cyclist may be easily seen at all times but also to
provide an adequate beam to illuminate the road ahead. Further
work in this area should be beneficial. Improvements to the night-
time visibility problem can be made by requiring that bicycles
are equipped with a range of high performance reflectors that will
be readily visible in most situations and will also aid recognition. Of
particular importance is an effective rear reflector and pedal
reflectors. The cost of providing such reflectors is small
especially if this carried out during manufacture. Better legal
requirements for lights and reflectors are indicated.

The increasing popularity of light-weight bicycles indicates that
rim brakes are now more widely fitted. It has been demonstrated
that dangerously long stopping distances occur in wet conditions
if rubber brake blocks are used with the chromed steel rims. Since
this is a common combination of block and rim a legal braking
requirement based on wet and dry braking standards schould improve
the situation. Such a requirement could apply to all new bicycles
offered for sale.

Regular bicycle maintenance checks may reduce the number of poorly
maintained bicycles. This could be carried out at schools or by
the Police. At the present time it seems unlikely that in annual
inspection similar to that required for motor vehicles would be
feaslible.
Steps could be taken to persuade manufacturers to improve bicycle
design so that maintenance is reduced to a minimum for example the
fitting of brakes that are automatically adjusted. Consideration
should be given to a requirement that there should be no sharp
edges and dangerous protrusions on bicycle and mopeds and chain
guards should be fitted. In addition, there may be a case for a
minimum requirement for the strenghts of essential parts such as
brake system, frame and fork assembly, wheels, pedals and chain.

A measure that could be taken to reduce the risk of accidents to
both bicycles and moped riders is the promotion of the wearing of
conspicuous clothing particularly during daytime and twilight.
It would be helpful to have a standard for conspicuous clothing
so that only high visibility clothing of an adequate standard would
be promoted in publicity and training courses. Consideration should
also be given to the encouragement of the use of cycle spacers.
Since they have been shown to decrease the numbers of vehicles
passing very close they should reduce the risks in the overtaking
situation. They have the advantage of being very cheap to fit.

If a safety requirement is introduced on a large scale it is
recommended that relevant accident statistics are compared before
and after the change so that the effectiveness of the measure in
reducing the accident risk can be established.

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TABLE 1

Average detection distance of clothing options

Option	Detection distance (m)
Jacket	63.2
Waistcoat	55.8
Hat	53.9
Armbands	49.8
Black jacket (control)	49.6
Shoulder and waist belt	47.1

TABLE 2

Passing distances for clothing options of different styles

Option	Median (m)	Percentage less than 0.8m	Number of readings
Jacket	1.20	8.4	547
Waistcoat	1.16	10.1	544
Hat	1.14	11.0	520
Armbands	1.13	14.1	475
Shoulder and waist belt	1.09	16.4	482
Black jacket (control)	1.03	21.1	526

TABLE 3

Passing distances for jackets of different luminance factor

Option	Colour specification*			Median	Percentage less than 0.8m	Number of readings
	x	y	Y			
Thin nylon	0.39	0.44	0.49	1.10	15.2	841
Thick nylon	0.36	0.51	0.74	1.13	12.4	833
Reinforced PVC	0.38	0.52	0.95	1.15	12.1	840
PVC	0.38	0.53	1.37	1.17	9.4	879
Black jacket	(not measured but expected reflectance close to zero)			1.05	23.5	927

TABLE 4

Mean detection distances of rear lamps and reflectors

Distance of glare source from bicycle (m)	Rear lamp Luminous intensity (cd)		Reflectors Coefficient of luminous intensity (mcd/lx)*		No reflectors or lamps (control)
	0.65	0.15	1450	101	
1	358	241	247	153	41
3	635	507	399	214	64

*Coefficients of luminous intensity were measured at 0° 12' observation angle and 0° entrance angle. The observation angle is the angle between the straight lines connecting the reflector to the source of illumination and to the observer's eye. The entrance angle is the angle between the line perpendicular to the plane of the reflector face and the straight line connecting the reflector to the source of illumination.

