A DESCRIPTION OF BICYCLE AND MOPED RIDER ACCIDENTS AIMED TO INDICATE PRIORITIES FOR INJURY PREVENTION RESEARCH

J.J.W. Huijbers
Crash and Post Crash Department
Institute for Road Safety Research SWOV, Leidschendam

1. INTRODUCTION

The aim of the study mentioned in this paper is to indicate priorities in the field of bicycle and moped injury prevention research, based on criteria given. This study is a part of a preparation for a SWOV accident investigation project that has to identify and to quantify factors influencing injuries of pedestrians, cyclists, moped- and motorcycle riders in accidents.
A global description of the accidents of bicyclist and moped riders in terms of age, collision partner and collision type will be given in this paper.
The development of hypotheses for accident investigations can be concentrated on these priorities.
The results may also be used to select representative accident situations for mathematical modelling and for experimental research methods.
Due to a relatively high level of registration of numbers killed and severely injured road users by the police in the Netherlands these data may be used to quantify these priorities.

2. THE DATA USED FOR THE STUDY

The study is mainly based on police information of accidents resulting in deaths or severe injuries, available in national statistics and provided with supplementary data according to SWOV specifications.

3. UNDERREPORTING OF THESE ACCIDENTS

The underreporting of accidents is well documentated in international literature but mostly based on regional data. For instance Pedder et al. [8] gave an overview of three British studies. From two-wheeled motor vehicle accidents resulting in seriously injured two-wheel riders, 27% was not reported to or by the police. These figures for severely injured pedal cycle casualties range from 60% up to 80%. Underreporting of slightly injured is even higher from 40% up to 60% for the motorized two-wheeler accidents and 70-90% for the bicycle accidents. In Sweden underreporting seems to be a much smaller problem according to Bunketorp et al. [3]: 29% for the severe injury cases and 45% for the light injury accidents. The reporting of accidents by the Dutch police seems to be quite good, according to a SWOV study conducted by Maas [7] on a national base. Fatal road accidents were reported almost 100%. To establish the underreporting of severely injured the figures of the police data were compared with the figures of the Medical Registration Foundation (SMR).
The SMR is an institute where data from nearly all (± 94%) Dutch hospital in-patients are sampled, processed and produced in statistics.
From this comparison it followed that accidents resulting in serious injuries were reported quite complete, with an average reporting rate of 80%.
Reporting rates for the various groups of road users are: car occupants: 98%; moped riders: 97%; bicyclists: 82%; and pedestrians 78%. Because of the relatively low underreporting figures the police data were used in this study.

4. CRITERIA USED FOR THE INDICATIONS OF THE PRIORITIES

For road accidents the absolute number of casualties is a common criterion. Also other criteria such as a combination of severity and relative proportion may be used. In this study the number of casualties (magnitude) and an approximation of severity will be used next to each other.
Let us assume that the group of casualties under study is divided into n classes. The total number of killed or severely injured road users of the group are d_n resp. w_n. These figures are for class i: d_i and w_i.

4.1. Magnitude

Priorities with magnitude as a criterion can be based on the number of killed and injured. According to van Minnen (see [2]) the relative proportion d_i/d_n and w_i/w_n can be added up and a variable (a) can be substituted as follows:

$$S = (1-a).\frac{d_i}{d_n} + a.\frac{w_i}{w_n} \quad , \; 0 \leq a \leq 1 \qquad (S = \text{magnitude depending on (a)})$$

The values given to (a) depend on many variables and will also be socially defined. The main purpose of using this function is that it illustrates the results of the criterion magnitude in a very clear way (fig. 1, 5, 6).

4.2. Severity

Severity of a road accident is a complex term. A lot of dimensions are involved such as damage, injury, economic consequences. In injury prevention research the injury dimension is used. Injury is complex too and not adequately described by location and nature. The severity part of it can be described in terms of energy dissipation, threat to life, disability, etc. Scaling according to the Abbreviated Injury Scale (AIS) seems to be appropriate at this moment, although the disability aspect is almost not represented in the scaling result. Especially for pedestrian (leg) injuries (EEVC [4]), this seems to be a problem. Scaling according the AIS is not often used in Dutch hospitals, and is therefore not available in the above mentioned SMR data. An approximation of injury severity had to be used. Because of the relatively complete reporting of the number of killed and severily injured road users "letality" was used for this purpose.

$$\text{Letality: } \frac{100\, d_i}{d_i + w_i}$$

4.3. Other criteria and conclusion

A combination of the above mentioned criteria can be considered. However, some weighting factors than must be introduced.
In this process some factors have to be socially defined. Besides, some thought must be given to other factors that also influence priorities, such as estimated effectiveness of possible counter measures, their feasability and political preferences.
In order to avoid disturbing the technical meaning of this paper and due to the fact that much information on those factors is not available this will be deleted for the moment.
In this paper therefore only two criteria will be used: magnitude and letality, either seperately or sometimes combined, especially in those cases that the priority is supported by both criteria.
As a result priorities in this paper only indicate which injury producing

process, on grounds of magnitude or letality, deserves extra attention. The paper further indicates representative accident situations for mathematic or other simulations.

