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THE FRENCH TECHNICAL PRESENTATION

SECTION 2 PART 1

INTRODUCTION

MR. MICHEL FRYBOURG, *Director*

Institute of Transport Research, Ministry of Transport

Thank you, Mr. Chairman.

The French report will consist of three parts. We will first hear a review by Mr. Leroy, who is the Director of the Laboratory of Impacts, which belongs to the National Organization for Road Safety.

The second part will address particularly the work done by the Citroen Company. And the third part will include presentations of the research done by the Association of Peugeot-Renault. Therefore, I will immediately recognize Mr. Leroy of the National Organization of Road Safety.

Mr. Leroy will speak on the "Aggressiveness of Vehicles."

COMPARISON OF THE AGGRESSIVENESS OF DIFFERENT VEHICLES AND THE SAFETY THEY AFFORD

MR. CLAUDE BERLIOZ

Organisme National de Securite Routiere

AREA OF STUDY

The purpose of this study is to compare different vehicles, by making the distinction between various classes of passenger cars.

On the one hand, we consider, in the personal injury accidents where they are involved, the damage inflicted on the pedestrians or the occupants of the other vehicles, which constitutes the study of their aggressiveness, on the other hand, the damage inflicted on their own occupants, which constitutes the study of their safety.

This study relates to the 221,000 personal injury accidents recorded in France in 1969 by the "Gendarmerie Nationale" and the "Surete Nationale" which had killed 14,700 people of whom 50 percent were in passenger cars, 25 percent on two-wheelers and 21 percent pedestrians.

In order to eliminate a possible effect of the occupancy-rate of vehicles, only the state of the drivers (or pedestrians) is taken into account, according to the categories: killed, seriously injured, slightly injured, uninjured.

To be considered as killed the victims must have died within 6 days following the accident, and as seriously injured the victims must have stayed in the hospital more than 6 days.

METHOD

We have characterized different classes of agents involved in personal injury accidents as follows:

1. The pedestrians.
2. The two-wheelers which are mainly constituted in France by motorcycles with engine displacement inferior to 50 cm^3.
3. The passenger cars.

   This class is first divided into two subclasses:

   1) The French passenger cars of great diffusion patterns.
   2) Other passenger cars. This subclass includes the French passenger cars of small diffusion patterns and the foreign cars.

   Then, the first subclass is split into seven groups according to the design criteria, to those of the weight and to the seniority of the conceiving:

   a) "former rear-engine car", (F.R.E.), i.e. which production had stopped in 1969 and which weight is between 560 kg and 670 kg and the top speed between 95 km/h and 115 km/h.

   b) "new rear-engine car", (N.R.E.), i.e. still produced in 1969, which weight is between 700 kg and 795 kg and the top speed between 125 km/h and 135 km/h.

   c) "very light front-wheel drive"*, (V.F.W.), which weight is between 495 kg and 725 kg and the top speed between 85 km/h and 125 km/h.

   d) "light front-wheel drive"*, (L.F.W.), which weight is between 805 kg and the top speed between 138 km/h and 142 km/h.

   e) "middle front-wheel drive"*, (M.F.W.), which weight is between 980 kg and 1400 kg and the top speed between 140 km/h and 175 km/h.

   f) "former classical propelled car", (F.C.P.), which weight is between 930 kg and 1190 kg and the top speed between 115 km/h and 135 km/h.

   g) "new classical propelled car", (N.C.P.), which weight is between 960 kg and 1200 kg and the top speed between 130 km/h and 160 km/h.
4. Vans, i.e. commercial vehicles of full weight inferior to 3, 5 T.
5. Trucks and other vehicles.

The accidents are regrouped into different classes according to the agents involved and defined above:

*All "front-wheel drive" are new patterns, i.e., still produced in 1969.

- single-vehicle accidents without pedestrian.
- accidents involving two agents which include as many classes as number of ways of choosing two classes of agents.

We do not know, in these accidents whether the main crash was between both these agents or with a fixed obstacle, hit by one of the vehicles after having struck the other agent. Yet, the probability that a fixed obstacle had been hit in these classes of accidents is less than in classes of single-vehicle accidents without pedestrian.

- accidents involving more than two agents.

At least, we have characterized the accidents that occur on highways outside built-up areas, because we wanted to eliminate the possible influence that the more urban character of certain classes of cars might have upon the outcomes.

The total conciliation between the aggressiveness and the safety of a class of vehicles was noted by means of the aggressiveness-rate in fatal accidents, ratio of the number of pedestrians or other vehicles drivers (external victims) which were killed in the accidents involving this class of vehicles, to the number of killed drivers in this last class (internal victims).

The statistical significance of the differences observed is noted by means of χ^2 tests which compare the distributions of internal and external victims according to the different agents.

The analysis of the relative aggressiveness of two classes of French passenger cars of great diffusion patterns is made by having the numbers of casualties (killed or seriously injured) among drivers in the two classes compared to each other, and that in accidents involving both of the agents which represent a vehicle of each class. The statistical significance is analyzed by means of χ^2 tests (df = 1) by interfering the numbers of drivers involved (same amount for the two classes).

The safety level afforded by a class of vehicles is noted by means of death-rate and casualty-rate of drivers in three types of accidents:

- single agent accident (i.e. involving one vehicle without pedestrian)
- accident involving two agents, the other being a passenger car or a van
- accident involving two agents, the other being a truck

The statistical significance of the differences of the rates observed between the classes is analyzed by means of χ^2-tests on the distributions of casualties and involved people.

MAIN RESULTS

Aggressiveness rates

The differences in the frequencies of internal killed drivers and external killed drivers according to the classes are highly significant as well on highways as on the whole of France (table 3).