TABLE 5

Mean detection and recognition distances for conspicuity aids
(glare source 3m from bicycle)

	Rear lamp (11.1cd) and reflector (100mcd/lx*)	Flashing amber beacon	Reflective jacket (10,000mcd/lx)	Shoulder & waist belt (1000mcd/lx)	Spacer (500mcd/lx)	Pedal reflectors (100mcd/lx each)
Detection distance	651†	588	284	185	292	182
Recognition distance	54	59	102	68	60	124

*Coefficients of luminous intensity were measured at $0°$ $12'$ observation angle and $0°$ entrance angle

†Maximum detection distance was limited to just over 650m corresponding to the length of the range.

TABLE 6

Passing distances for spacers of various lengths

Lighting condition	Length of spacer (m)	Projecting length (from elbow) (m)	Median gap (m)	Percent passing less than 0.8m	Number of measurements
Day	Control (no spacer)	–	1.097	14.97	855
Night	"	–	1.076	16.14	477
Day	0.35	0.025	1.156	11.50	844
Night	"	"	1.198	8.85	407
Day	0.40	0.075	1.132	9.74	780
Night	"	"	1.134	11.08	415
Day	0.45	0.125	1.192	9.16	819
Night	"	"	1.194	7.28	481
Day	0.50	0.175	1.215	7.83	855
Night	"	"	1.221	6.92	492

TABLE 7

Comparison of longest spacer with a conspicuous jacket (daylight)

Option	Median gap (m)	Percent passing less than 0.8m	Number of measurements
Control	1.060	21.77	698
Spacer	1.157	11.37	686
Yellow jacket	1.162	11.09	712

TABLE 8

Mean decelerations and expected braking distances from 16 km/h

Block	Type	Condition	Plain chrome Deceleration (g)	Braking distance (m)	Light alloy Decel.	Braking distance	Dimpled chrome Decel.	Braking distance	Grooved chrome Decel.	Braking distance
(a)	Patterned synthetic	Dry	0.76	1.3	0.46	2.2	0.58	1.7	0.58	1.7
		Wet	0.21	4.9	0.39	2.6	0.24	4.2	0.20	5.0
(b)	Plain synthetic	Dry	0.71	1.4	0.51	2.0	–	–	–	–
		Wet	0.27	3.7	0.42	2.4	–	–	–	–
(c)	Plain synthetic	Dry	0.66	1.5	0.51	2.0	–	–	–	–
		Wet	0.28	3.6	0.43	2.3	–	–	–	–
(d)	Plain rubber	Dry	0.57	1.8	0.45	2.2	0.47	2.1	0.47	2.2
		Wet	0.12	8.1	0.25	4.0	0.13	7.5	0.12	8.5
(e)	Patterned rubber	Dry	0.54	1.9	0.47	2.2	–	–	–	–
		Wet	0.12	8.8	0.35	2.9	–	–	–	–
(f)	Patterned rubber	Dry	0.52	1.9	0.45	2.2	–	–	–	–
		Wet	0.12	8.6	0.21	4.8	–	–	–	–
(g)	Patterned rubber	Dry	0.55	1.8	0.48	2.1	–	–	–	–
		Wet	0.12	8.6	0.36	2.8	–	–	–	–
(h)	Patterned rubber	Dry	0.50	2.0	0.43	2.3	–	–	–	–
		Wet	0.11	8.9	0.26	3.9	–	–	–	–
(i)	Plain leather	Dry	0.40	2.5	0.46	2.2	0.46	2.2	0.48	2.1
		Wet	0.44	2.3	0.36	2.8	0.44	2.3	0.41	2.5