5. PRIORITIES WITHIN THE DIFFERENT CATEGORIES OF ROAD USERS

5.1. Magnitude

The number of killed bicyclists in the Netherlands in 1981 was 356. This is nearly twice as much as the number of killed moped riders (158). The relative numbers related to the total number of killed road users are 20% for the cyclists and 9% for the moped riders (table 1).
The number of severely injured bicyclists an moped riders in 1981 are 4123 resp. 3693 and the percentages of the total number: 23% resp. 21%.
The sequence based on the criterion magnitude depends from the factor a (fig.1).
For a < 0.5: car occupants, bicyclists, pedestrians, moped and motorcycle riders. For a > 0.5: car occupants, bicyclists, moped riders, pedestrians, motorcycle riders.

5.2. Severity

As can be seen in fig. 1, the severity of the car occupant casualties is nearly as high as for the other categories of road users except for the moped rider and the bicyclist.

5.3. Conclusion

Injury prevention research in the Netherlands should be focused (apart from the car occupants) on bicyclists, pedestrians and moped riders, when magnitude is used as a criterion. On pedestrians, motorcycle riders, bicyclists and moped riders when letality is used as criterion.
In this paper attention will be given to the bicycle and due to the great analogy to the moped rider accidents.

6. AGE DISTRIBUTIONS OF THE BICYCLIST AND MOPED RIDER CASUALITIES

Based on the information of the Central Bureau of Statistics the age distributions of the killed and severly injured bicyclists and moped riders are given in fig. 2. The numbers shown here are divided by 100.000 people of the different age groups.
There is a large difference between these figures. The distribution of the bicyclists is comparable to that of the pedestrians. The distribution of the moped rider resembles the motorcycle casualty age distribution (Huijbers [5]).
For the age distribution of the bicyclists casualties peak values can be seen in the age group 5-25 years for the severely injured and > 65 years for the killed bicyclists.
For the moped riders considerable higher peak values in a narrow age band of 16-20 years can be seen.
Letality shows the same pattern for the various age groups of moped riders. Letality is increasing with increasing age (fig. 3, Welleman [9]).

7. PRIORITIES WITHIN THE VARIOUS ACCIDENT TYPES

The particular combination of a two-wheeler and its collision opponent is called accident type (e.g. bicycle-car; moped-car).
The accidents in which a cyclist or a moped rider were killed or severly injured, were sampled and categorised in four groups.

A. Accidents with a pedestrian or one (parked or moving) vehicle.
B. Accidents with no other vehicle or a pedestrian involved. Subdivided into:
   1. Collisions with an obstacle (tree, house, animal)
   2. Collisions without an obstacle.
C. Multi (> 2) vehicle accidents.

The distribution of the relative number of killed or severly injured two-wheel riders over these groups are shown in table 2.
The group defined under A will be analysed further on in this paper and consists of ± 80% of the bicycle and moped rider casualties.

7.1. Magnitude (tab. 3; fig. 5, 6)
The car is most frequent the collision partner for the killed (62%) and severly injured (69%) bicyclist. The same is true for the moped rider (killed 48%, severly injured 74%). The heavy goods vehicle is second most the collision partner for the killed bicyclist (23%) and moped rider (21%). The severely injured bicyclist and moped rider came second most in contact with a moped (10% resp. 7%).

7.2. Severity (tab. 3; fig. 5, 6)
The collisions with a tram or a train have the highest letality because there were only a small number of casualties reported. The amount of casualties for this accident type is small for bicyclists (2%) but not for moped riders (10%).

For the bicyclists the collision with a heavy goods vehicle has second priority followed by the collision with a delivery van. Collisions with a passenger car do not seem to have priority.
For the moped riders the collision with a motorcycle has second priority followed by the heavy goods vehicle and delivery van. Collisions with passenger cars again do not seem to have priority.

7.3. Conclusion
Due to the relative high proportion of collisions with cars and the combination of high severity and relative high magnitude of the number of collisions with heavy goods vehicles these accident types will be studied in more detail.

8. PRIORITIES WITHIN THE VARIOUS COLLISION TYPES

A collision type is defined as a particular combination of the impacted sites of the two-wheeler and the collision opponent (e.g. front bicycle - side of car).
The accident types in this paragraph will be subdivided in terms of collision types.
The collisions of a bicyclist or a moped rider with a passenger car or heavy goods vehicle in which the bicyclist or the moped rider was killed or severely injured will be described here.
The impacted sites on the two vehicles are noted by the police, based on damage characteristics and witness statements. The collision types were categorised as shown in fig. 4.

8.1. Bicycle-car accidents (fig. 7).
Most of the cyclists were hit broadside by the front of the car (type F1), 65% of the killed cyclists and 60% of the severely injured. The left side of the bicycle was hit twice as often as the right side (Huijbers [5]). The other collision types did not occur as often: the types F2 and F3 were relatively

important. Collisions with the side of the car happened in most cases with the front of the bicycle (type S1), 10% of the severely injured cyclists. With letality as criterion collision type F3 (front car - rear end bicycle) was the most severe type.

8.2. Moped - car accidents (fig. 8)
In the moped-car accidents the impact type F1 (front car - side moped) dominated again. For 62% of the killed moped riders. The severely injured moped riders were nearly equally hit sideways (F1) and frontal (F2) by the front of the car (39%; 31%).
Frontal collisions with the side of the car happened nearly as frequent for the killed moped rider (13%) as for the severely injured (14%).
The collision types F3 where the front of the car hits the rear end of the moped did not occur as much as for the cyclists (3% killed; 1% severely injured); but this collision type had the highest letality in analogy with the bicycle - car accident. The opposite rear-end collision (R1) happened for 10% of the severely injured moped riders. The letality from this type was minimal because there were no killed moped riders registrated for this collision type.