The two-wheelers and the pedestrians have obviously the weakest rate values, and the trucks the strongest (8 or 9 times higher than for passenger cars). On highways, this rate value is about three times higher for the two passenger cars classes that are the speediest and heaviest ("middle front-wheel drive" and "new classical propelled car") than for the three classes that are the least speedy and lightest ones ("very light front-wheel drive", "former and new rear-engine cars"). The differences are less marked on the whole of France.

Relative aggressiveness between passenger cars on highways

27 percent of passenger car drivers are killed in crashes between passenger cars in the whole of France, 40 percent in single-vehicle crashes and 22 percent in crashes against trucks (table 1). On highways, the 27 percent become 29 percent (table 2).

Among the pairs of French passenger car classes of great diffusion patterns, some give a strong dissymmetry in the distribution of casualties concerning the drivers of two classes of vehicles, in crashes involving them both (tables 4 and 5). Thus, in crashes involving a "very light front-wheel drive" and a "new rear-engine car", we may note among the drivers of the former 118 casualties for 70 among those of the latter, difference highly significant (.01).

The six pairs corresponding to crashes involving a "middle front-wheel drive" or a "new classical propelled car" and a "very light front-wheel drive" or a "former or new rear-engine car" give all of them a highly significant dissymmetry. The casualties, in these crashes, are about three times out of four in the lightest and the least speedy vehicles.

The casualty-rate of drivers of "very light front-wheel drives" is twice weaker when the crash occurs against another "very light front-wheel drive" than when it does against a "middle front-wheel drive."

Safety of Passenger car drivers (tables 6,7,8,9)

a) in crashes with passenger cars and vans

The death-rates and the casualty-rates are in general higher for the classes which relative weak aggressiveness has been mentioned above.

b) in single-vehicle crashes without pedestrian

The death-rate and the casualty-rate are slightly higher on highways than in the whole of France (about 15 percent) and appreciably proportional for the different classes of vehicles.

On highways, the death-rates are for the two least speedy classes though they were the lightest ("former rear engine car" and "very light front-wheel drive"), about twice weaker than for the three speediest ones ("new classical propelled cars", and "light and middle front-wheel drive"). These differences are highly significant (.01). The results according to the casualty-rates are the same but the differences are more reduced.

c) in crashes with trucks or similar

The death-rates, on highways, are the highest for the rear-engine cars, may be more vulnerable to the embedding phenomenon, and about twice stronger than they are for the heaviest class. (differences highly significant for the "former rear-engine cars" and the "middle front-wheel drives").

CONCLUSION

The results observed in France are identical to those observed in Italy and presented at the Stuttgart Conference by Mr. A. Margara. The fact that the cars the most vulnerable in crashes with other vehicles, are the least vulnerable in those with fixed obstacles occurring on the same type of roads (highways) and, vice-versa, shows that the rules of the secondary safety can't be seriously made without taking the ways of using and the ruling speeds into account (correlated to the afforded speeds as the measures done in France had shown). The greatest care must be then taken in the regulation of the matter in order to avoid the possible risk of eliminating the vehicles of little aggressiveness which could offer a better safety when they are not met with more aggressive vehicles.

TABLE I

KILLED DRIVERS (OR PEDESTRIANS) CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON THE WHOLE OF FRANCE IN 1969

Vehicle class conducted	TYPE OF ACCIDENT: Single vehicle accident without pedestrian	Accident involving two agents, the other being: Pedestrian	Two-wheeler	Passenger car or van	Truck or similar	Accident involving more than two agents	TOTAL
Pedestrian	0.0% 0 0.0%	0.0% 0 0.0%	4.0% 124 50.8%	76.3% 2,379 42.9%	14.5% 452 23.0%	5.2% 162 20.0%	100% 3,117 28.6%
Two wheeler	14.6% 521 23.0%	2.0% 72 94.7%	3.1% 111 45.5%	57.8% 2,066 37.3%	16.8% 602 30.6%	5.7% 203 25.1%	100% 3,575 32.8%
Passenger car or van	40.2% 1,589 70.2%	0.1% 3 4.0%	0.2% 8 3.3%	27.2% 1,076 19.4%	21.8% 861 43.8%	10.5% 412 50.8%	100% 3,949 36.2%
Truck or similar	59.0% 154 6.8%	0.4% 1 1.3%	0.4% 1 0.4%	8.4% 22 0.4%	19.2% 50 2.6%	12.6% 33 4.1%	100% 261 2.4%
TOTAL	20.8% 2,264 100%	0.7% 76 100%	2.2% 244 100%	50.8% 5,543 100%	18.0% 1,965 100%	7.5% 810 100%	100% 10,902 100%

TABLE II

KILLED DRIVERS (OR PEDESTRIANS) CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON RURAL HIGHWAYS IN FRANCE IN 1969

Vehicle class conducted	TYPE OF ACCIDENT: Single vehicle accident without pedestrian	Accident involving two agents, the other being: Pedestrian	Two-wheeler	Passenger car or van	Truck or similar	Accident involving more than two agents	TOTAL
Pedestrian	0.0% 0 0.0%	0.0% 0 0.0%	0.8% 6 24.0%	85.2% 655 34.7%	6.9% 53 7.8%	7.1% 55 12.7%	100% 769 19.7%
Two wheeler	9.7% 88 10.2%	1.7% 15 100%	1.7% 15 60.0%	67.6% 614 32.6%	12.1% 110 16.3%	7.2% 68 15.3%	100% 908 23.3%
Passenger car or van	34.1% 718 83.6%	0.0% 0 0.0%	0.2% 4 16.0%	28.9% 609 32.3%	23.1% 485 71.6%	13.7% 289 66.7%	100% 2,105 54.1%
Truck or similar	47.3% 53 6.2%	0.0% 0 0.0%	0.0% 0 0.0%	6.3% 7 0.4%	25.9% 29 4.3%	20.6% 23 5.3%	100% 112 2.9%
TOTAL	22.1% 859 100%	0.4% 15 100%	0.6% 25 100%	48.4% 1,885 100%	17.4% 677 100%	11.1% 433 100%	100% 3,894 100%