Rounding errors account for apparent discrepancies between columns.
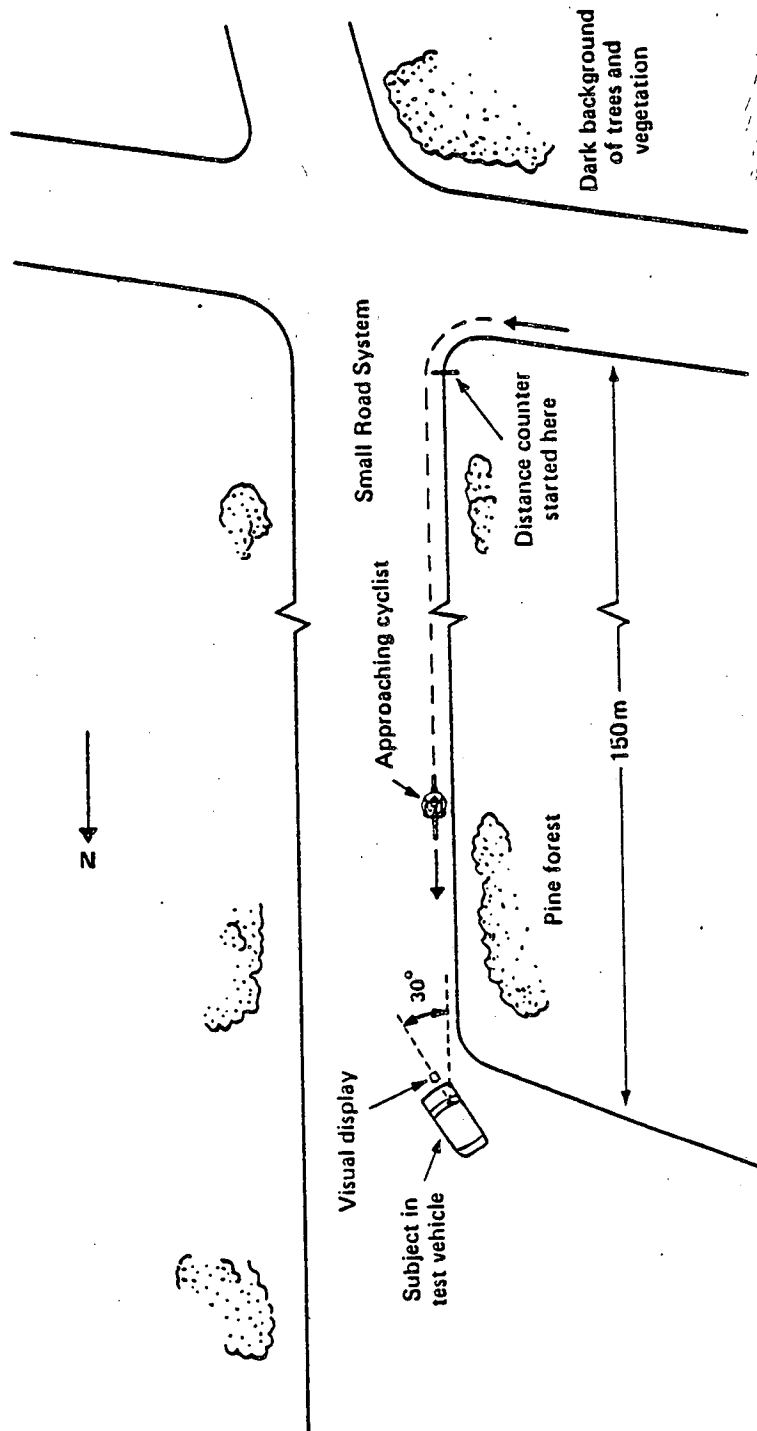