8.3. Bicycle - heavy goods vehicle accidents (fig. 9)
The collision type front heavy goods vehicle - side bicycle (F1) happened most frequent (42% for both the killed and the severely injured cyclists). The second important collision type was F2 (front heavy goods vehicle - front bicycle) for the killed (19%) and S1 (side heavy goods vehicle - front bicycle) for the severely injured cyclists (18%).
The frontal collision with the rear end of the heavy goods vehicle (R1) happened relatively often for the severely injured cyclists (11%). The collision types F2, F3, S2 and R2 have nearly all the same highest letality.

8.4. Moped - heavy goods vehicle accidents (fig. 10)
The collision type distribution for this accident type is more homogeneous. Collision type F1 dominates for the killed moped riders but collisions with the heavy goods vehicle (F1 en F2) happen nearly as frequent as collisions with the rear end (R1) for the severely injured moped rider (28%), followed by collisions with the side of the heavy goods vehicle (S1).
The collision side moped - side heavy goods vehicle (S2) seems to be most severe, followed by F1.

9. DISCUSSION AND CONCLUSIONS

From a SWOV study described in this paper follows that in the Netherlands the amount of completeness of reporting of accidents resulting in severely injured road users is quite satisfactory. These data may be used therefore to indicate priorities in the field of injury prevention research. The development of hypotheses as a base for an accident investigation project can be concentrated on these priorities.
From the analysis follow different peak values for the age distribution of killed (> 65 years) and severely injured (5-25 years) bicyclists.
Differences in injury tolerance for the various age groups may be part of the explanation. (Letality increases with age).
The small age interval for the moped rider casualties (16-20 years) may be due to the high usage rate and the higher accident rate of this age group.
Mathematical modelling and experimental research projects should take notice of these specific age groups within the population.
Most of the bicyclists and moped riders collided with passenger cars or heavy

goods vehicles. It also follows that the relative share of single vehicle moped accidents is quite high.
If a simple criterion for severity is used, collisions with trams or trains are the most severe, followed by collisions with heavy goods vehicles for the bicyclist.
Accidents with a motorcycle seem to be most severe for the moped rider.
It is quite obvious that injury prevention research should firstly be focused on collisions with passenger cars and heavy goods vehicles.
The distribution of collision types of these accidents is more homogenous divided over the parts of the car and heavy goods vehicles than is the case in car - pedestrian accidents (EEVC [4]), and even more homogenous for moped accidents especially in collisions with heavy goods vehicles.
For cars attention should be focused on the front (type F1, F3) and the side (type S1), especially for collisions with mopeds. For heavy goods vehicles attention should be given to front (F1, F2), side (S, S2) and rear end (R1).
Differences of and direction of speeds at impact and different body locations that may be hit first by the two-wheeler or the car i.c., differences in injury producing mechanisms, make it necessary that injury prevention research studies different collision types seperately. In terms of possible effect of counter measures though it must be realised that seperate measures may be interacting, not only within the population of two-wheeler accidents but also with accidents that involve pedestrians, car occupants and to a certain extent the whole accident population. Therefore an integral approach to a "safety car" will be benificial.
The setting up of Working Group 8 of the EEVC is one step foreward. A lot of information, described in this paper, is used for the report of this group.

10. LITERATURE

1. Ashton, S.J.; Pedder, J.B.; Mackay, G.M. Pedestrian Injuries and the Car Exterior. Accident Research Unit, University of Birmingham. SAE, 1977, Detroit.
2. Blokpoel, A.; Van Minnen, J. & Wegman, F.C.M. De verkeersonveiligheid in cijfers. (The lack of Traffic Safety in ciphers) R-83-17. SWOV, 1983. (IRRD 275490).
3. Bunketorp, D. et al. Traffic Accident Registration and Analysis in Göteborg. Ircobi Conference, Köln, 1982.
4. EEVC (Werkgroep 7). Pedestrian injury accidents. European Experimental Vehicles Committee ESV Conference, Kyoto, 1982.
5. Huijbers, J.J.W. Een beschrijving van fietser- en bromfietserongevallen ten behoeve van prioriteitsindelingen bij het letselpreventie-onderzoek. SWOV, (not yet published).
6. Huijbers, J.J.W. Factoren van belang voor het verminderen van de ernst van ongevalsletsels en onderzoek naar de blijvende gevolgen ervan bij voetgangers, fietsers, bromfietsers en motorrijders, Deel 1. Proloog; voetgangers. SWOV. (Not yet published).
7. Maas, M.W. De politieregistratie van verkeersgewonden in ziekenhuizen. (Police recording of road accident in-patients). R-82-34. SWOV, 1982. (IRRD 268004).
8. Pedder, J.B.; Hagues, S.B.; Mackay, G.M. & Roberts, B.J. A study of two-wheeled vehicle casualties treated in a city hospital. In: IRCOBI, Salon de Provence, 1981.
9. Welleman, A.G. Traffic Safety of bicycles and mopeds. SWOV. (Not yet published).

category of road users	killed		severely injured		letality
	numbers	%	numbers	%	
car occupants	851	47	6349	36	11,8
bicyclists	356	20	4123	23	7,9
moped riders	158	9	3693	21	4,1
pedestrians	293	16	2125	12	12,1
motor riders	106	6	904	5	10,5
others	43	2	366	3	10,5
N - total	1,807	100	17,560	100	9,3

Tab. 1 Distribution of killed and severely injured road users, and letality, by mode of transport (1981).