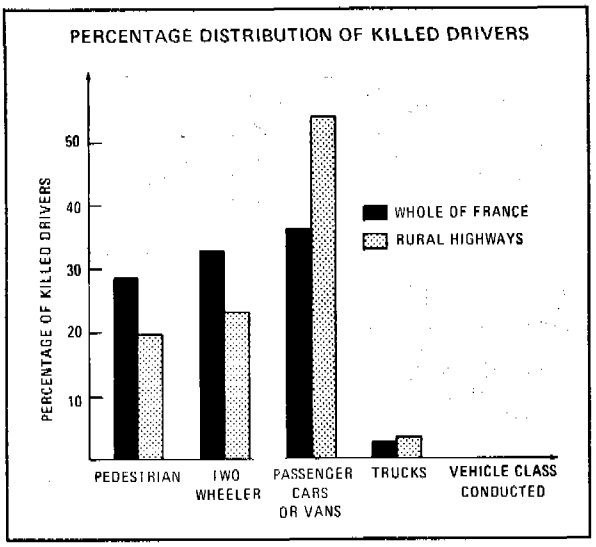


FIGURE 1

TABLE III

NUMBER OF "INTERNAL KILLED DRIVERS" (1) AND "EXTERNAL KILLED DRIVERS" (2) CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED IN CRASHES INVOLVING TWO AGENTS IN FRANCE IN 1969

Vehicle class conducted		Whole of France: Internal killed drivers	External killed drivers	Aggressiveness-rate	Rural Highways: Internal killed drivers	External killed drivers	Aggressiveness rate
Pedestrians		2,955	76	0.03	714	15	0.02
Two wheeler		2,851	133	0.05	754	10	0.01
French passenger car of great diffusion patterns	Former rear-engine car	151	193	1.28	84	44	0.52
	New rear engine car	216	457	2.12	125	127	1.02
	Very light front-wheel drive	563	852	1.51	307	252	0.82
	Light front wheel drive	104	391	3.76	67	121	1.81
	Middle front wheel drive	160	650	4.06	97	305	3.14
	Former classical propelled car	112	366	3.27	62	106	1.71
	New classical propelled car	174	811	4.66	104	303	2.91
Other passenger cars		411	1,389	3.38	222	454	2.05
Vans		57	372	6.53	30	92	3.07
Trucks and similar		74	1,815	24.53	36	648	18.00

(1) An internal killed driver of a class is a killed driver of a vehicle (or a killed pedestrian) of this class.

(2) An external killed driver of a class is a killed driver of a vehicle not belonging to this class but involved in an accident with a vehicle of this class.

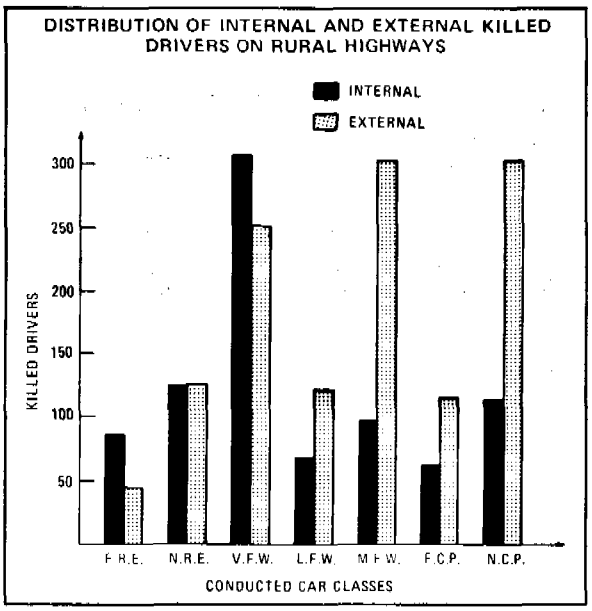


FIGURE 2

TABLE IV

CASUALTIES (KILLED OR SERIOUSLY INJURED) AMONG DRIVERS INVOLVED IN CRASHES BETWEEN TWO FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS ON RURAL HIGHWAYS IN FRANCE IN 1969, CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED

WE FIND IN THE CELL (LINE i, COLUMN j), THE CASUALTIES AMONG DRIVERS OF A j VEHICLE CLASS, IN CRASHES INVOLVING AN i VEHICLE CLASS AND A j VEHICLE CLASS

French passenger car of great diffusion patterns	Former rear-engine car	New rear-engine car	Very light front wheel drive	Light front wheel drive	Middle front-wheel drive	Former classical propelled car	New classical propelled car	Total
Former rear-engine car	7	19	45	13	12	9	19	124
New rear-engine car	22	36	118	21	27	18	27	269
Very light front wheel drive	40	70	210	34	65	41	60	520
Light front-wheel drive	19	32	85	18	20	11	22	207
Middle front wheel drive	36	70	217	32	62	32	49	498
Former classical propelled car	16	32	109	15	31	17	33	253
New classical propelled car	44	62	221	30	51	31	66	505
TOTAL	184	321	1005	163	268	159	276	2376