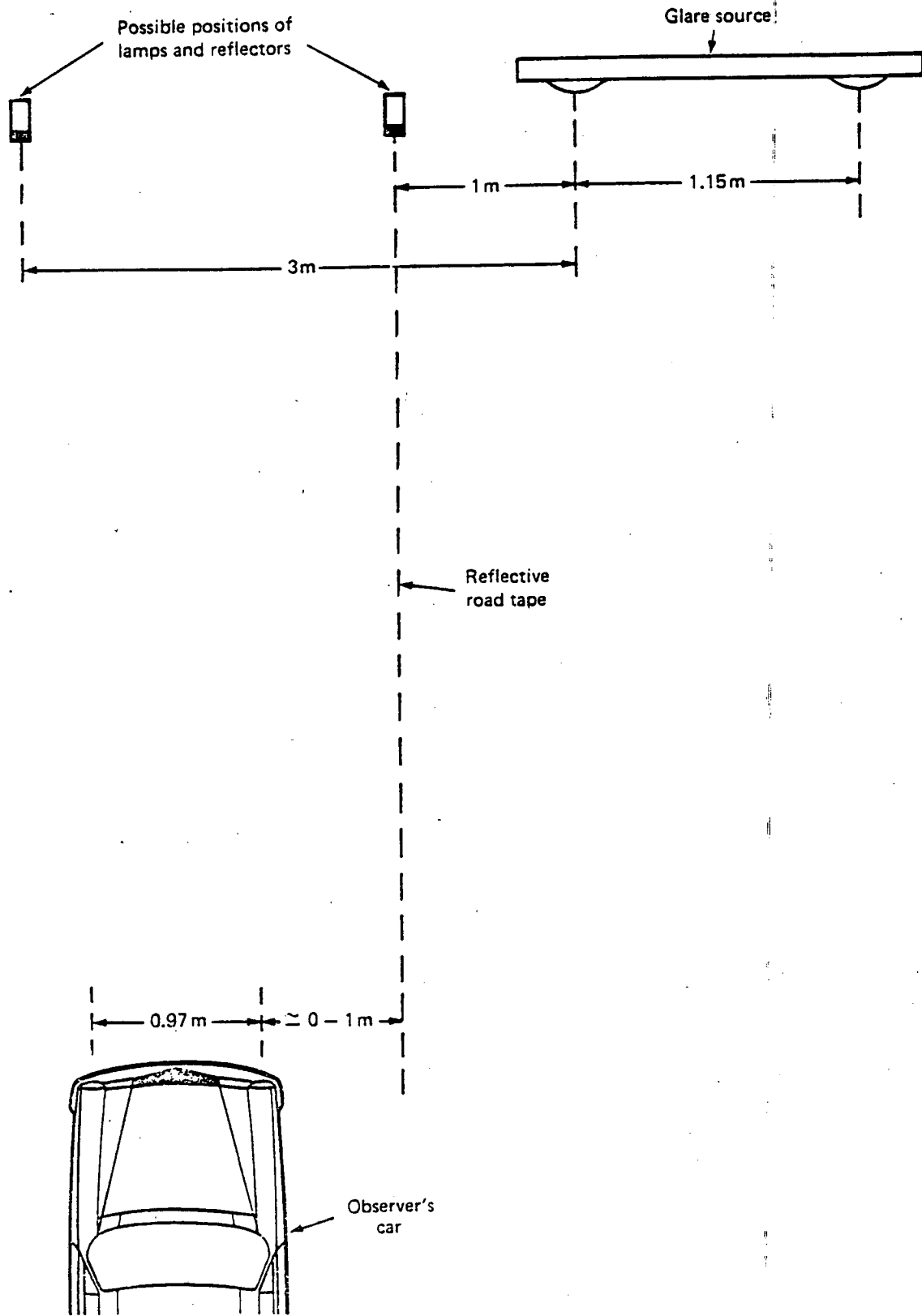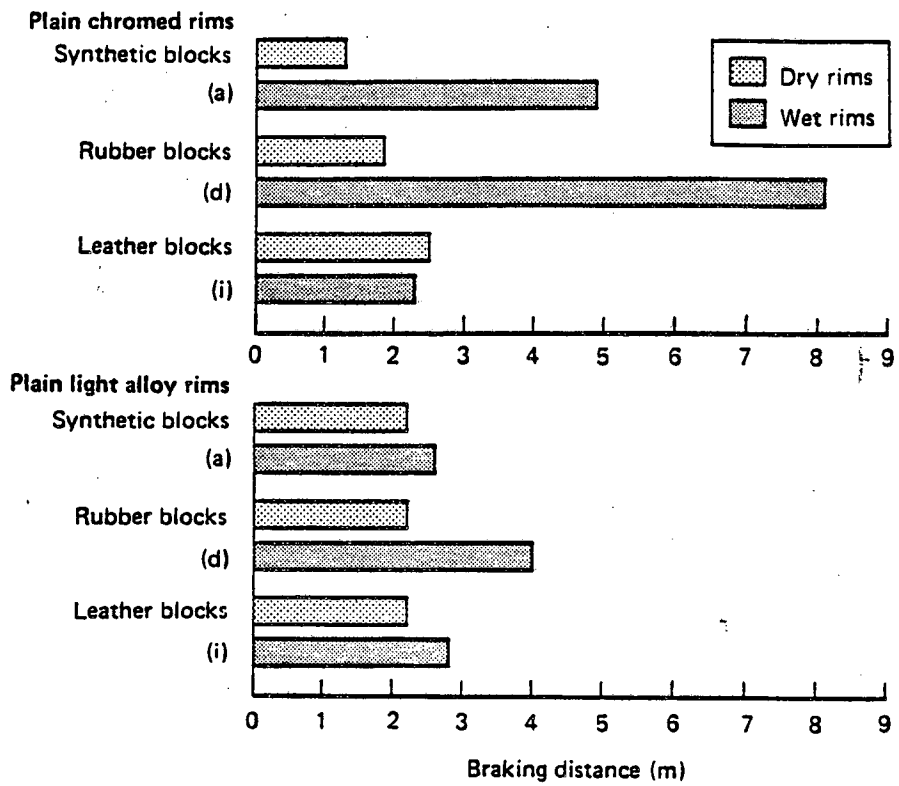Fig. 1 Test conditions for conspicuity aids

