A SYNTHESIS OF DATA FROM A MULTI-PURPOSE SURVEY ON PEDESTRIAN ACCIDENTS.*

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ABSTRACT.

The first results of a medical and technical multi-purpose survey on 87 "car-pedestrian" accidents are stated.

The configurations of the "car-pedestrian" collisions are examined, and the influence of collision speed and age on the seriousness of the injuries whether taken as a whole or per body area is looked into.

The second phase consists in analysing what causes injuries (ground or vehicle). Special attention is paid to "head-vehicle" impacts.

INTRODUCTION.

Among the people killed on the roads, the relative importance of pedestrians with relation to motorists has, over the past few years, been ever-increasing due to the various safety measures adopted to the latter's benefit.

A twin-purpose survey of a sample of 87 dead and injured pedestrians, which was carried out in conjunction with experimental work with dummies and cadavers is developed in the following pages (1, 2).

SURVEY EQUIPMENT.

The vehicles - Our investigation was limited to only those accidents between pedestrians and private cars (85 cases) + forward cabins (2 cases). The average profile of private cars (empty) is given by the height of the bumper (42cm), the top edge of the front face (73cm) (fig. 1-a) and the average length of the bonnet (111cm).

People killed - The sample is particularly severe as it has 25 people killed out of 87 victims (29%), whereas the national percentage is 6% (3). It can be seen that two of the dead were on the ground at the time of collision. It would seem that one was manifestly drunk and the other a suicide. We will not take these two cases into account for this survey.

Size and age of pedestrians - The number of children less than 10 years old in this investigation is 19/85, i.e. 22%, which is very close to the national French rate (23,1%). The percentage in Federal Germany is 34,3% and 32% in the United Kingdom (4) (1973).

We have limited the class of children to pedestrians less than 10 years old because of the special kinematics of small pedestrians in comparison with adults.

14 years would seem to us too-high an age because the average height would then be 159cm (mixed population), i.e. the 45° adult percentile (mixed population)(fig.1-a) (5).

The distribution according to height of our sample of 85 injured pedestrians is very similar to the national distribution (fig. 1-b). You will notice the low density of pedestrian heights in the region 140cm (i.e. 10 years old).

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*This survey is being carried out under contract with DGRST (French Government).

figure 1-a : HEIGHT OF CHILD AND ADULT PEDESTRIAN BY AGE FRANCE 1971
AVERAGE HEIGHT OF BUMPERS (B) AND LEADING EDGE OF BONNET (A)
IN FRANCE