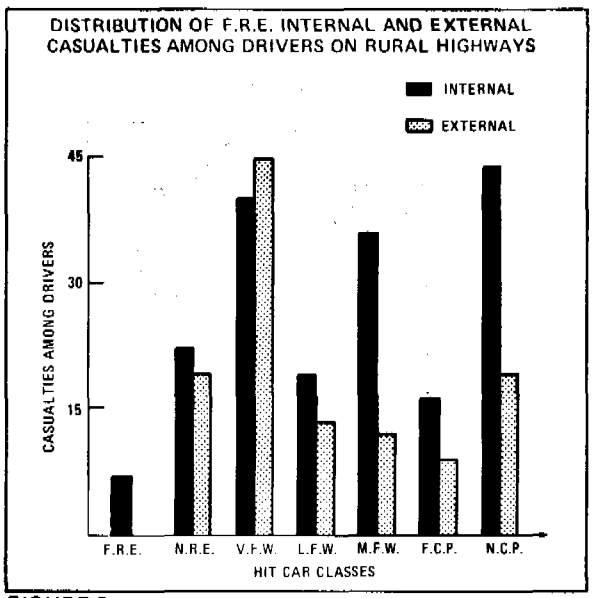
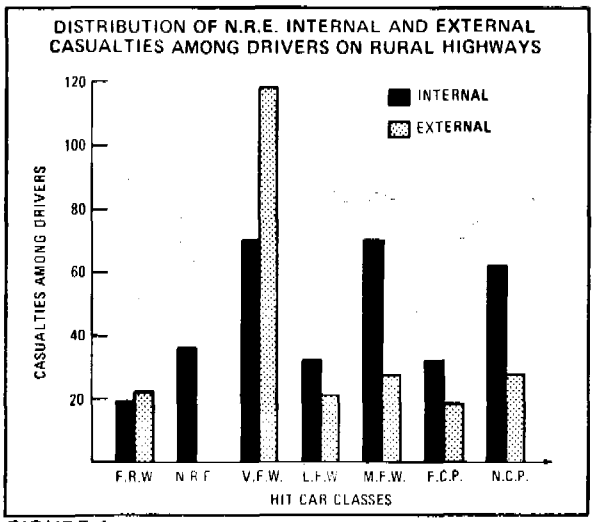


FIGURE 3



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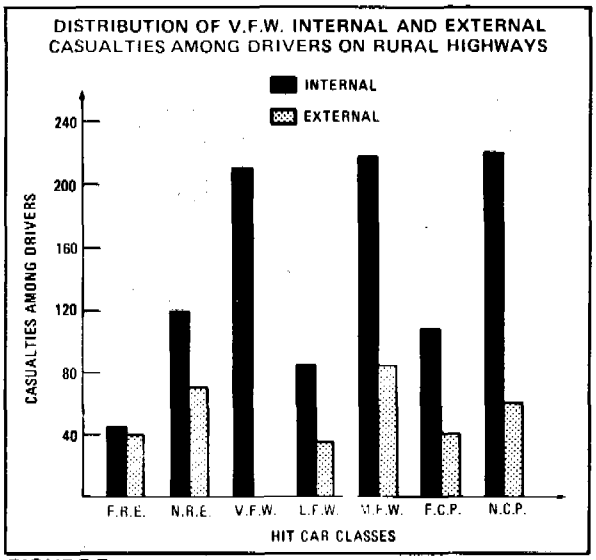

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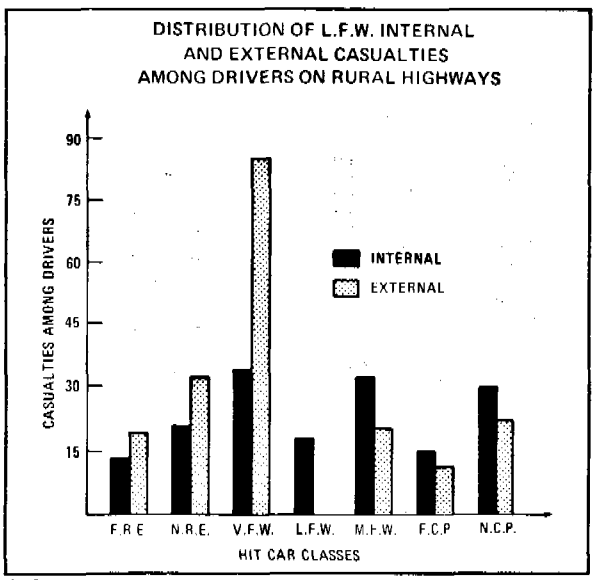

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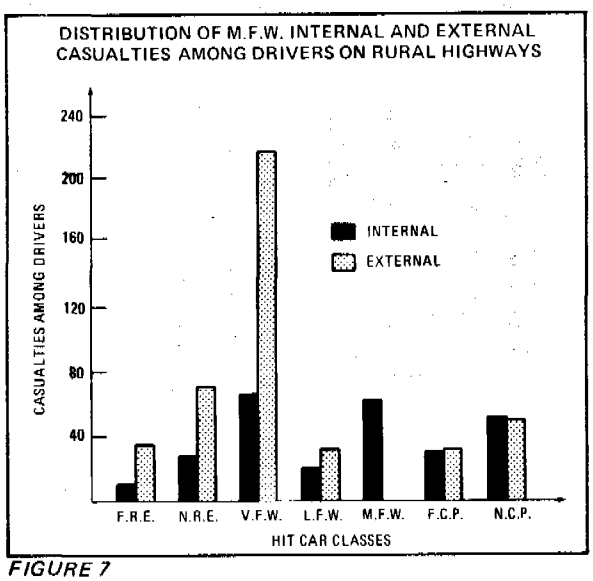

