SELF-PROTECTION AND PARTNER-PROTECTION FOR NEW VEHICLES (UNECE R94 AMENDMENT)

Cyril Chauvel
Gérard Faverjon
Nicolas Bertholon
Laboratory of Accidentology, Biomechanics and Human Behavior
PEUGEOT CITROËN RENAULT,
France
Sophie Cuny
European Center of Safety Studies and Risk Analysis
CEESAR
France
Pascal Delannoy
Safran Engineering, SAFRAN Group - UTAC Passive Safety Department
France
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ABSTRACT

This work aims at bringing evidence for mass incompatibility in frontal impact for cars built according to the UNECE R94 regulation. French national injury accidents database census for years 2005 to 2008 were used for the analysis. The heterogeneity of frontal self-protection among cars of different masses is investigated, as well as the partner protection parameter offered by these cars. The last part of the analysis deals with the estimation of the benefit, in terms of fatal and severe injuries avoided, if crashworthiness was harmonized for the whole fleet of vehicle. This calculation is done for France and is extended to all Europe.

INTRODUCTION

About 42 000 people die each year in Europe due to road traffic accidents. In France there were 2 446 fatalities in cars and 1 290 involved in car to car or car to vehicle accident. This figure represents more than half of people that die in a car collision. Our approach has been for many years to study real world accidents and try to understand what were and are the mechanisms of injury causation. Accident studies during the last twenty-five years clearly showed that car-to-car head-on collision is a major impact configuration to take into account in order to improve safety on the roads. With the new self-protection regulation, all cars offer equivalent behaviour against a fixed obstacle. Therefore, in the future, it is expected that the main progress will have to be made in car-to-car compatibility.

Over the past ten years, vehicle stiffness has been increased a lot. We also have a better understanding of the front-end design energy absorption. Front-end design is at the cross road of numerous contradictory constraints: self-protection of occupants, protection of vulnerable users such as pedestrians, reparability, styling, aerodynamics, engine cooling and so on. Therefore, each manufacturer has developed its own solution to solve the difficult equation that resulted in a wide variety of front-end designs, structure and stiffness regardless of the overall mass of the vehicle. Solutions however have been optimized for meeting R94 regulation but not in car-to-car configuration.

This work aims at bringing evidence of the impact of UNECE R94 regulation on car designs and the need to amend and improve it to answer new compatibility requirements. The heterogeneity of frontal self-protection level among cars of different masses is investigated, as well as the partner protection parameter offered by these cars. The last part of the analysis deals with the estimation of the benefit, in terms of fatal and severe injuries avoided, if crashworthiness test severity was harmonized for the whole fleet of vehicle. The calculation is based on French accident data and is extended to all Europe.

RELEVEVANCE OF THE FRONTAL IMPACT IN THE FRENCH NATIONAL STATISTICS

The relative magnitude of frontal impacted car is revealed through the French national statistics of road accidents (BAAC database - year 2007). Figure 1 describes the proportion of accident types for fatally injured car occupants. Single vehicle crashes and car-to-car accidents represent the most important part of the accident types (respectively 47% and 30%)

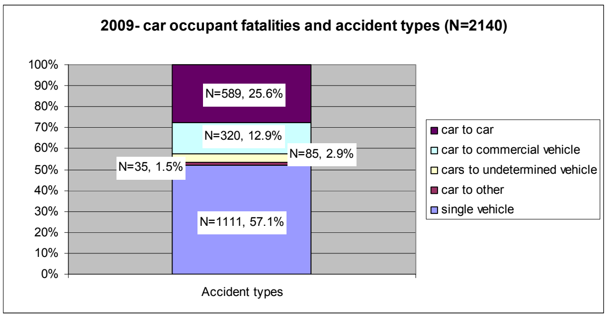

Figure 1. Car occupant fatalities and accident types.

Figure 2 has a look on the main impact for single vehicle crashes and car to other vehicle accidents. It is noticeable that frontal impact is not of the same importance for single vehicle crashes and for car-to-car accidents. Frontal impact in car to vehicle accidents represents 32.2% of all the car occupant fatalities, whereas single vehicle frontal impact stands for 15.3% of these fatalities.

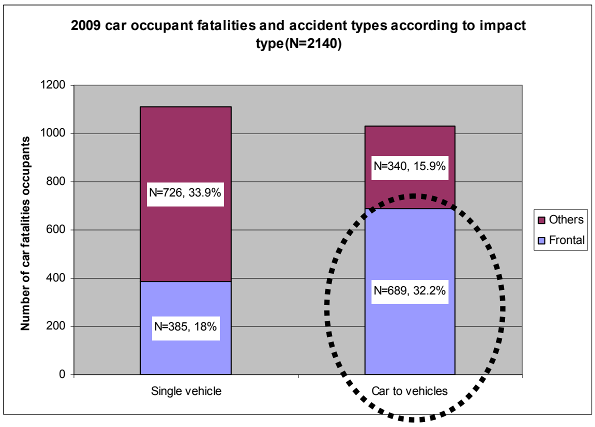

Figure 2. Car occupant fatalities and accident type according to impact types.