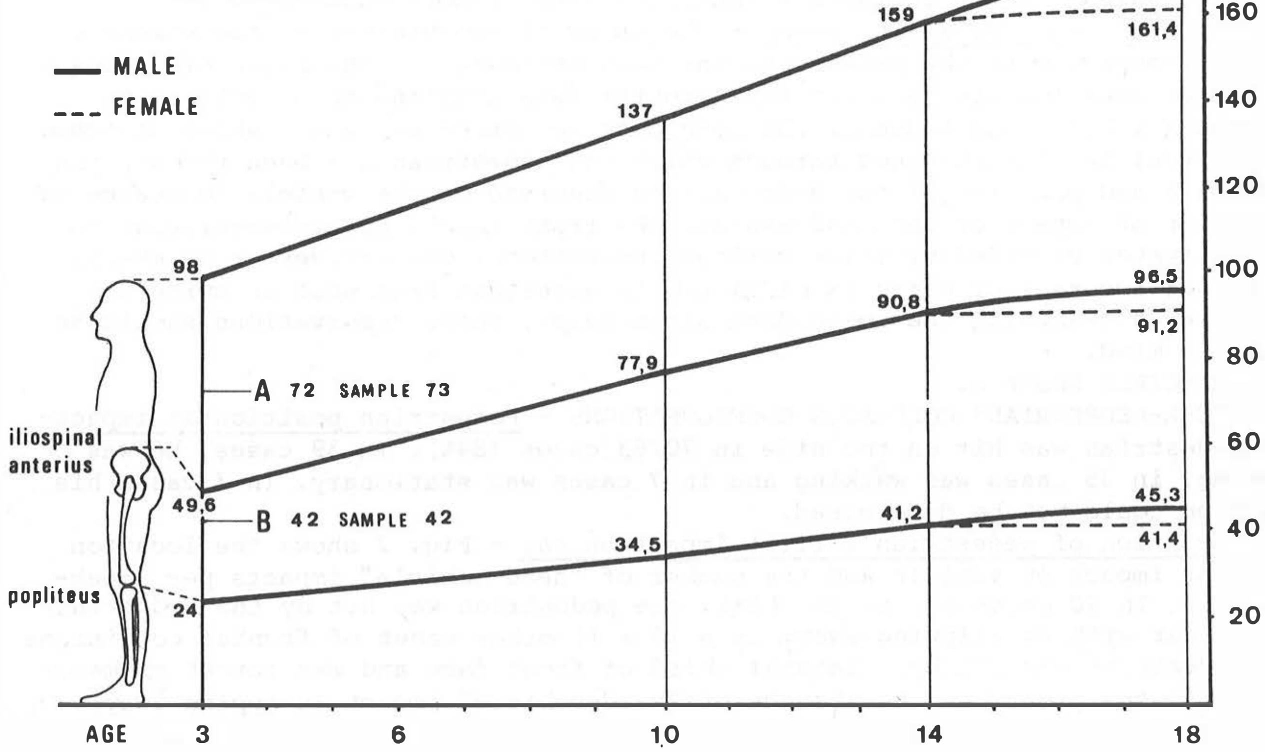
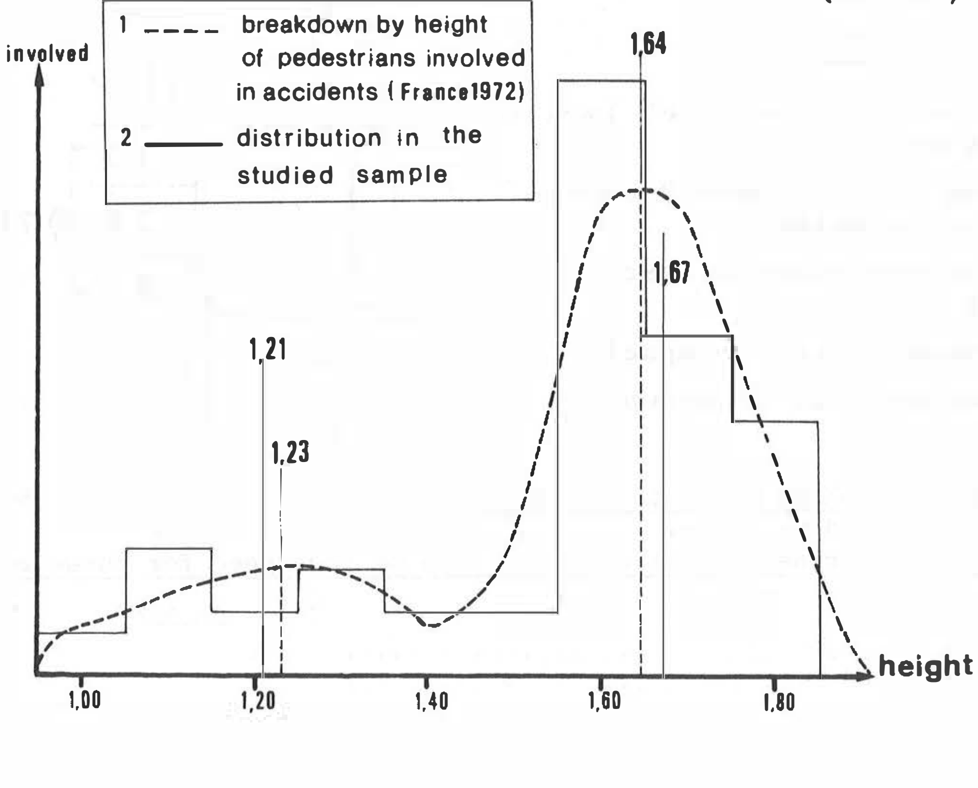


figure 1b. pedestrians involved in accidents versus height (in m)



This height could be taken as the dividing line between child and adult pedestrians.

Old people (more than 60) represent 21% (18/85) of the sample, i.e. a portion equivalent to the children's (National rate of more than 60's: 25%).

Evaluation of collision speed - The speed of the vehicle at the moment of initial contact with the pedestrian has been estimated on the basis of accidentological data compared against experimental data acquired in 60 collisions between a vehicle and a dummy. The main data concerned are the braking distance of the vehicle, the distance through which the pedestrian has been thrown, the amplitude and position of the deformations observed on the vehicle (distance of the point of impact of the head against the front face). By cross-correlating the estimates provided by these various indications, one arrives at an evaluation, the accuracy of which is difficult to ascertain from what is currently known. When examining the speed data given below, these reservations should be borne in mind.

THE PRINCIPLE RESULTS.

"CAR-PEDESTRIAN" COLLISION CONFIGURATIONS - Pedestrian position at impact- The pedestrian was hit on the side in 70/83 cases (84%). In 39 cases, he was running, in 35 cases was walking and in 7 cases was stationary. In 2 cases his position could not be determined.