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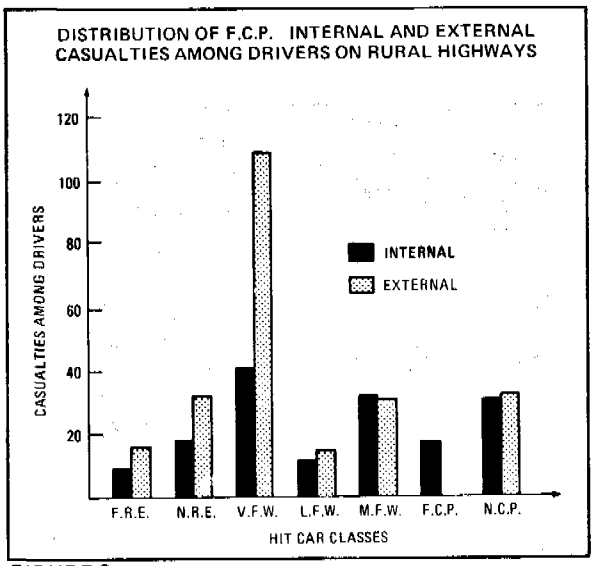

FIGURE 8

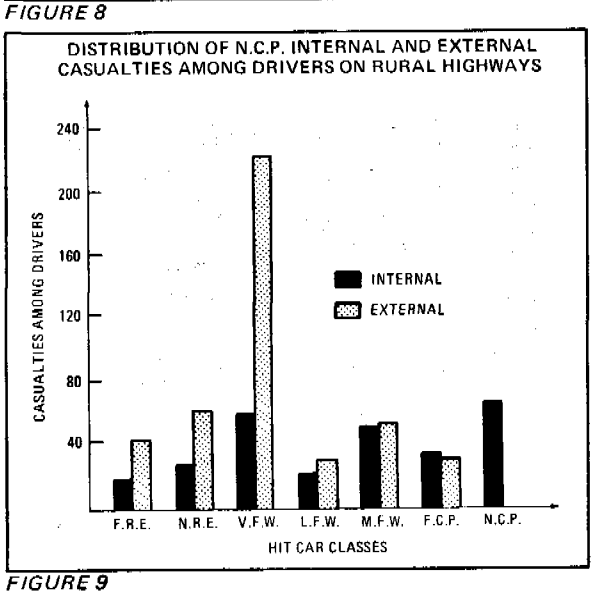

FIGURE 9

TABLE V

CASUALTY-RATE OF DRIVERS INVOLVED IN CRASHES BETWEEN TWO FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS ON RURAL HIGHWAYS IN FRANCE IN 1969, CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED

WE FIND IN THE CELL (LINE i, COLUMN j), THE CASUALTY RATE OF DRIVERS OF A j VEHICLE CLASS IN CRASHES INVOLVING AN i VEHICLE CLASS AND A j VEHICLE CLASS.

French passenger car of great diffusion patterns	Former rear-engine car	New rear-engine car	Very light front wheel drive	Light front wheel drive	Middle front wheel drive	Former classical propelled car	New classical propelled car
Former rear-engine car	12.5	16.0	16.4	16.7	11.7	14.1	13.3
New rear-engine car	18.5	18.8	23.9	16.2	13.8	14.6	11.7
Very light front wheel drive	14.6	14.2 HS	16.0	10.2	9.7	10.1	8.2
Light front-wheel drive	24.4	24.6	25.5 HS	23.7	14.6	13.1	14.2
Middle front-wheel drive	35.0 HS	35.7 HS	32.4 HS	23.2 FS	24.2	19.8	19.9
Former classical propelled car	25.0	25.8 S	26.9 HS	17.9	19.1	17.7	18.9
New classical propelled car	30.6 HS	27.1 HS	30.4 HS	19.4	20.7	17.7	25.2
TOTAL	22.0	21.6	23.8	16.4	15.1	14.3	14.2

TABLE VI

DEATH-RATE OF DRIVERS OF FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS, CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON THE WHOLE OF FRANCE IN 1969

Vehicle class conducted	TYPE OF ACCIDENT								
	Single vehicle accident without pedestrian			Accident involving two vehicles without pedestrian the other being:					
				passenger car or van			truck or similar		
	killed	involved	rate	killed	involved	rate	killed	involved	rate
Former rear-engine car	108	2,164	5.0 HS	99	5,278	1.9 HS	52	532	9.8 S
New rear-engine car	175	2,768	6.3	139	8,391	1.7 HS	77	945	8.1
Very light front-wheel drive	217	4,204	5.2 HS	346	25,481	1.4 FS	213	3,181	6.7
Light front-wheel drive	96	1,126	8.5 S	50	5,077	1.0	53	643	8.2
Middle front-wheel drive	176	1,757	10.0 HS	82	7,393	1.1	77	1,073	7.2
Former classical propelled car	120	1,627	7.4	45	6,516	0.7 HS	66	719	9.2 FS
New classical propelled car	201	2,305	8.7 HS	88	10,537	0.8 HS	86	1,279	6.7 FS
TOTAL	1,093	15,951	6.9	849	68,623	1.2	624	8,372	7.5