The 32.2% fatalities occurring in frontal impact enlightens the accidentological importance of this configuration.

METHOD AND DATA SOURCES

Definition of self-protection, partner protection and severity rate.

Compatibility can be described as the capacity of two vehicles to distribute in a balanced way the energy (proportionally to its mass) of an impact to offer to their occupants the same chances of survival. In this study, it will be evaluated as the proportion of fatal and serious injuries observed in the considered car model (internal injuries) and called Severity Rate (SR) Compatibility mixes two features: self-protection (SP) and partner protection (PP). Self-protection or crashworthiness is the capacity offered by a car to protect its own occupants (1).

$$\mathrm{SR(protection)} = \frac{(\mathrm{Fatalities} + \mathrm{Severe\_injuries})_{\mathrm{int}}}{(\mathrm{Fatalities} + \mathrm{Severe\_inj} + \mathrm{Slight\_inj} + \mathrm{Not\_inj})_{\mathrm{int}}} \quad (1).$$

On the other side, partner protection or aggressivity characterizes the propensity of a vehicle to create or not injuries in the vehicle it impacts. In this survey, it will be evaluated as the proportion of fatal and serious injuries observed in the impacted vehicle by the considered car model (external injuries) (2).

$$\mathrm{SR(partner)} = \frac{(\mathrm{Fatalities} + \mathrm{Severe\_injuries})_{\mathrm{ext}}}{(\mathrm{Fatalities} + \mathrm{Severe\_inj} + \mathrm{Slight\_inj} + \mathrm{Not\_inj})_{\mathrm{ext}}} \quad (2).$$

Safety benefits calculation.

The benefit of having an homogenous fleet in term of frontal protection is estimated by calculating the reduction number of fatal and severe injuries expected if all cars come up with the severity rate of the most crashworthy vehicle in frontal impact.

One might expect that introducing the Progressive Deformable Barrier (PDB) within the test of frontal impact regulation will harmonize the severity of the impact, whatever the mass of the vehicle. This harmonization should lead to an hamonization of the frontal impact protection offered by the new vehicle, whaterver their massses. This hypothesis will support the safety benefit estimation of the introduction of the PDB in the frontal test regulation. If frontal protection is set at the same level among all vehicles of different mass, the result should be observed in accidents : under this assumption, severity rates for car occupants are expected to be identical among all classes of vehicle masses.

At first, a target population is choosen to represent the level of frontal protection to be reached by all vehicle. The class of vehicle performing best in frontal impact is determined on the basis of accidental data as the group of vehicle for whom the severity rate is the lower one in frontal impact. This severity rate is set to be the objective to achieve an harmonization in term of frontal protection among all vehicle. Once the target severity rate is defined, it is applied on the effective of the other classes of vehicle. A new number of severe and fatal injuries is then calculated for each class of vehicle under the asumption that all vehicles have the same severity rate. The difference betwwen the observed number of severe and fatal injuries and the number expected under the hypothesis of identical frontal protection represents the estimated number of casualties that could be avoided in case of harmonised frontal protection. This number is then extrapolated to the whole number of severe and fatal injuries for car passengers occuring in France.

Data sources and cases selection

National data base French national injury accidents database census (BAAC - Bulletin d'Analyse d'Accident Corporel) for years 2005 to 2008 has been used for the analysis. This is an disaggregated database which records only accidents with at least one injuries involved into the accident. Injury severity is assigned as follow : fatal injuries are considered up to 30 days after the accident, injuries are classified as serious injuries if the occupants stay more than 24 hours at the hospital, and slight injuries if they stay then 24 hours in the hospital. Uninjured occupants involved in an accident making at least one injuries also have to be recorded in the database. The national census also describes the circumstances of each accident through a series of descriptive variables.

Cars designed according to UNECE 94 regulation were selected in the database. Cars have been considered in compliance with this regulation if they have been designed since the year 2000 or if they were registered since 2004. Among these new cars, only those with a frontal impact against another car were taken into account. Accident involving high goods vehicle, pedestrian or two wheelers were excluded from the analysis as the frontal impact severity for the car could be either to high or to low in these configuration. Single vehicle crashes were also not analysed there. Belted driver and belted front right passenger cars were included in the sample. As the analysis deals with protection, it requires that restraint status of the occupants is comparable and optimal, so no unrestraint occupant, nor rear seat passenger were used for this study (and no child occupants). Cars were selected if their mass could have been identified and classified among 6 classes, defined as follows : [<950], [950-1149], [1150-1349], [1350-1549], [1550-1749], [>1750].