Location of pedestrian's first impact on car - Fig. 2 shows the location of first impact on vehicle and the number of "head-vehicle" impacts per impacted area. In 70 cases out of 85 (82%), the pedestrian was hit by the front face of the car with no slipping away. In 6 (5 + 1) other cases of frontal collisions the pedestrian was hit by a lateral third of front face and was thrown prematurately to the ground in the absence of "head-vehicle" impact (slipping away). In 9 cases, the pedestrian was struck by the side of the vehicle.

Fig. 2 - Location of initial pedestrian impact on vehicle - N = 85

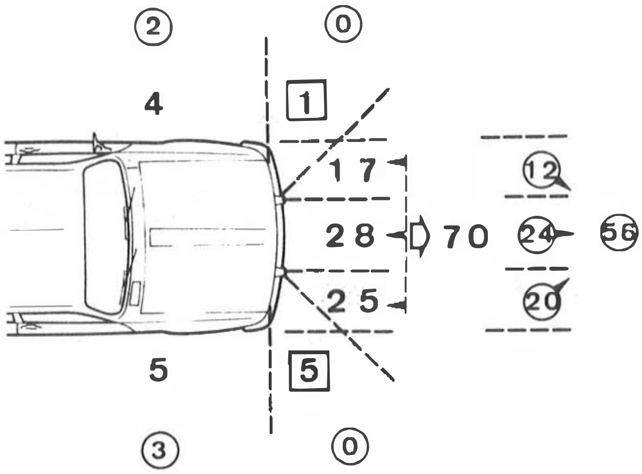
Number of "head-vehicle" impacts - N = 61.

LEGEND

Number of "head-vehicle" impacts per hit area ○

Slipping away □ These 3 conditions are combined :

- "car-pedestrian" contact on front 1/3,
- no "head-vehicle" impact,
- premature fall to ground.



Vehicle braking prior to collision - In over half the cases (54%), the vehicle had started to brake.

Injury severeness (OSI) as a function of the speed for three age groups.

	0	20 km/hr	40 km/hr
Children < 10 years old.......................	25%	39%	36%
10 < adults < 60............................	9%	27%	64%
Elderly people................................	22%	23%	55%

The higher violence of the sample for adults and elderly people can be seen in comparison with the children.

Table 1: two remarks concerning the severeness of the injuries according to the age groups can be stated:

- in frontal collisions at more than 30 km/hr, we can see there were nine survivals out of eleven involved in the children's groups as against none in the old people's group (9 dead/9 involved).
- for collision speeds higher than 40 km/hr, 8 dead/8 involved (100%) were recorded for old people as against 11/20 (55%) for the adult group.

O.S.I.	a) < 10 years (N = 18)						b) 10 to 60 (N = 47)						c) > 60 years (N=18)					
	<20	21 30	31 40	41 50	51 60	>60 km/h	<20	21 30	31 40	41 50	51 60	> 60 km/h	<20	21 30	31 40	41 50	51 60	>60 km/h
6				1	1		(1)			3	2	4 (2)			1	6	1	1
5		(1)		1					1	1								
4			1															
3		(1)						1	1	2		(1)		2				
2	(2)	2	5 (1)		1		1 (1)	5 (4)	6 (2)	1 (1)	1		2 (1)	2 1				
1	(1)						(1)	1 (1)	1	2			(1)					
Total:	3	4	7	2	2		4	12	11	10	3	7	4	5	1	6	1	1

Table 1 - Severeness of injuries as a function of speed for 3 age groups (N=83)
(No "head-vehicle" impact is shown in brackets).

Distribution of impact speeds according to seriousness of injuries - Fig. 3-a shows the cumulated distribution of collision speeds for the sample as a whole.

The 50° pedestrian in our sample was struck at 36km/hr, the 25° and 75° victim centiles being situated respectively at 25 and 47 km/hr.

The data corresponding to Birmingham (6) and Hanover (7) are offset to the left by, respectively 9 km/hr and 2 km/hr. This difference is relatively small if we admit that our sample is distinctly more severe than those of Birmingham and Hanover (which are turn more severe than their respective national accident populations).

Fig. 3-b shows the cumulated distribution of collision speeds in fatal "car-pedestrian" accidents. Our sample shows that the 25°, 50° and 75° centiles killed are struck respectively at 45, 51 and 65 km/hr.

We compared this result with that for Birmingham (6) and Heidelberg (8). It can be seen that those killed in the Birmingham sample were struck at speeds of on an average 8 to 10 km/hr lower - the 50° killed in the afore-mentioned sample were struck at 42 km/hr, i.e. 9 km/hr less than in our investigation (APR).