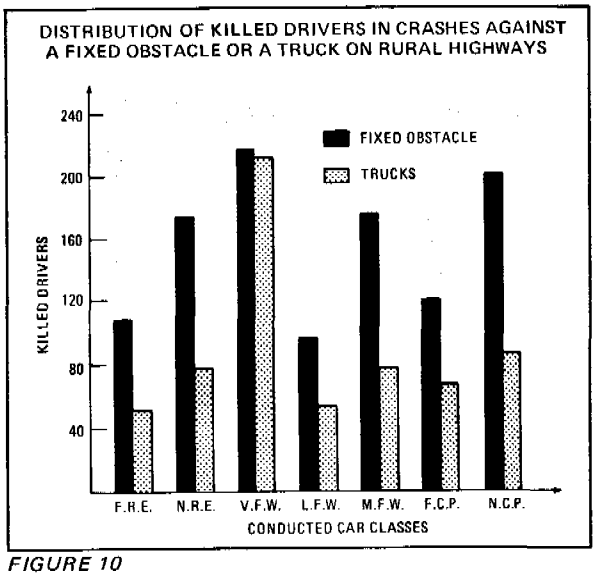

FIGURE 10

TABLE VII

CASUALTY RATE OF DRIVERS OF FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS, CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON THE WHOLE OF FRANCE IN 1969

Vehicle class conducted	TYPE OF ACCIDENT								
	Single vehicle accident without pedestrian			Accident involving two vehicles without pedestrian the other being:					
				passenger car or van			truck or similar		
	killed + seriously injured	involved	rate	killed + seriously injured	involved	rate	killed + seriously injured	involved	rate
Former rear-engine car	717	2,164	33.1 HS	699	5,278	13,2 S	173	532	32.5
New rear-engine car	1,031	2,768	37.2	1,047	8,391	12.5	304	945	32.2
Very light front wheel drive	1,479	4,204	35.2 HS	4,008	25,481	15.7 HS	986	3,181	31.0
Light front wheel drive	488	1,126	43.3 HS	538	5,027	10.7 HS	232	643	36.1 S
Middle front-wheel drive	763	1,757	43.4 HS	676	7,393	9.1 HS	336	1,073	31.3
Former classical propelled car	623	1,627	38.3	598	6,516	9.2 HS	223	719	31.0
New classical propelled car	936	2,306	40.6 HS	882	10,537	8.4 HS	428	1,279	33.4
TOTAL	6,037	15,951	37.8	8,448	68,623	12.3	2,682	8,372	32.0

TABLE VIII

DEATH RATE OF DRIVERS OF FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS, CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON RURAL HIGHWAYS IN FRANCE IN 1969

Vehicle class conducted	TYPE OF ACCIDENT								
	Single vehicle accident without pedestrian			Accident involving two vehicles without pedestrian the other being:					
				passenger car or van			truck or similar		
	killed	involved	rate	killed	involved	rate	killed	involved	rate
Former rear-engine car	44	797	5.5 S	55	1,140	4.8 HS	29	158	18.4
New rear-engine car	79	1,070	7.4	80	1,955	4.1 HS	45	301	15.0
Very light front wheel drive	85	1,378	6.2 S	188	5,692	3.3 FS	118	922	12.8
Light front wheel drive	58	493	11.8 S	34	1,336	2.5	33	247	13.4
Middle front-wheel drive	80	785	10.2 MS	51	2,337	2.2 S	46	529	8.7 S
Former classical propelled car	37	544	6.8	28	1,501	1.9 S	33	229	14.4
New classical propelled car	97	951	10.2 S	52	2,634	2.0 MS	52	503	10.3
TOTAL	480	6,018	8.0	488	16,595	2.9	356	2,889	12.3

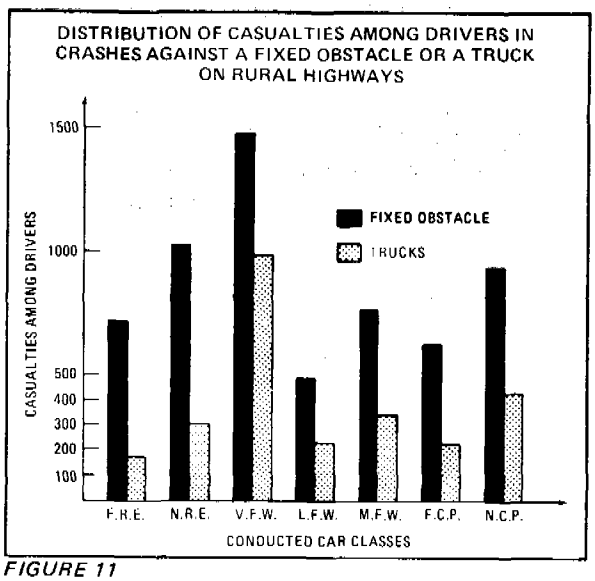

FIGURE 11

TABLE IX

CASUALTY RATE OF DRIVERS OF FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS, CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON RURAL HIGHWAYS IN FRANCE IN 1969

Vehicle class conducted	TYPE OF ACCIDENT								
	Single vehicle accident without pedestrian			Accident involving two vehicles without pedestrian the other being					
				passenger car or van			truck or similar		
	killed + seriously injured	involved	rate	killed + seriously injured	involved	rate	killed + seriously injured	involved	rate
Former rear-engine car	294	797	36.9 HS	264	1,140	23.2 S	74	158	46.8
New rear-engine car	474	1,070	44.3	434	1,955	22.2 FS	128	301	42.5
Very light front wheel drive	593	1,378	43.0	1,422	5,692	25.0 HS	407	922	44.1
Light front-wheel drive	241	493	48.9 S	250	1,336	18.7 FS	114	247	46.2
Middle front-wheel drive	372	785	47.4 FS	381	2,337	16.3 HS	199	529	37.6 S
Former classical propelled car	236	544	43.4	249	1,501	16.6 HS	97	229	42.4
New classical propelled car	449	951	47.2 FS	400	2,634	15.2 HS	209	503	41.6
TOTAL	2,659	6,018	44.2	3,400	16,595	20.5	1,228	2,889	42.5

STUDY ON THE INJURIES OF THE INFERIOR MEMBERS DUE TO ROAD ACCIDENTS

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INTRODUCTION

Multidisciplinary investigations allow us to evaluate the relative importance of road safety problems. But, dealing with essential subjects, that is, protection of head and chest, it is most important to remember that certain injuries which, if they do not lead to death, may conserve, despite the safety devices already made, a functional and social cost not to be neglected.