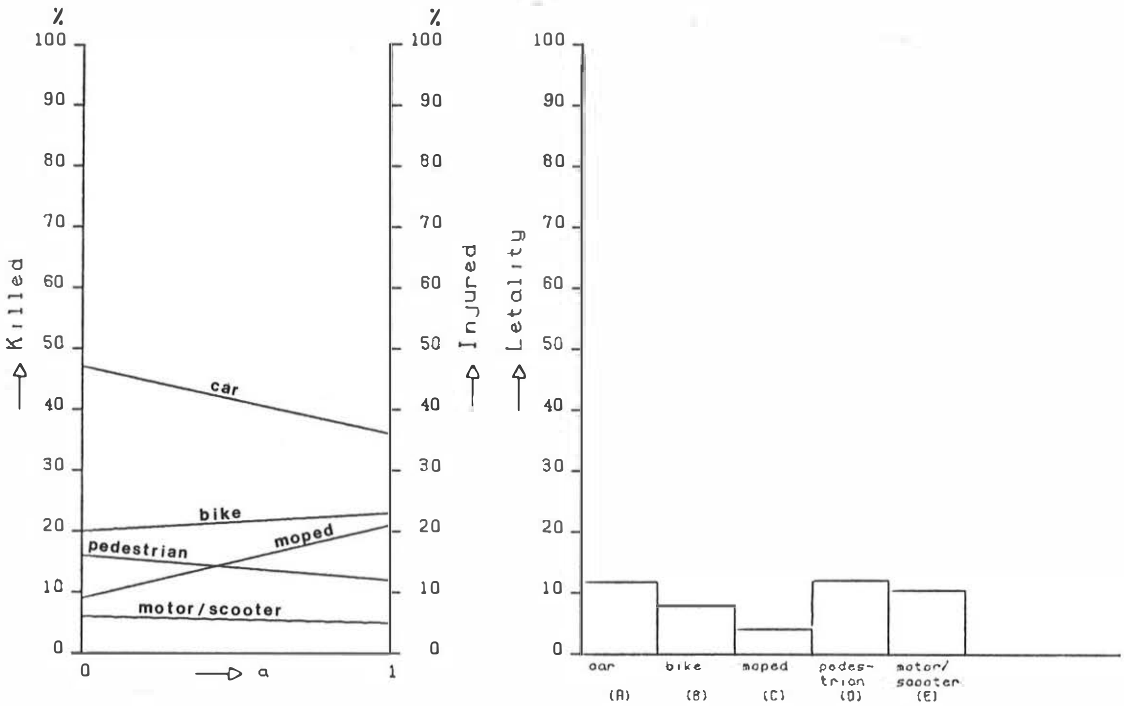

Fig. 1 Priorities within the various categories of road users.