The Polk database It contains data regarding the european fleet. Number of vehicles per mark, model and year of registration are avalaible for 23 out of the 27 of the European Community (Bulgaria, Romania, Malta, Cyprus are missing). The database has been implemented with information regarding the compliance of the models with the ECE R94 regulation, and with the mass of the models. The mass distribution of the vehicles among the European fleet is then readily available to be compared with the repartition among the French fleet. Data on the year 2007 is used for the analysis.

RESULT

Sample description

In the national census year 2005-2008, 2 871 belted front occupant of cars designed according ECE R94 were identified (figure 3). The selected cases are frontal impact type against another car.

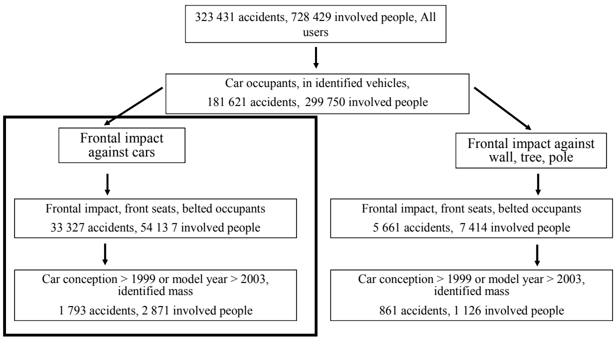

Figure 3. Selection process of the sample.

Table 1 below describes the vehicle mass distribution and the main segment associated with the mass.

Table 1.
Vehicle mass distribution.

Mean mass of the vehicle	Segment	Nb of occupant
<950 kg	Super mini	97
950-1149 kg	Super mini et Small family cars	839
1150-1349 kg	Small et Large family cars	1026
1350-1549 kg	Large family cars et executive cars	638
1550-1749 kg	Large family cars, executive cars, Small et large MPV	170
1750 kg and more	Large MPV, off road cars	101
Total		2871

Heterogeneity of frontal self-protection among cars of different masses

Figure 4 shows the severity rates for belted frontal car occupants having a frontal impact against another car. Confidence intervals at the 95% level are also reported on the graph. Both cars in the selected accidents have been designed according to ECE R94 regulation. The figures show that severity rates decrease as weight of the cars increase.

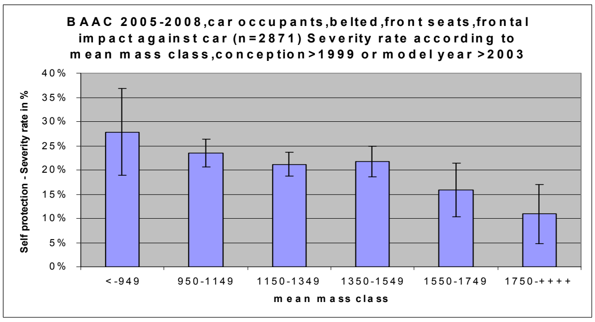

Figure 4. Severity rate in frontal impact according to the mass of the vehicle. Vehicle designed since 2000 or registered since 2004.

Cars weighting more than 1750 kg display the lowest severity rate for their front occupant, whereas light cars weighting les than 950 kg present the highest severity rate. Confidence intervals allow to assess that severity rate for front occupants is statistically better for car weighting 1750kg and over compared to cars of the following categories : less than 950kg, 950-1149 kg, 1150-1349 kg and 1350-1549kg. This illustrates a discrepancy between frontal protections offered by cars of different masses.

Partner protection parameter offered by these cars. Self-Protection vs. Partner-Protection.

In taking into account injuries caused in the opposite vehicle hit by the studied vehicle, the notion of partner is introduced. A focus is made on how frontal protection varies with the mass of the focus vehicle. Head on collisions are selected from the initial sample of 2 871 front occupant of new cars. The sample related to partner protection ends up with 1 875 belted front occupant involved in an head collision, both cars being in compliance with ECE R94 regulation.

Table 2.
Vehicle mass distribution. Head on collision.

Mean mass of the vehicle	Segment	Nb of occupan t
<950 kg	Super mini	70
950-1149 kg	Super mini et Small family cars	561
1150-1349 kg	Small et Large family cars	659
1350-1549 kg	Large family cars et executive cars	419
1550-1749 kg	Large family cars, executive cars, Small et large MPV	110
1750 kg et plus	Large MPV, off road cars	56
Total		1875

The distribution of the mass in this sub sample is presented in the table 2.
Severity rate for self and partner are calculated as noted in equation 1 and 2, according to the mass of the focus vehicle and presented in figure 5 below.