It is for this reason that we are about to deal with the injuries of the inferior members and particularly with the distal segment. It is not a question of anatomical limit but it is a combination including the ankle joint and the lowest third of the shin-bone and of the splint-bone which constitute a functional combination and undergo injuries connected to the same mechanisms.

Functional combination studied in this paper.

Which are the mechanisms causing these injuries?

Involuntary rotations of the foot either by wedging between the pedals or in the folds of the car floor. The rotative movements being extremely limited, any form of excessive movement ends in a fracture either at the level of the tibio-tarsal joint, or, if the foot is squeezed lower down, in dislocations of the foot with frequent fractures of the metatarsals.

A compression of the foot can arise. This occurs especially when the driver has his legs spread out or his knees squeezed under the dashboard. The reverse movement of the floor and pedals or even the simple motion of the foot breaking desperately, can create certain injuries only due to compression which can break the astragalus as well as the extremity of the shin-bone and the splint-bone.

AETIOLOGY

Since 1969, we have been leading a bidisciplinary investigation on road accidents of which the main aims are to define the correlation between occupant injuries and vehicle deformation, to precise energy level, to verify the effectiveness of safety devices and to build up our knowledge of human impact tolerance.

We have noticed that little more than 5% of injured people suffer from foot injuries, dislocations or fractures mainly being open. About 10% of these wounds present bilateral injuries.

Almost 80% of these people were drivers. This clear predominance explains itself:

1. because numerous vehicles have only one occupant
2. because of the pedals' existence
3. by the deformation of the floor or by the introduction of wheels often being more important on the driver side, since 40% of these impacts are on the left front side.

What are the vehicle's structures causing these injuries?

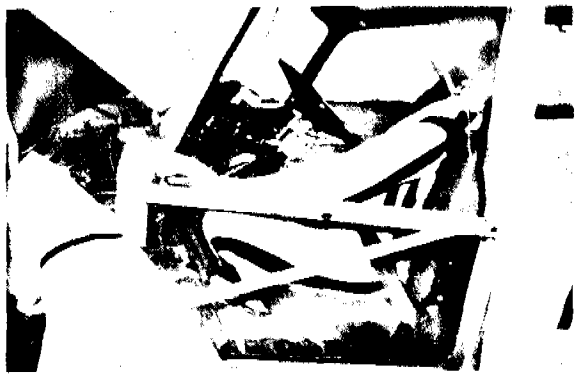
Outside view of the VW 1300 (lateral impact, fatal injury).

View of the pedals (we can notice the shoes of the driver squeezed between the pedals).

The pedals can effect in two ways, either by imprisoning the driver's feet when in twisting motion or due to the fact that the driver attempting to save himself pushes his feet down on the pedals which, during the impact, literally project the foot bones into articulation.

The floor's deformation is of great importance in the pedals rejection as well as for its own action. Frequently we can indice very evident folds which

Outside view of the left foot of the driver (dislocation under the astragalus).



Crash test on barrier (Peugeot 204 – v=50 kmh – 30° on the left). The feet of the dummy are squeezed by the reverse movement of the pedals and of the wheel-arch.

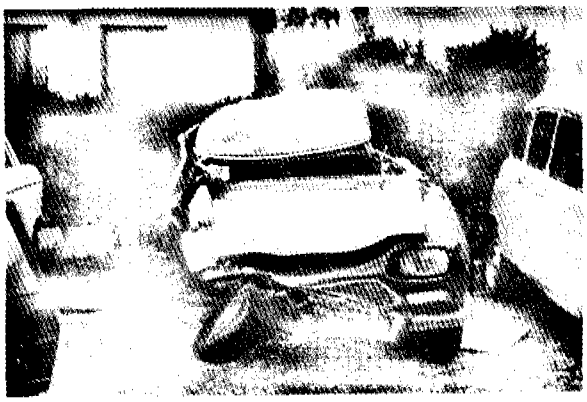
swell the floor's formation causing wounding fractures brutally contacting the occupants' feet.

This was clearly shown in several vehicles where the driver and passenger both showed feet injuries, occasionally bilateral.

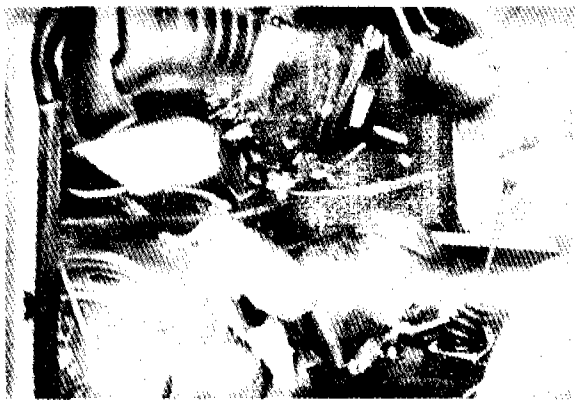
We will here give a typical example. Driver and passenger were wearing three point safety belts during a particularly violent frontal impact; the floor was deformed. The driver showed only a right astragalus fracture, and an ankle-bone dislocation with a left splint-bone fracture without any other injury. The passenger was suffering from a left ankle-bone fracture.