Possible positions of
lamps and reflectors

Glare source

1m

1.15m

3m

Reflective
road tape

0.97m

≃ 0 – 1m

Observer's
car

Fig. 2 Layout for visibility studies

M1119

Plain chromed rims

Synthetic blocks
(a)

Rubber blocks
(d)

Leather blocks
(i)

Dry rims
Wet rims

0 1 2 3 4 5 6 7 8 9

Plain light alloy rims

Synthetic blocks
(a)

Rubber blocks
(d)

Leather blocks
(i)

0 1 2 3 4 5 6 7 8 9

Braking distance (m)

Fig. 3 Expected braking distances from a speed of 16km/h

Bicycles

Folding bicycle

Standard bicycle
high handlebars

Racing bicycle

Standard bicycle
ladies type

1 hand

2 hands

Mopeds

Light moped
engine on front wheel

Heavy moped
high handlebars

Modern light
moped

Motorcycling
model

0 20 40 60 80
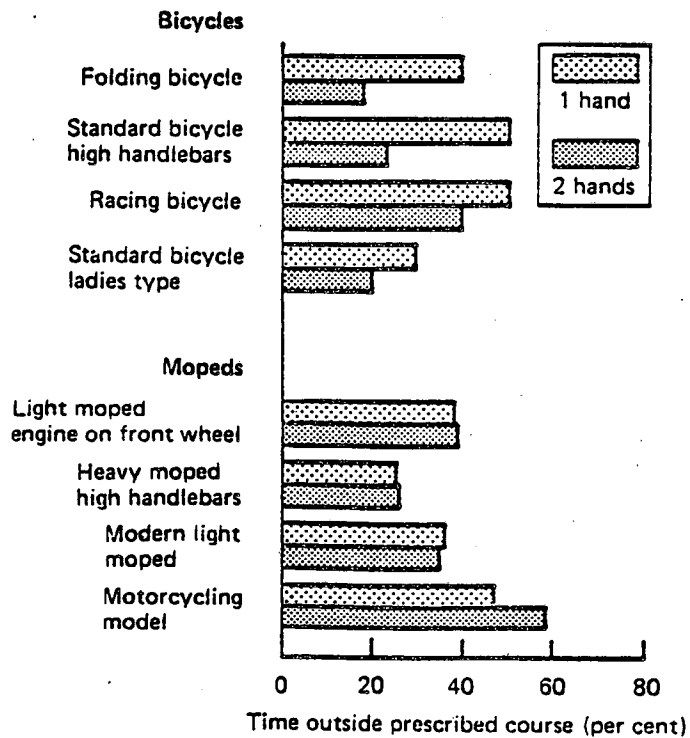
Time outside prescribed course (per cent)