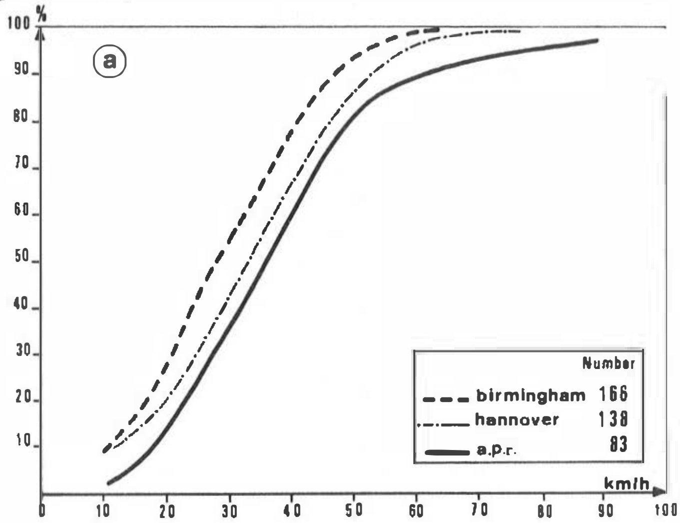
Fig. 3-c shows the cumulated distribution of non-fatal corporal accidents. The APR curve situates the 25°, 50° and 75° injured centiles at the following respective speeds: 22, 29 and 37 km/hr. The Birmingham curve is offset by approximately 6 km/hr to the left.

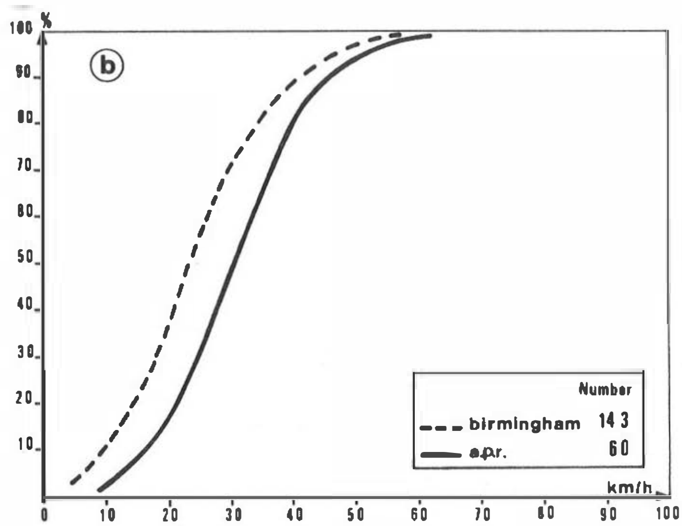
According to our sample, the 75° injured centile and the 25° killed centile are struck respectively at 37 and 45 km/hr.

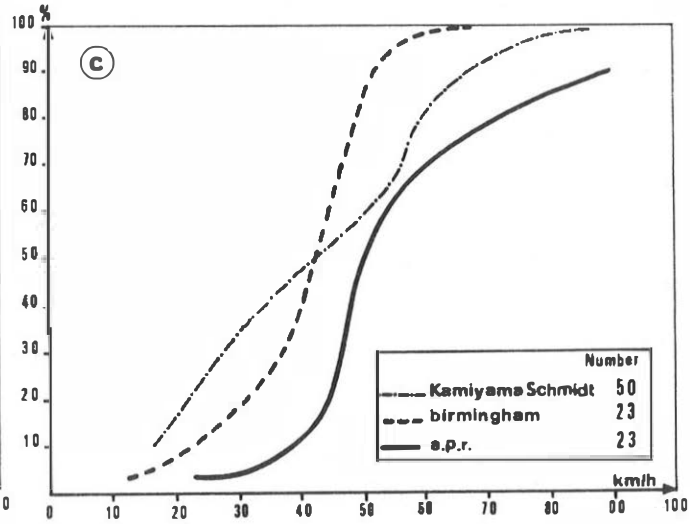
Fig. 3-a: Distribution of collision speeds in "pedestrian-car" accidents where there is injury.

Fig. 3-b: Distribution of collision speeds in non-fatal "pedestrian-car" accidents.

Fig. 3-c: Distribution of "car-pedestrian" collision speeds. Fatal accidents.







CAUSE, FREQUENCY AND SEVERENESS OF INJURIES PER BODY AREA - A thorough knowledge was had of injuries in 20/23 cases of people being killed (11 autopsies + 9 cases using X-ray examination, operating reports, etc.), and 61/62 cases of people being injured (insufficient injury for one person who was slightly hurt), i.e. a total of 81 victims.

Frequency of injuries per body area (any degree of injury severeness, N=81). 270 injuries were recorded in all, i.e. an average of more than 3 per victim. The head was the most involved body part (89 injuries), i.e. more than one head injury per person on an average. Then come the lower members (73), the thorax (31), the upper members (31), the pelvis (18) and the abdomen (12). It is to be remarked that the neck is hardly ever wounded.