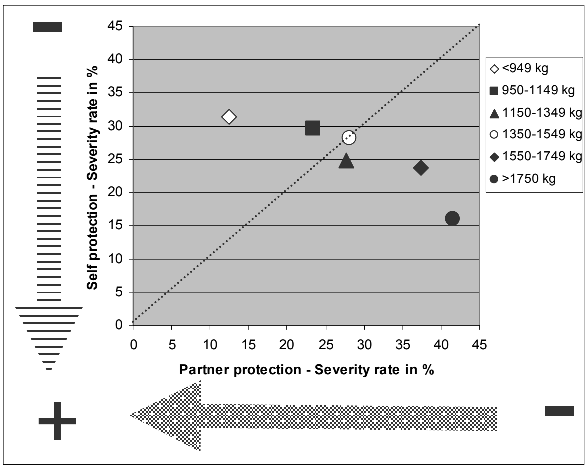

Figure 5. Self-Protection and Partner Protection according to the mass of the vehicle Vehicles designed since 2000 or registered since 2004.

Figure 5 enlightens heterogeneity in partner protection bring by vehicles designed according ECE R94 regulation. The line on the graph represents cases for which self-protection and partner protection are identical. Vehicles ranging from 950 to 1549 kg are relatively close to this configuration. Heaviest vehicles (above 1550 kg) show high level of crashworthiness and weak performance regarding partner protection, whereas vehicles under 950 kg present a smaller self-protection level associated with a small percentage of casualties in the opposite car.

UNECE R94 AMENDMENT PRESENTATION

According to figure 4 and figure 5 the present demand on self-protection is increasing the local strength and global force deformation of all cars and conducts to an inhomogeneous fleet.
The design of a large car makes it stiffer than a small one in order to compensate the mass. Furthermore, the current frontal offset test is more severe for heavy vehicles because of the specific barrier used.

With self-protection offset test regulations and ratings, all cars offer equivalent behaviour against a rigid obstacle. Solutions have been optimized against a rigid wall or soft obstacle but not in car-to-car configuration, accident data shows clearly this lack of consideration.

Problem raised with the current regulation R94

Current ODB barrier was developed fifteen years ago and adapted to car designs (geometry and force deformation) from 90's. Since then, introduction of regulation, ratings, insurance test and recently pedestrian have modified a lot car front design in terms of stiffness and geometry to achieve that requirements. The current barrier is becoming more and more obsolete regarding to new generations of vehicles.

Instability and bottoming out of the barrier

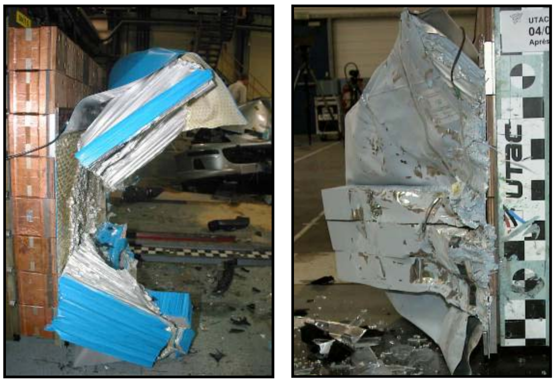

Figure 6. Current ODB barrier instability and bottoming out.

Since this time, vehicles were reinforced and became stiffer. The stiffer front end leads to unstable behavior of the barrier that creates serious problems in the design of vehicles. Today, all vehicles bottoms out the barrier (figure 6) that leads same amount of energy absorbed by the barrier. Usually this is achieved through different load paths, which absorb energy and transmit the load from the front to the occupant compartment.

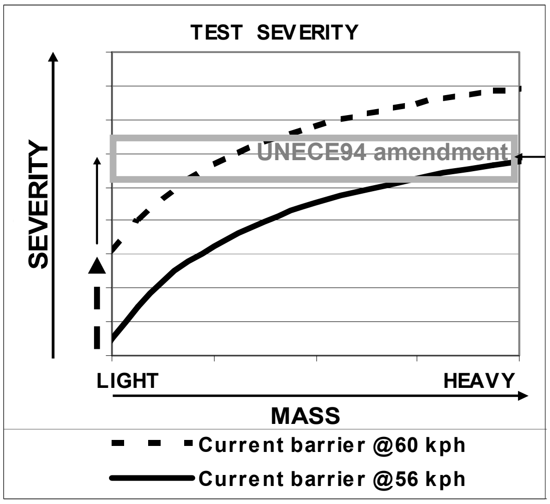

Figure 7. Theoretical Test severity depends on the vehicle mass. Need to harmonize this phenomenon with introduction of new barrier.

These load paths are designed and tuned against two types of obstacles: full width rigid barrier or soft deformable barrier. This means that the front-end design is not controlled by the barrier stiffness because the structure collapses with the help of the rigid wall behind the barrier. In all cases, the obstacle is far from representing a car front unit. That is why structural behaviour in car-to-car accidents is different. So in order to reach the same level of self-protection, design against deformable barrier with bottoming out heavy cars is designed stiffer (figures 7 and 8). The result is that heavy cars cannot be made compatible, in term of stiffness, with small ones.