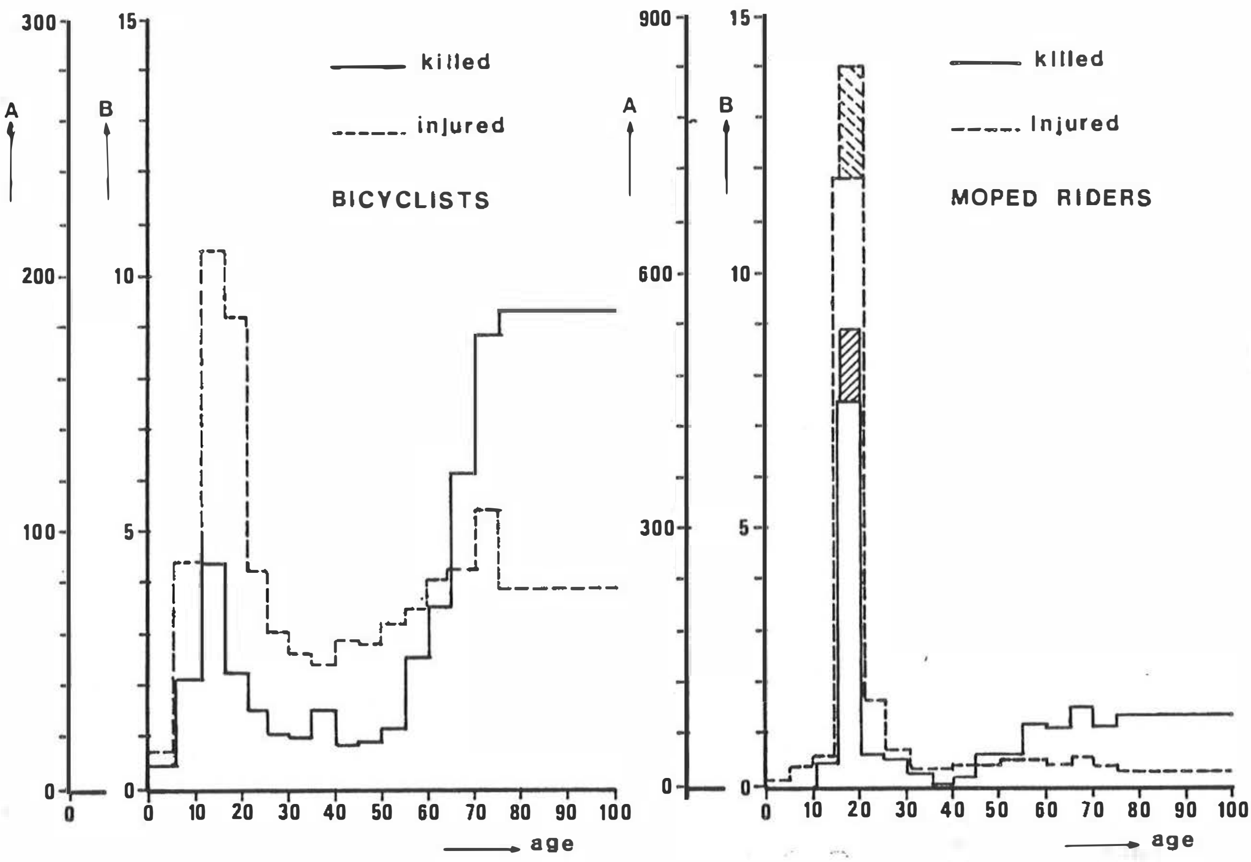

Fig. 2 Age distributions of killed (B) and severely injured (A) bicyclists and moped riders per 100,000 people of various age groups (1981).

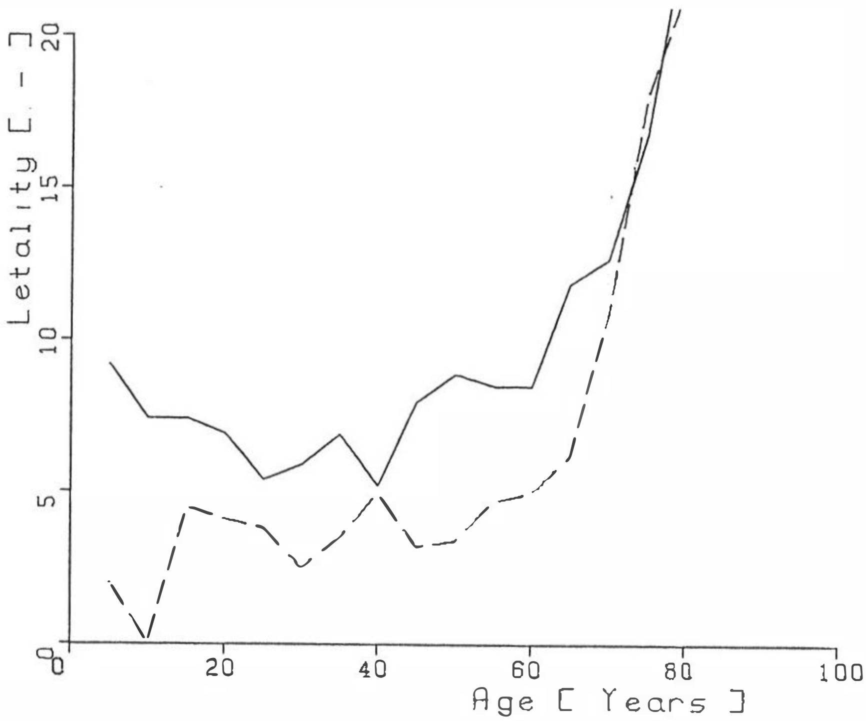

Fig. 3 Letality of bicyclists and moped riders by various age groups. (Welleman (9)).

		killed	severely injured
A	bicyclist	89 %	79 %
	moped rider	72 %	78 %
B_1	bicyclist	4 %	8 %
	moped rider		
B_2	bicyclist	1 %	3 %
	moped rider	17 %	7 %
C	bicyclist	5 - 10 %	
	moped rider		

Tab. 2 Percental distribution of road accident casualties by some groups defined in this study.

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	-	54.5	10	-	56.5
bicycle	-	6	0,0	-	3	0,0
moped	3	10	3,1	4	7	2,2
other 2-wheelers	-	-	-	-	-	-
pedestrians	-	1	0,0	-	2	0,0
others	2	2	10,1	4	2	7,4
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 (1979).

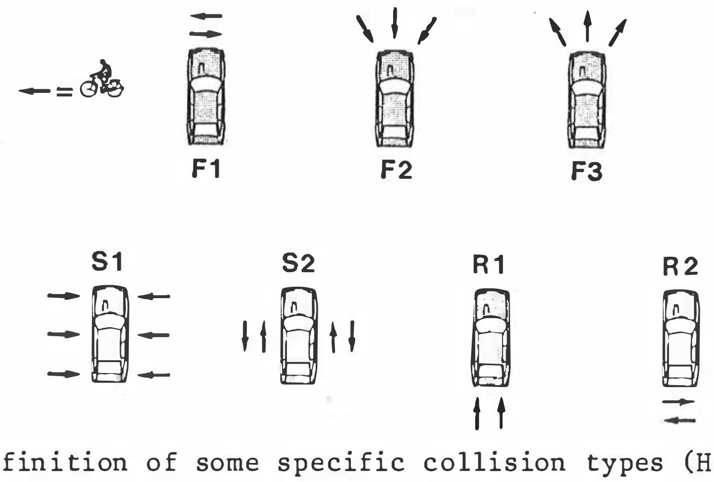

Fig. 4 Definition of some specific collision types (Huijbers (5)).