THE KILLED (Table 2-a) (N=20) - Causes of death - Isolated fatal head wounds (9 cases) or associated fatal head wounds (10 cases) are the cause of nearly all deaths (19/20, i.e. 95%). Associations with fatal head wounds are as follows: abdomen (5), thorax (4), neck (1). Out of these 19 fatal head traumatisms, 13 fractures of the cranium were recorded. In one case, death was due to rupturing of a femoral artery following the traumatic amputation of a lower member of a 46 years old man (collision at approximately 70 km/hr).

Table 2-a:Cause, frequency and severeness of injuries per body area for the killed (N = 20).

TOTAL	A.I.S. VEHICLE CONTACTS 1	2	3	4	5	BODY AREAS	A.I.S. ROAD CONTACTS 5	4	3	2	1	TOTAL
17				1	16	HEAD	2				5	7
1					1	NECK					1	1
13	1	3	5	2	2	THORAX			1			1
3	1	2				UPPER LIMBS				1	1	2
6			1	5		ABDOMEN						0
1		1				DORSO-LUMBAR SPINE						0
6	1	2	3			PELVIS						0
17	1	8	5	3		LOWER LIMBS					1	1
64	4	16	14	11	19	TOTAL	2		1	1	8	12

<u>Cause and severeness of wounds for the killed</u> - Five times more wounds due to the vehicle (64) than to the ground (12) were recorded. Slight wounds of level AIS 1 were due more often to the ground than to the vehicle. For serious wounds, the trend is reversed as it can be seen that 30/32 wounds of level AIS 4 and 5 were due to the vehicle.

Among these 30 wounds caused by the vehicle, 17/30 (57%) were caused by "head-vehicle" impacts alone.

In only 2 cases, did we see fatal head wounds due to a "head-ground" impact. It would seem to us an elementary precaution to underline the difficulty in evaluating the severeness of a "head-ground" impact following a severe "head-vehicle" impact. Because of this, "head-ground" injuries are probably under-estimated.

THE WOUNDED (Table 2-b) (N=61) - <u>Frequency and severeness of wounds per body area</u> - The most frequent wounds are head wounds (65 wounds) and lower members (55). The neck (8) and abdomen (6) are hardly injured in comparison.

The linear AIS scale does not correctly reflect the relative severeness of the wounds. This is why it seemed more realistic to us to specify the "weight" of each wound by its AIS cubed. It is quite possible, as states PETERSEN (9), that doing this could lead to a better approach to the "social cost". 53% of the sum of AIS^3 is attributable to the head against 27.6% for the lower members and 11.3% the thorax. This order reflects fairly well the "weight" of each body area taking into account the frequency and severeness of wounds among the injured pedestrians in our investigation.

<u>Cause of wounded pedestrian's injuries</u> - Ground injuries (66/194) represent a low percentage of all the AIS^3 (20%) recorded for the wounded pedestrians in our sample.

The vehicle appears to be responsible for 2 out of 3 wounds of injured pedestrians.

The head represents 51% of all AIS^3 imputed to the vehicle against 32% for the lower members, although injuries to the lower member due to the vehicle are greater in number (45) than head wounds (41). This can be explained by the fact than in four cases, some pedestrians victim of 4-5 level "head-vehicle" impacts survived.

Finally, it should be noted that the neck, the abdomen and the pelvis were hardly injured.

Table 2-b: Cause, frequency and severeness of injuries per body area for the injured (N = 64).

BODY AREA	VEHICLE CONTACTS A.I.S. 1	2	3	4	5	ΣAIS^3	%	ΣAIS^3 total	%	ΣAIS^3	%	ROAD CONTACTS A.I.S. 5	4	3	2	1	BODY AREA
Head	17	18	2	1	3	654	40,7	851	53	197	12,3	1			7	16	Head
Neck	4	1				12	0,7	15	0,9	3	0,2					3	Neck
Thorax	4	4	3			117	7,3	182	11,3	65	4,0			2	1	3	Thorax
Upper members	6	6				54	3,4	75	4,7	21	1,3				1	13	Upper members
Abdomen	5					5	0,3	6	0,3	1	0,0					1	Abdomen
Dorso-lumbar spine	3					3	0,2	5	0,3	2	0,1					2	Dorso-lumbar spine
Pelvis	3	3				27	1,7	33	2,1	6	0,4					6	Pelvis
Lower members	12	26	7			409	25,5	440	27,4	31	1,9				3	7	Lower members
Total	54	58	12	1	3	1281	79,8	1607	100	326	20,2	1		2	12	51	Total

"HEAD-VEHICLE" IMPACTS - Table 3 gives the location, frequency and severeness of "head-vehicle" impacts recorded in the investigation. Out of 84 collisions, 61 cases of "head-car" impacts were recorded, in 3 of which there were no injuries.