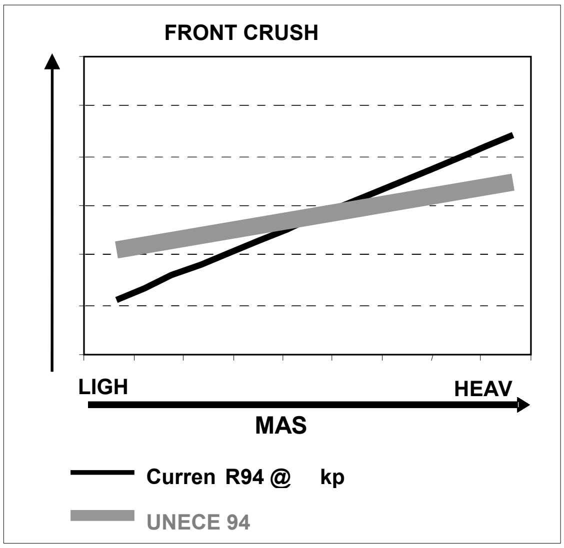

Figure 8. Front end force more homogenous among different vehicle mass with UNECE 94 amendment

The energy absorbed by the barrier does not depend on the vehicle mass. Severity for the vehicle structure rises up with the mass. Figure 8 clearly shows this unequal energy distribution. The fraction of energy absorbed in the barrier is roughly the same regardless of the car mass resulting in a higher fraction of energy to be absorbed by the large vehicle than by the small one. For a light car, energy in the barrier represents 40% of the total kinetic energy but only 10% for a heavy one (figure 9).

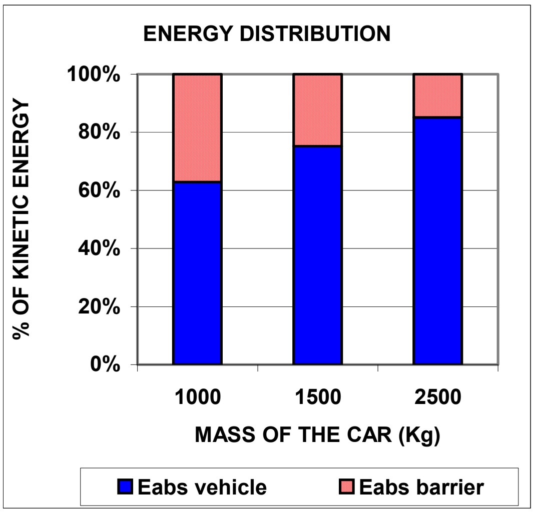

Figure 9. Severity situation with current barrier, percentages of kinetic energy absorbed.

UNECE R94 test procedure

Moreover, it is yet required to improve light cars compartment's strength without increasing heavy cars' one and to limit vehicle front units' aggressiveness. In other words, it is necessary to assess the possibility to check and improve partner protection with regards to self-protection. To achieve this new requirement, an amendment of UNECE R94 test procedure was proposed in 2007, based on PDB barrier, in order to check both parts of compatibility (structural interactions -partner- and compartment strength -self).

Details of the procedure are fully explained in document ECE/TRANS/WP.29/GRSP/2007/17 published at May 2007 GRSP. Test configuration is not so far from current regulation but some essential changes must be included.

- Test speed: 60 km/h
- Overlap: 50 %
- Barrier: PDB

Figure 10. PDB test configuration (UNECE 94 amendment).

Compatibility is a mix between self-protection and partner protection and cannot be separate for investigation because both act simultaneously.
Compartment strength is an answer for the first one, homogeneous front end is an answer for the second to improve structural interaction.

Barrier used

It is a progressive increase in stiffness in the depth, and two height dependant stiffness's, which contribute to its name: PDB as Progressive Deformable Barrier. Its dimensions and stiffness make the bottoming-out phenomenon very unlikely.

New test speed

To answer the question of improving compartment strength of the light car, it was necessary to increase the test speed to reach compartment deformation. 60 km/h seams reasonable.

Self-protection

Car design for frontal crash must limit passenger compartment intrusion and generate acceptable deceleration from the occupant point of view. Higher acceleration pulse combine with higher intrusion level allows getting closer to real life accident where both parameters are responsible for fatal injuries and injured.
Compartment intrusion was shown as the most important parameters in car-to-car head on collision, so this parameter must be put under control. This parameter is directly linked to the force generated by the compartment. A harmonisation among fleet masses is possible (figure 9 grey line).

Partner protection

UNECE R94 amendment protocol allows checking also partner protection. In addition to test all vehicles at a more or less constant equivalent energy speed (EES), the barrier used (PDB) gives the ability to check the front unit aggressiveness.

The current barrier deformation does not contribute to improve partner protection. No chance to detect front unit homogeneity, all vehicle deformations are completely flat smoothed by the rigid wall (figure 11).

Figure 11. Front deformation against current ODB barrier.