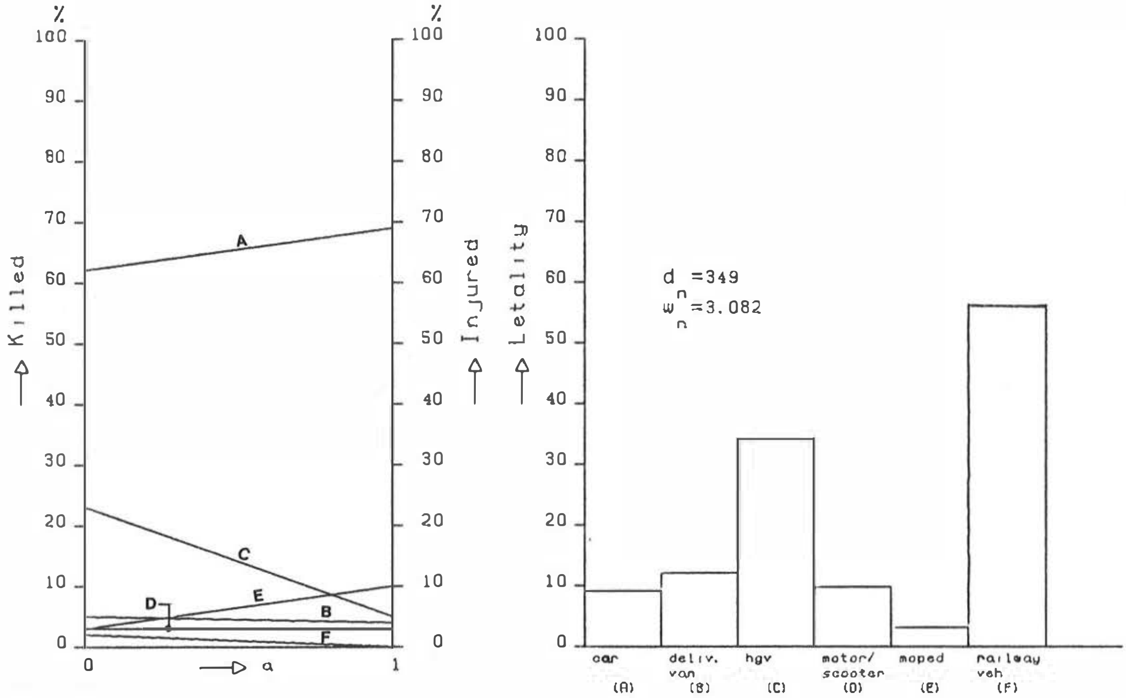

Fig. 5 Priorities within the various accident types resulting in killed and severely injured bicyclists (1979).

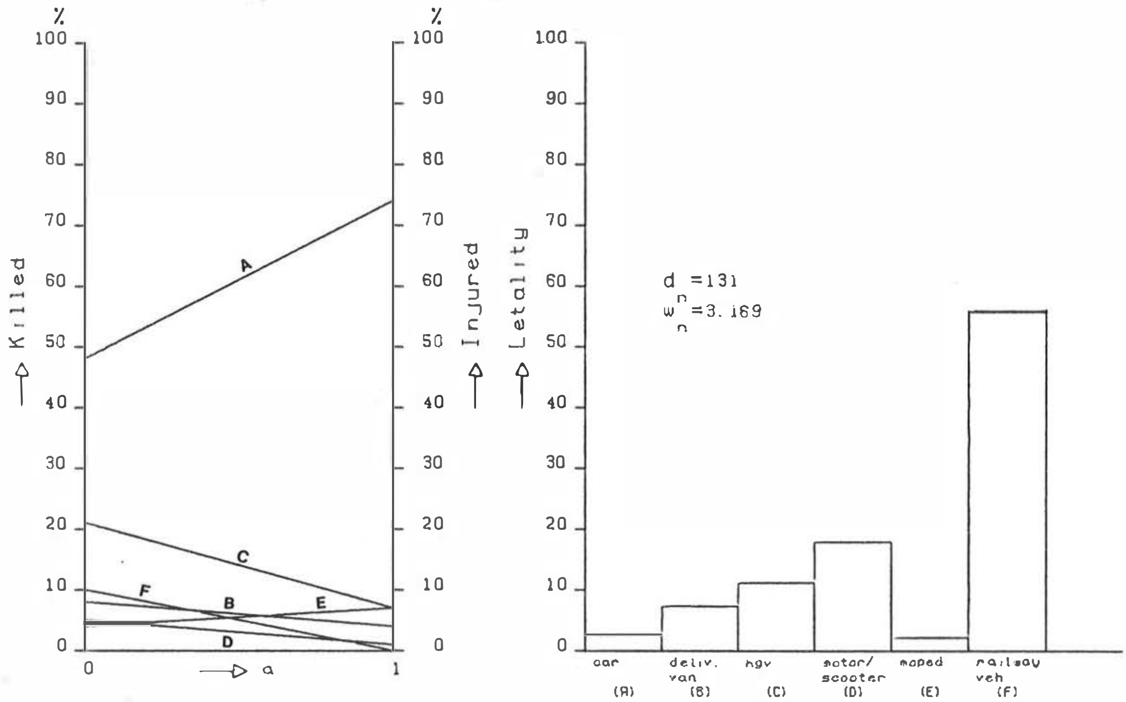

Fig. 6 Priorities within the various accident types resulting in killed and severely injured moped riders (1979).