If we impute the corresponding portion of all AIS^3 to each area of the vehicle, we find 33 % of points were imputed to the windscreen surround, 22% to the bonnet (and wings), 13% to cowl opening, 11 % to windscreen, 9 % to dashboard (after having gone through the windscreen), 9% to the roof and finally 9% on accessory parts such as aerial or rear-view mirror.

"Head-windscreen surround" impact - In our investigation, this represent 25% (15/61) of "head-vehicle" impacts, 23% (7/30) of all fatal injuries and 36% (7/19) of fatal "head-vehicle" impacts. One "head-windscreen" impact out of two was the cause of fatal injury.

"Head-bonnet" (and wings) impact - In our investigation, this represents 26% (16/61) of "head-vehicle" impacts, 13% (4/30) of all fatal injuries, 21% (4/19) of fatal "head-vehicle" impacts. One "head-bonnet" impact out of four was the cause of fatal injury.

"Head-cowl opening" impact - The cowl opening was struck in 7 cases out of 61 (11%) and was the cause of 2 fatal wounds.

"Head-windscreen" impact - The "head-windscreen" impact on its own is quite frequent, 12/61 cases (21%), but the average severeness index $\sqrt[3]{\frac{\Sigma AIS^3}{n}} = 2.9$

is the lowest of all the other types of "head-vehicle" impacts except the impacts on the side units (rear-view mirror, aerial, etc.).

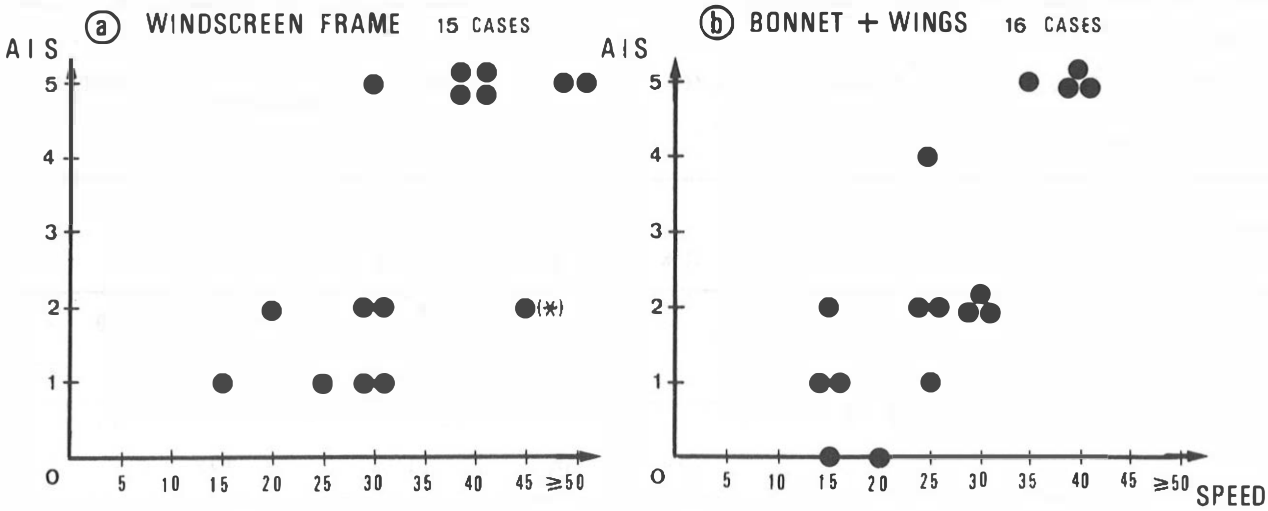
Table 3 - Location, Frequency and severeness of "head-vehicle" impacts (N = 61).

VEHICLE HEAD CONTACT	ΣAIS^3	%	N	$\sqrt[3]{\frac{\Sigma AIS^3}{n}}$	A.I.S. 5	4	3	2	1	0
Windscreen frame....	911	33,5	15	4	7			4	4	
Bonnet + wings......	615	22,6	16	3,4	4	1		6	3	2
Scuttle............	351	12,9	7	3,7	2	1	1	1	2	
Windscreen glass....	287	10,6	12	2,9	2			4	5	1
Dashboard (+ windscreen glass broken)	251	9,2	3	4,4	2				1	
Roof	250	9,2	2	5	2					
Lateral elements (wing mirror, aerial)	53	2	6	2,1			1	3	2	
Total:	2718	100	61		19	2	2	18	17	3