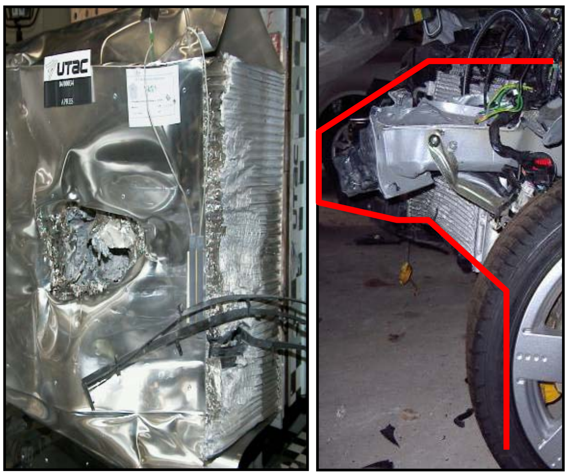

Figure 12. Front deformation of same car against PDB barrier.

Barrier analysis

The UNECE R94 procedure puts under control the energy absorbed by vehicle, the barrier is supposed to represent the vehicle we want to protect.

<u>Inhomogeneous front-end example</u> Stiff longitudinal with weak crossbeam penetrates the barrier. Forces are badly distributed. Cross member is not able to spread the force coming from the longitudinal. The surface in front of the load path is not in line with its stiffness. Deformation is inhomogeneous (figure 13).

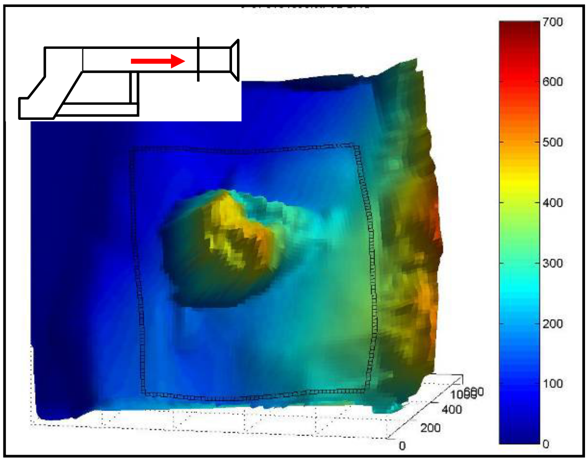

Figure 13. PDB deformation corresponding to inhomogeneous front end.

<u>Homogeneous front-end example</u> High forces generated by longitudinal and subframe is well distributed on a large surface. No over crushed between upper and lower load paths. Deformation is homogeneous (figure 14).

The PDB barrier is able to detect local stiffness but also transversal and horizontal links among load paths. The barrier records front cross member, lower cradle subframe, pendants linking position and stiffness that improve vehicles compatibility.

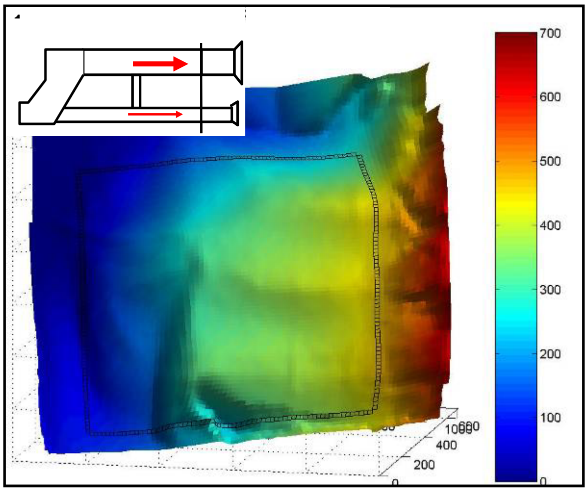

Figure 14. PDB deformation corresponding to homogeneous front end.

Conclusion of the UNECE R94 introduction

Harmonisation of offset test severity is considered by several passive safety experts as the main priority, the most effective way and probably the first step towards compatibility, to change the trend of inhomogeneous fleet showed by accident data. The UNECE R94 amendment is a good opportunity to solve problems of current regulation.

This amendment is closer and more representative of real world accident and will improve the current incompatibility.

The development of future vehicles with respect to these targets would result in a compatible fleet that gives clear answers to accident data presented before.

SAFETY BENEFIT CALCULATION

Since vehicles designed according the latest regulation exhibit unequal crashworthiness and aggressivity characteristics, it is of interest to evaluate the benefit of bringing cars at the same level of frontal protection. For this evaluation, it is assumed that all cars would have the same level of frontal protection as the more crashworthy vehicles. In this case, the target population is represented by cars weighting 1750 kg and above, which show a severity rate for self-protection of 16.07%. Severity rate of belted front occupants involved in head on collision between two newly designed cars are presented in table 3. Knowing the effective of each mass class, the number of severe and fatal injuries expected under the hypothesis if equal severity rate among cars of different mass is calculated in table 3.

Table 3.

Frontal protection harmonization based on the heaviest vehicle. Severe and fatal injuries expected.