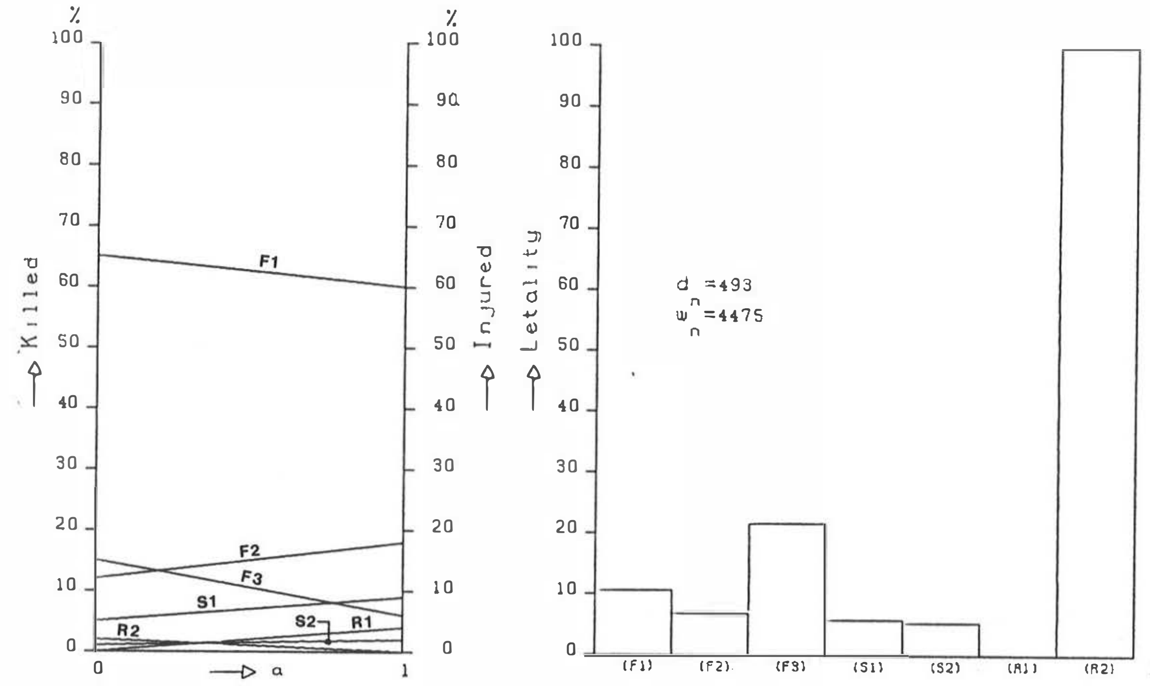

Fig. 7 Priorities within the various collision types for bicycle to car collisions (1978, 1979).

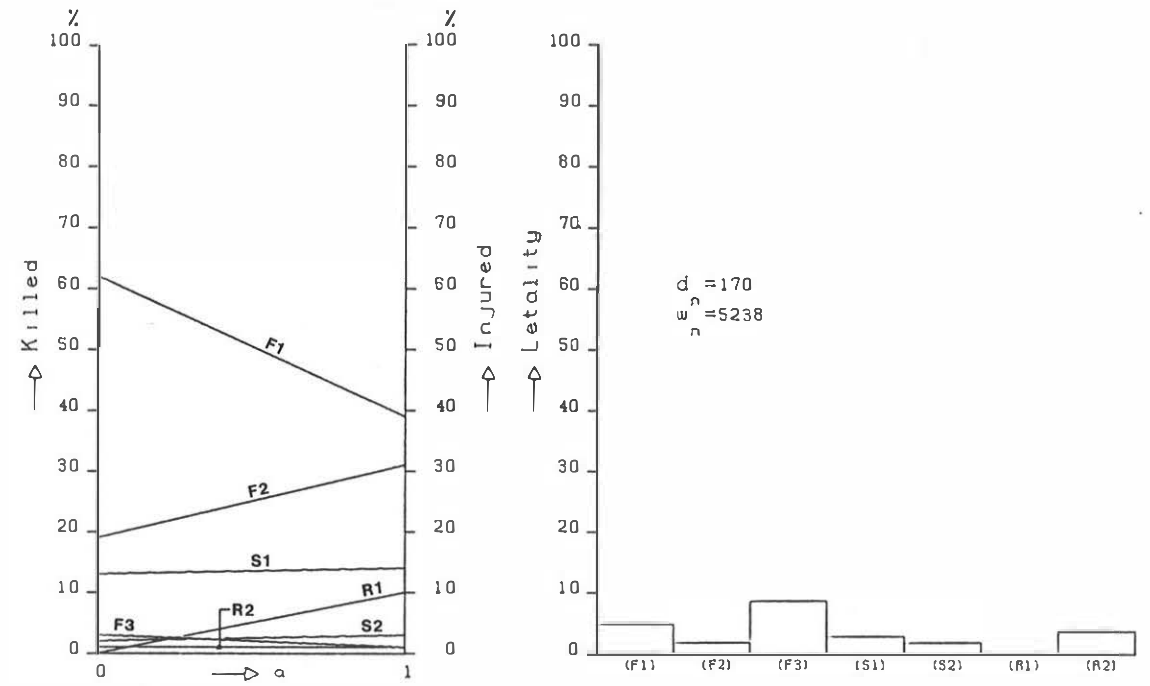

Fig. 8 Priorities within the various collision types for moped to car collisions (1978, 1979).