**Fig. 4 Time (per cent) outside prescribed path in test 2:
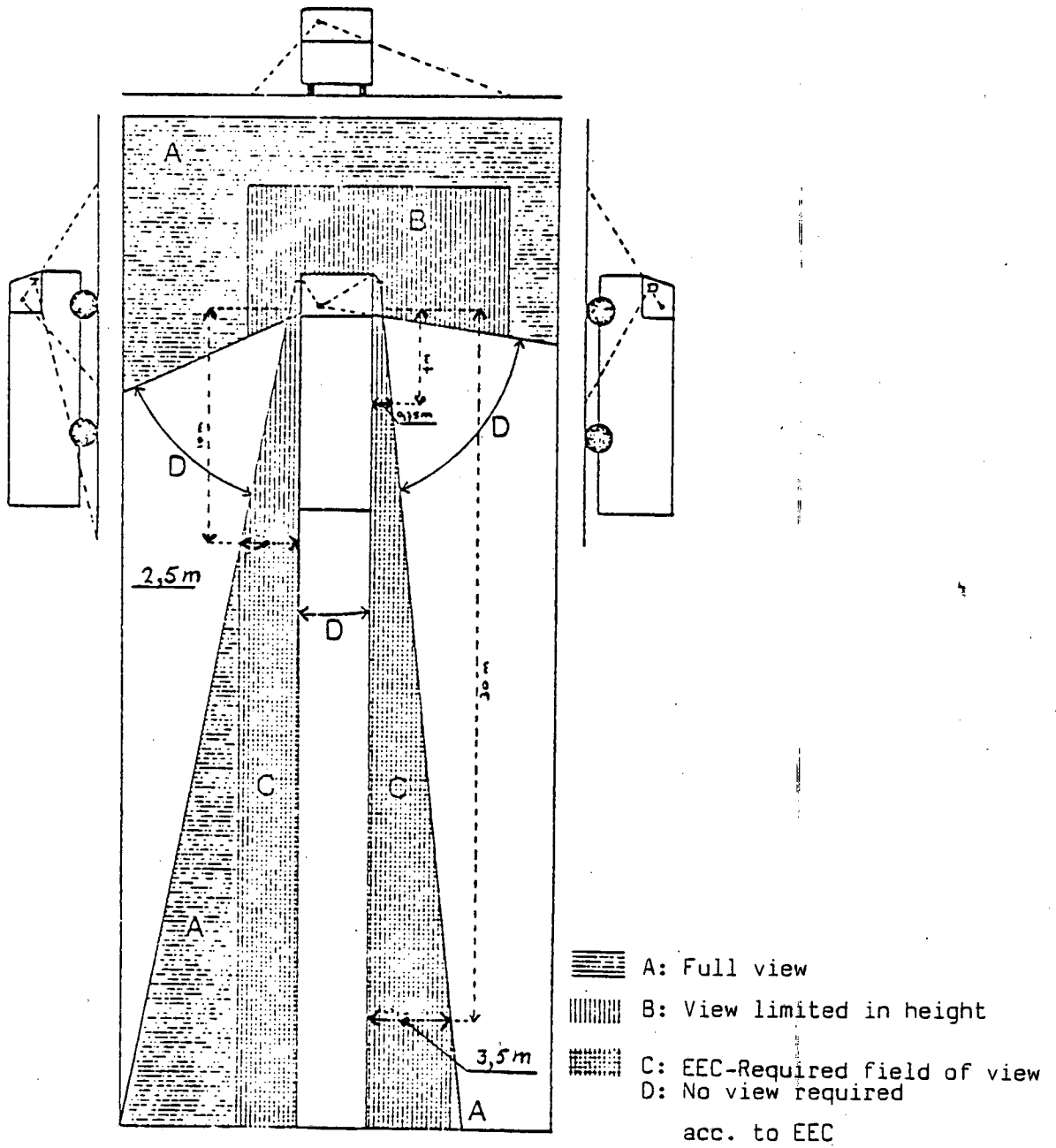'Course holding in a curve' (768 runs)**

Fig. 5: Field of view for heavy goods vehicles, right-hand
traffic; right and left external mirrors according
to EEC-requirements. (Blokpoel [37]).