Mean mass of the vehicle	Observed SR	Target SR	Number of severe and fatal injuries expected with the target SR=16,07%
<950 kg	31,4%	16,07%	11
950-1149 kg	29,6%	16,07%	90
1150-1349 kg	24,9%	16,07%	106
1350-1549 kg	28,2%	16,07%	67
1550-1749 kg	23,6%	16,07%	18
> 1750 kg	16,07%	16,07%	9
Total	26,9%		301

If crashworthiness turns out to be identical within the all new vehicles, 301 instead of 505 severe and fatal injuries would be observed for belted front occupant of new cars in head on collision. That is a 40.3% reduction. Given that severely or fatally injured belted front occupant involved in head on collision represent 17% of the totality of the severe and fatal injuries in France, the overall safety benefit of harmonization of the frontal protection is evaluates at 7% (40.3% x 17%), as summarized in table 4.

Table 4.
Safety benefit evaluation.

	Head on collisions	All impacts
	Victims reduction on pertinent accidents (front occupant, belted, head on collision between two cars of conception > 1999 or model year > 2003)	Victims reduction extrapolated to the whole set of car occupants
Reduction in fatalities and severe injuries (SR)	40.3%	7.0%

Provided that in 2007, 18 950 car occupants have been severely injured or killed, the safety benefit of such a harmonization would lead to 1 327 avoided casualties.

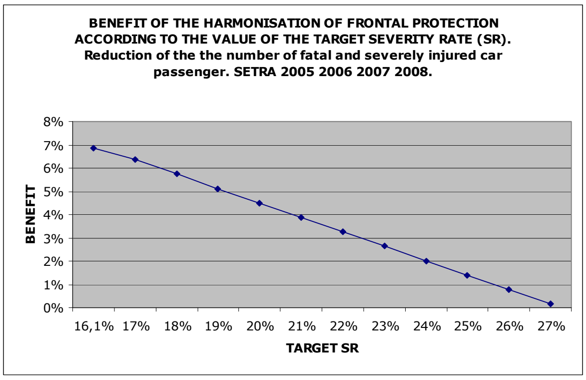

Figure 15. Benefit of the harmonization of frontal protection according to the value of the target severity rate.

If we estimate the benefit for several levels of harmonization, we obtain the figure 15. On this figure, we note that the benefit became null for a self-protection level of 27%. This figure corresponds to mass vehicle class of about 1350kg (table 3).

Extension to European data

Because regulations are done on a European level, it is crucial to obtain estimated benefice of safety measure not only for France but also for the whole Europe. As no European data on mass, year of registration or year of conception for crashed cars is available, fleet data will be analyzed. For that purpose, the Polk database which gathered information for 23 out of 27 of the European country is used. The goal is to make a link between the characteristic of the French fleet and the characteristics of the European fleet. Distributions of the mass of the vehicle among the French fleet as well as the percentage of cars in compliance with the ECE R94 regulation are available. The figures for the European fleet were obtained from the Polk data base and are presented in tables 5. Information was available for more than 95% of the vehicles.

Table 5.
Percentage of the fleet compliant with R94.

	France	Europe
Fleet designed according to R94 (%)	33.9%	35%
Fleet not designed according to R94 (%)	66.1%	65%

The figures make clear that the percentage of the fleet in compliance with ECE R94 is nearly identical in

France and in Europe: in France 33.9% of the car fleet is designed according to the latest frontal regulation whereas the percentage for Europe is estimated at 35%. If looking at the distribution of the mass within the fleet, one can say that they are quite similar for the total fleet, for car in compliance with ECE R94 regulation and also for older cars (not ECE R94 compliant).

When we have a look at the distribution of car fleets within the European countries (table 6), we can notice that five countries (France, UK, Germany, Italy and Spain) represent more than 70% of the European fleet.

Table 6.
Distribution of car fleets regarding the different countries in Europe.

Country	**Number**	**%**	**Cumulative %**
Germany	41,183,594	18.8%	18.8%
Italy	31,414,905	14.4%	33.2%
France	30,700,623	14.1%	47.3%
United King	30,257,323	13.8%	61.1%
Spain	21,760,174	10.0%	**71.1%**
Poland	13,393,451	6.1%	77.2%
Netherlands	7,509,649	3.4%	80.7%
Belgium	5,006,294	2.3%	82.9%
Greece	4,805,156	2.2%	85.1%
Portugal	4,379,071	2.0%	87.1%
Czech Repub	4,285,465	2.0%	89.1%
Sweden	4,249,344	1.9%	91.1%
Austria	4,245,583	1.9%	93.0%
Hungary	3,012,165	1.4%	94.4%
Finland	2,553,556	1.2%	95.5%
Denmark	2,060,418	0.9%	96.5%
Ireland	1,899,639	0.9%	97.4%
Lithuania	1,592,051	0.7%	98.1%
Slovakia	1,433,926	0.7%	98.7%
Slovenia	1,029,342	0.5%	99.2%
Latvia	869,656	0.4%	99.6%
Estonia	523,766	0.2%	99.9%
Luxembourg	321,538	0.1%	100.0%
Total	218,486,689	100.0%	

Assuming that types of crashes are nearly the same in all these countries, and as the fleet are identical in France and Europe, it is estimated that the Safety Benefit Estimation of frontal protection harmonization expected in Europe would be of the same extend of the one observed in France : 7% of avoided severe and fatal injuries.