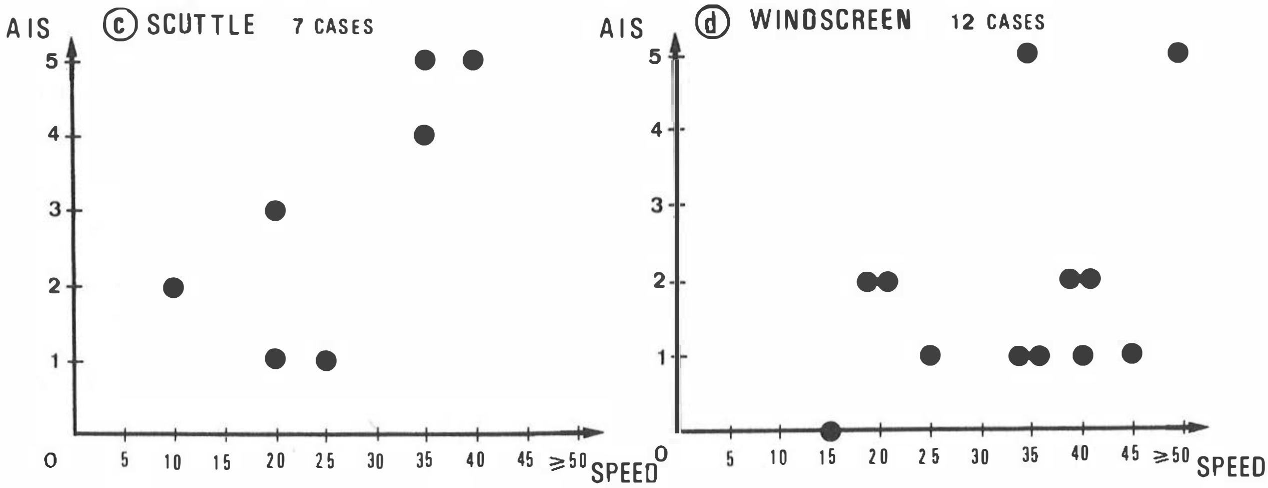
The other "head-vehicle" impacts - The "head-dashboard" impacts (after hitting and breaking the windscreen), and impacts with the roof (very high average severeness indices) take place only at speeds respectively of 40 km/hr and 50 km/hr.

Tables 4-a-b-c-d give the distributions of "head AIS" against the four most frequently hit vehicle units struck by the head, as a function of the speed. The severeness of "head against windscreen surround, bonnet and cowl opening" impacts increases with the collision speed. On the other hand, the severeness of "head-windscreen" impacts depends but little on the speed (except in two cases (AIS = 5) of head impacts with the windscreen surrounding area).

Table 4 - Location, frequency and severeness of "head-vehicle" impacts (N = 50).



* 9 years old child hit by a vehicle of "forward cabin" type.



"Vehicle-lower members" impacts - For the analysis of injury to the lower members caused by the front face of the vehicle, we have excluded the victims of fatal cranium, cervical and thoracic wounds (22 cases) for which eventually equipping the front face of the vehicle with the sole aim of reducing the severeness of the injuries to the "lower member" body area on its own would have no meaning.

Out of 61 injured victims and 1 killed (AIS = 4 on lower member), 34 (56%) had injury to the lower members of the type "fracture or dislocation". Out of these 34 injuries of level AIS $\geqslant$ 2, 26 (76%) were caused by the bumper.

The knees were injured in only 4 cases out of 62 - the limited number of knee injuries is in relation to the average bumper height of the cars in our sample (42 cm empty) (see figure 1-a).

Table 5 shows the number of injuries recorded on each area of the lower member as a function of its cause on the vehicle (bumper or foremost edge of bonnet and headlights). The percentages show the portion of total AIS^3 "lower members-car" for the injured (plus 1 killed). It seems that 70 % of the total is imputed to the bumper.

Table 5 - Cause, frequency and severeness of "lower members - front face of vehicle" impacts for all injured (with 1 killed whose death was due solely to a "lower member" body area) (N = 62)

TITLE (Injuries No.) (1) % Σ Total AIS^3	ANKLE	LEG	KNEE	THIGH	MULTIPLE INJURIES	TOTAL
Bumpers..............	2 3%	23 38%	4 5%	5 7%	3 17%	37 70%
Leading edge of bonnet + lights				7 10%	2 20%	9 30%
TOTAL................	2 3%	23 38%	4 5%	12 17%	5 37%	46 100%

(1)$\Sigma AIS^3 = 409 + 4^3 = 473$ has been reduced to a 100.