Another factor causing the inferior members injuries is the introduction of wheels. This mechanism is only to be found in very serious impacts but feet injuries are most concurrent.

Thus, we examined a vehicle after a very violent frontal impact. The passengers were restrained and only the passenger whose side was entered by the wheel and the body destructed by this introduction

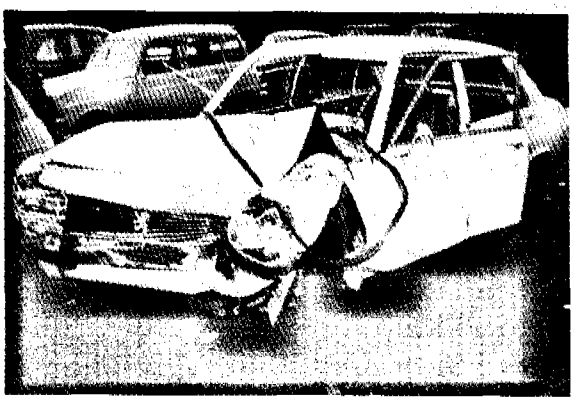


Citroen Ami 8. Frontal crash in another vehicle, then rollovers.

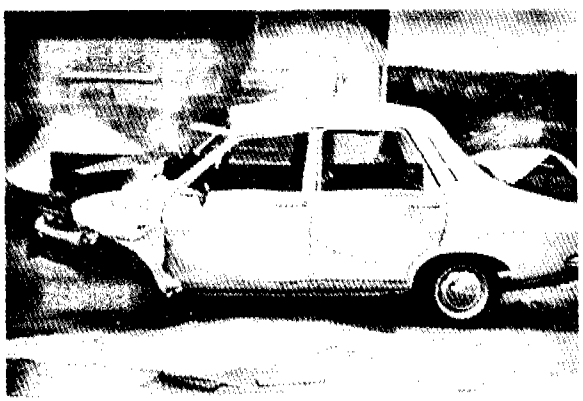


Inside view – Introduction of the left front wheel.

Floor deformation in front of the front occupant.



Peugeot 504 – Frontal crash on the left side in the side of this van.



Outside view – Renault 12 which crashed in a post.

Inside view – Deformation of the wheel-arch pushed by the left side front wheel.

has to suffer from very serious bilateral injuries of the two inferior members.

The wheels are one of the strongest elements in the car body. If, during a frontal impact, the front wheels push the beam floor backwards they act very well with the compressive force and they limit the deformation, but the wheels are in this situation only if they are not deflected.

In the opposite case, even if they are lightly deflected, they move out of the floor beams. One of them pushes on the wheel-arch which, if the impact is very serious, can break in two parts; then the wheel introduces into the car compartment. The feet are

often near the wheel-arch. Moreover, the wheel-arch's deformation produces the floor's deformation because they are butt-welded together. At the end, the wheel-arches are mainly made with two sheet-metal pieces butt-welded together under a horizontal direction, so they can easily move out under the compressive force of the wheels.

The rear occupants present less frequently feet injuries.

Usually, these injuries occurred when the rear occupant moving forward, kept his feet squeezed under the front seats. We can notice fractures of ankle-bones or of the part situated just upon. These injuries are due to direct impact; they are not frequent in our cases.

THE ENGINE DISPOSITION INFLUENCE

We noticed that the engine disposition has an important influence on the frequency of the inferior members traumas:

- in the rear engine cars, in frontal impact, the deformation arises very frequently, even if the crash speed is low, at the front floor part. A third of the kind of cars involved in frontal impacts produce feet injuries to the front occupants.
- for cars with engine placed forward, the latter seems to screen. If the engine is longitudinally placed, it protects in the case of taking part in the crash. Now, in 40% of frontal impact accidents less than a third of the forward part is concerned.

In the vehicle with longitudinal frontal engines, which are very numerous, we can find about 10% of vehicles whose front passengers have suffered from feet injuries during frontal impact.

But, if the engine is transversal it works as a screen in the most part of frontal impacts; just 4% of these cars produced feet injuries to their occupants during frontal impacts.

POSTURE'S IMPORTANCE

Apparently the occupants' posture intervenes in the occurrence of the inferior members injuries. In the vehicles where the seat is straight and high, the driver sits up strictly, his leg making an almost straight angle with the thigh; for the latter no feet injuries have been remarked. For example, no occupant of the Renault R.4 investigated showed any such wound.

CONCLUSION

Medico-Legal Aspect

The tibio-tarsal articulation particularly fitted demands an exact reconstitution to avoid functional problems. It constitutes, as well as the foot an area exposed due to the lack of muscular or fat protection and the fractures and dislocations of this region are mainly open injuries, which always leads to a risk of infection particularly dangerous on an articulation.

The medico-legal examination of these traumas is always most careful: we are studying a person who has been in hospital for some time and was reeducated in a specialized center and whose articulation has not entirely recovered.

We must point out that these anatomical troubles tend to become more serious during the years and this injury if not being a vital factor, can cause invalidity for life.

Some Considerations on the Development of Safety Devices

The study carried out on safety problems tends to protect the head, chest and knees; it does not seem that presently any research is leading on inferior members protection.

In regard to the problem of the pedals, it could be interesting to study the distribution of forces in terms of the surface of the pedal.

For the floor deformation, it would be interesting to conduct frontal impact tests concerning only a third of the front part of the vehicle (test on a corner of a barrier). For the introduction of the wheels, crash tests would be conducted with deflected wheels during the impact.