With this assumption, the number of fatalities and severe injuries reduction in Europe is calculable. For that, the CARE database for year 2005 is used. 20 countries (missing Germany, Lithuania, Slovakia Slovenia, Latvia, Cyprus and Bulgaria) are available. It represents 95 659 fatalities and severe injuries in cars. The result will be then, after multiplication with the 7% safety benefit, of 6 696 severe and fatal car occupants injuries avoided in case of frontal protection harmonization, for these 20 countries.

LIMITS

As we may observed in many safety studies, result limitations often come from available data. Either data are in-depth data with high quality coding but not representative, either they are available at a macro level (i.e. national or international level) with lower quality but representative from a country. In our survey, we rather chose to use French national data to have a consequent sample and less dispersion for the safety benefit calculation. The Europe extension study shows again the limit of available data. In that case, it was necessary to use fleet data rather than safety data. Another limitation concerns the national data years used. Only years after 2005 were taking into account due to the count changes for severe injured and fatalities.

We observe that compatibility represents a significant stake and that the potential of improvement is important. Only a few new systems launched on the market nowadays can afford an equivalent safety potential of 7 % (level of self-protection and partner-protection align on the best mass class). However, the result depends on the severity rate target we would like to obtain. Benefit is null for intermediate class mass of vehicles.

Finally, this calculation concerns only head-on car-to-car collisions and it is also necessary to add the possible benefit for an improvement of the compatibility between car-to-light truck or car-to-heavy truck collisions.

CONCLUSION

A comprehensive accident study for frontal impact was performed to help prioritize frontal impact scenarios for casualty reduction and potential future changes to frontal impact legislation, namely Regulation 94. This study consisted of the following parts:

- quantification of associated French target populations for potential changes to frontal impact legislation;

- focus on self-protection and determination of severity proportion for different mass of vehicles;
- focus on self-protection versus partner protection;
- an example of safety benefit calculation that could be expected for France and for Europe.

According to our accident analysis, improving compatibility is a first priority to reduce the number of road accident victims. The regulation way is the most appropriate to switch towards a homogeneous fleet. The development of future vehicles with respect to these targets would result in a compatible fleet of new vehicles. Based on these remarks, the updated of the R94 regulation must include its capacity to verify the behaviour of new vehicles in regard to the partner protection targets (to be less aggressive) and one the other hand the new R94 must be more homogenous in terms of test severity for all class mass to avoid that heavy vehicles continue to be stiffer than light ones.

A new deformable element, more realistic, associated to a new test speed should be introduce. The R94 will become closer to real life accident and will solve a large part of compatibility problems. The introduction of these improvements will design new vehicles better in terms of:

- partner protection: vehicles should have an homogeneous front end and absorb a certain amount of energy before reaching self-protection force
- self-protection: vehicle should have a certain compartment crush force capacity and stability.

According to these improvements and with the amendment introduction, the estimated gains could reach 6 696 fatalities and serious injured in Europe.

REFERENCES

[1] European transport policy for 2010: time to decide. COM (2001) 370 final.

[2] Informal document No. GRSP-41-25, 41st GRSP, 7-11 May 2007,

[3] Improvement of Vehicle Crash Compatibility through the Development of Crash Test Procedures (VC-COMPAT) - Final Report, GRD2/2001/50083, 15/02/2007

[4] EEVC WG Final Report to EEVC Steering Committee, May 2007, www.eevc.org

[5] Design Considerations for a Compatibility Test Procedure, Stephen Summers, William T. Hollowell, Aloke Prasad, Society of Automotive Engineers Paper No. 2002-02B-169. March 2002,

[6] Australian Research To Support The Ihra Vehicle Compatibility Working Group, K A Seyer, C A Newland and M B Terrell, ESV 2003 Paper No: 274

[7] The Development of a Load Sensing Trolley for Frontal Off-set Testing, Marian Bosch-Rekveldt, Ton Versmissen, Cor van der Zweep. Herman Mooi, Steve McEvoy, ICRASH 2006 Paper 71

[8] NHTSA's Recent Compatibility Test Program, Stephen Summers & Aloke Prasad, 19th ESV Conference 2005, Paper No. 278

[9] Feasible steps towards improved crash compatibility, Henchen Dietmar, Schwarz Thomas, Thomas Gareth, Zobel Robert, SAE transactions ISSN 0096-736X 2004, vol. 113, n° 6 (1304 p.)

[10] ESV Washington DC 2005, P.Delannoy, T.Martin, P.Castaing

[11] UNECE 94 Amendment ECE/TRANS/WP.29/GRSP/2007/17 –