CONCLUSIONS

Studying a severe sample of 85 injured pedestrians (23 of whom were killed) has highlighted the following results:

- on conditions of accidents:
  1. 78% of pedestrians involved were of adult size (H > 140 cm) both in our sample and on a national scale (France, 1974).
  2. The pedestrians were struck on the side in 84 % of cases. In more than one case out of two, they were running.
  3. The "car-pedestrian" contact took place, in 76/85 cases (89%) on the front face of car.
  4. The average profile of the private cars on our investigation is specified by the height when empty of the bumper (42cm), the upper edge of the front face (73cm) and the distance separating the front face from the windscreen in front of the driver (111 cm).
  5. The car had started braking prior to the collision in over half the cases.
- on collision speeds: The methods employed for evaluating the speeds are susceptible to improvement, in particular by increasing the number of experimental collisions either in the form of control collisions, for reference, or the reconstruction of real-life accidents. On the basis of what is currently known, the results should be considered with all due precaution.
  6. The average collision speed for the whole sample was 36 km/hr as against 51 km/hr for the killed and 29 km/hr for the injured.
  7. At high collision speeds, it would seem the death rate for children is significantly lower than for elderly people (>60).
- on the killed and injured's wounds:
  8. 9 out of 20 are killed by a fatal head wound, whereas 10 out of 20 are killed by a fatal head wound associated with other fatal wounds: abdominal (5), thoracic (4) and cervical (1).
  9. For non-fatal injuries to the injured, the head (53%) and the lower members (27%) suffered 80% of injuries as a whole (% Σ total AIS^3).
- on cause (vehicle-ground) of injuries:
  10. It appeared that the ground was responsible for very few of the fatal and serious injuries (AIS 4 and 5) (3/37).
- on "head-vehicle"impacts:
  11. The "head-vehicle" impact alone represents 57% of all fatal and serious injuries (AIS $\geqslant$ 4).
  12. The "head-vehicle" impacts of level AIS 4 and 5 take place in 3 out of 4 cases with the windscreen surround, the bonnet (and wings), and the cowl opening.
  13. Studying "head-vehicle" impacts would seem to be interesting in the critical area of our sample situated between 37 and 45 km/hr (respectively 75° centile injured and 25° centile killed).
- on "car-lower members" impacts:
  14. For the injured (and 1 killed), the bumper was responsible for 70% of injuries due to contact with "front face of vehicle-lower members", compared with 30% with top part of front face (including the headlights)(%ΣAIS^3)
  15. The knees and pelvis were little injured in our sample.

To our mind, pedestrian accidentology should still make more progress, at the same time attempting to:

- refine techniques for evaluating collision speeds,
- better detect any "head-ground" injuries,
- to distinguish the difference in agressiveness of the different types of pri-

vate cars, not only concerning the profile (as has already been attempted) but also the stiffness of architecture of front of vehicle.

- allow an evaluation of the "cost/benefit" ratio to be made, in connection with experimental studies, of any arrangements while taking into account of the advantages which may result from this for two-wheeled users.

References.

1. G. Stcherbatcheff, C. Tarrière, P. Duclos, A. Fayon, Cl. Got, A. Patel: "Simulations of pedestrian accidents with adult and child dummies and with cadavers". In Proceedings of the 19th. Stapp Car Crash Conference, 1975.
2. G. Stcherbatcheff, C. Tarrière, P. Duclos, A. Fayon, C. Got, A. Patel: "Reconstitutions expérimentales d'impacts "tête-véhicule" de piétons accidentés". In Proceedings of the 2nd International Conference on the Biokinetics of Impacts (IRCOBI 1975).
3. S.E.T.R.A.: "Accidents corporels de la circulation routière", Ministère de l'Equipement, 1974.
4. United Nations: "Statistiques des accidents de la circulation routière en Europe", 1973.
5. M. Sempe et G. Pedron: "Etudes sur la Croissance", Paris, 1970.
6. S.J. Ashton: "The cause and nature of head injuries sustained by pedestrians". In Proceedings of the 2nd International Conference of Biokinetics of Impacts (IRCOBI, 1975).
7. H. Appel, G. Stürtz, L. Gotzen: "Influence of impact speed and vehicle parameters on injuries of children and adults in pedestrian accidents". In Proceedings of the 2nd International Conference on Biokinetics of Impacts, (IRCOBI, 1975).
8. S. Kamiyama, G. Schmidt: "Beziehungen zwischen Aufprallgeschwindigkeit Fahrzeugbeschädigungen, Frakturen und "Wurfweite" bei 50 tödlichen Fussganger- P.K.W. Unfällen". in Zeitschrift Rechtsmedizin, 67.282.292 (1970).
9. R. Petersen: "Interim report on accident analysis" Contract N.H.T.S.A. N° DOT HS-113 3-746 (Minicars) 1974.

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