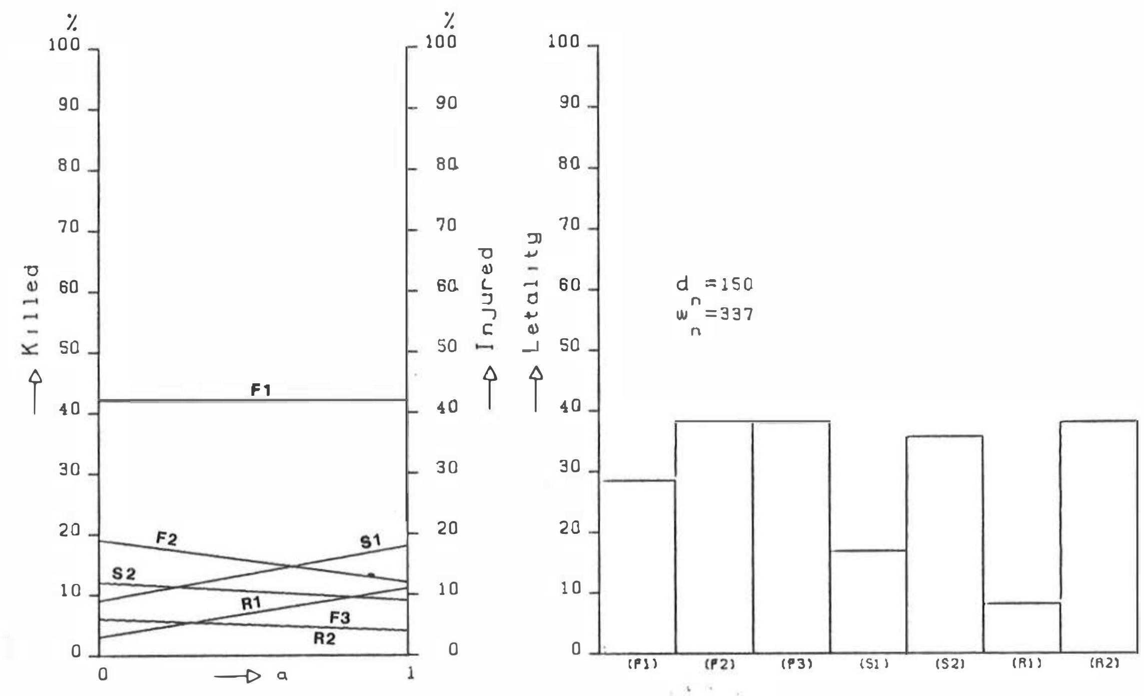

Fig. 9 Priorities within the various collision types for bicycle to heavy goods vehicle collision (1978, 1979).

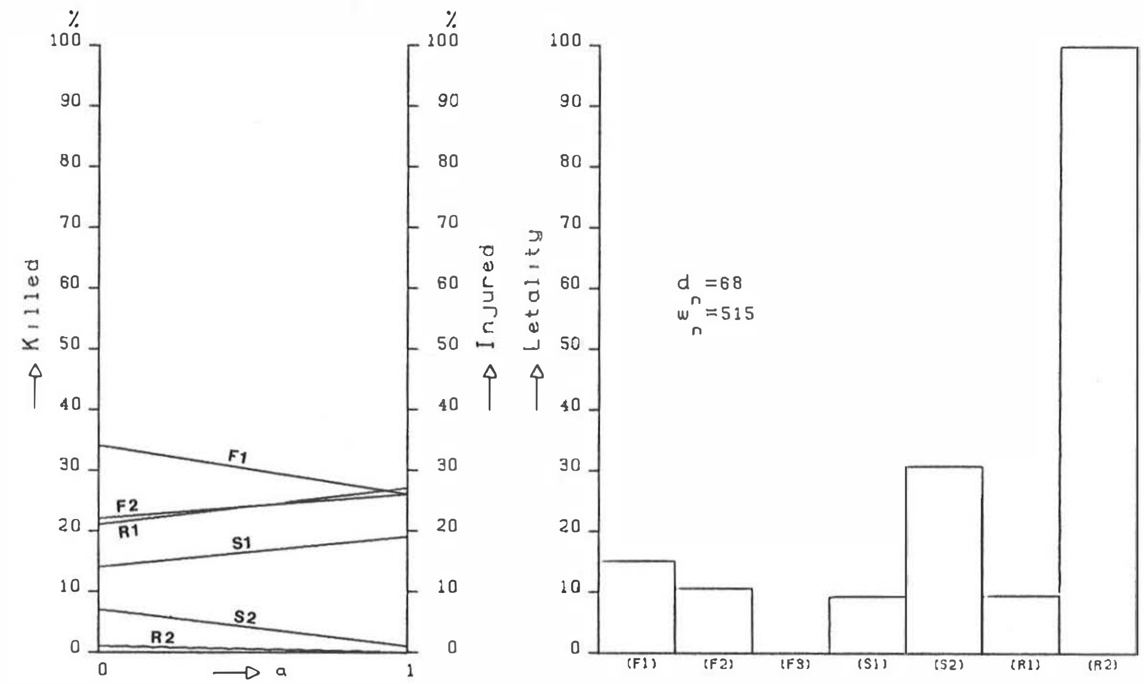

Fig. 10 Priorities within the various collision types for moped to heavy goods vehicle collisions (1978, 1979).