IMPROVEMENT OF CRASH COMPATIBILITY BETWEEN CARS

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ABSTRACT

This paper will provide an overview of the research work of the European Enhanced Vehicle-safety Committee (EEVC) in the field of crash compatibility between passenger cars. Since July 1997 the EC Commission is partly funding the research work of EEVC. The running period of this project will be two years. The progress of five working packages of this research project is presented: Literature review, Accident analysis, Structural survey of cars, Crash testing, and Mathematical modelling. According to the planned time schedule the progress of research work is different for the five working packages.

INTRODUCTION

Road accidents are the greatest source of accidental death throughout the European Union. The installation and use of seat belts resulted in a major improvement in protection and paved the way for further improvements in car structures.

Recent research, by the European Enhanced Vehicle-safety Committee (EEVC), has resulted in the development of a test procedure for side impacts and a new frontal impact test procedure. During the development of these procedures, it has been recognised that there is an interaction between them. In protecting car occupants most activity has been associated with improving the occupants own car to aid his protection. In future, improvements should be possible from improving the front of the other car involved. The term „compatibility" has been coined to describe this subject.

In February 1996 the EEVC Main Committee established the Working Group 15 to address to the problems of compatibility for the period of three years. The research work is done under the collaboration of the following partners: BASt, Chalmers University of Technology, Fiat, INRETS, INSIA/Universidad de Madrid, SWOV, TNO and TRL.

This project will provide for the start of a scientific approach to the question of compatibility. At the beginning, effort will be concentrated on the most important impact types: car to car frontal and side impacts. During this work, consideration will be given to the implications for pedestrian and other types of impact but they will not be directly addressed. Since July 1997 the research work is partly funded by the Commission of the European Community.

The work will cover three main activities:
Data from in depth accident studies will be used to identify the most important problems related to compatibility.

Typical accident configurations will be replicated by carrying out experimental car to car impacts. These crash tests should help to identify the major problems occurring when two cars impact.

Computer simulation modelling will be used to study the effects of changing the effective stiffness and mass of two cars impacting.

Vehicle incompatibilities can be observed in:

- structural incompatibility
  - stiffness and
  - geometry
- mass incompatibility.

Most vehicle safety experts agree that substantial reductions in casualties would be possible if the way cars interact in an accident were to be optimised. An estimate of the extent of possible benefits will be one of the outputs from the study.

WORKING PACKAGE LITERATURE REVIEW

SWOV is responsible for this working package.
The objective of this literature review is to see how scientists define and tackle the problem of incompatibility between cars. The literature study is based on a vast range of documents, for which the papers and reports presented at the ESV-, IRCOBI-, STAPP- and SAE-conferences are important sources. The search includes documents from 1985 till now; older documents are considered only if members of EEVC-15 emphasise their relevancy and usefulness.

The results of the literature review on compatibility of cars regarding car to car crashes, are listed according to the following main topics:

- the statistical view
- the mechanical view
- the geometrical view.

In the statistical view subjects related to influence of vehicle mass, vehicle size and ranking are considered, based on (statistical) accident analysis. Newtonian mechanics, (in-depth) accident analysis, crash tests and computer simulation are studied in the mechanical view. The third topic, geometrical view, deals with specific subjects as distribution of stiffness and the influence of collision type, especially frontal collisions versus side impacts.

Clearly there is an overlap between these groups, since in statistical analysis both mechanical and geometrical aspects are used. Statistical analysis is treated separately from in-depth analysis because of the different methods, and quantity and quality of their outcome.

Preliminary findings are the following.
The statistical approach of vehicle compatibility is based on the quality of available accident data. Some authors conclude that the safety of cars is closely related to vehicle size, where others conclude that vehicle mass is the most important factor. Because of the relatively limited data available for statistical analysis, it is difficult to isolate vehicle mass and vehicle length from disturbing factors as driver age and driver attitude.
With Newtonian mechanics the problem of compatibility can only be described in a simple way. Particularly the description of stiffness and vehicle shape are not well described in this view.

Data from in-depth studies can give additional information. More insight can be gained by crash tests and computer simulation. However, the problem of the latter two methods is that the relation between test data and real world accidents data (injury) is normally not available.
From a geometrical point of view compatibility is very complicated. There is a broad variance of vehicles on the road and there are numerous configurations of collisions. One individual car type may behave completely different in frontal and side collisions. Clearly the distribution of stiffness and the force levels by which cars absorb kinetic energy are important factors in the incompatibility problem.

From the interpretation of literature it is provisionally concluded in general that in car to car crashes, occupants in the smaller car are likely to be more severely injured than occupants in the bigger car. Hence, crash test(s) regarding compatibility should take the behaviour of the smallest cars of the vehicle population as reference.

WORKING PACKAGE ACCIDENT ANALYSIS

INRETS is responsible for this working package.
EEVC WG 15 considers in depth studies carried out by different teams in Europe and official overall statistics in Germany and The Netherlands.

Up to now mass incompatibility has been identified and quantified in a large number of studies. One task of the compatibility project should be to come to a better description of the effects and better established figures concerning the quantification of injury severity resulting from this effect. The most successful method in this field seems to be the analysis of overall accident statistics for vehicle groups of similar structure. A comprehensive structural survey for passenger cars shall help to define those vehicle groups of comparable vehicle structure.

In some studies structural incompatibilities have been identified in car to car accidents between apparently incompatible vehicles, e.g. passenger cars vs. trucks or passenger cars vs. large MPV's, but such incompatibilities also exist between similar passenger cars. The main problem in this field is the identification of acceleration- or contact-related injuries. Both injury types can be caused by stiffness and/or geometry incompatibilities. One of the main topics of the compatibility project is the identification and quantification of incompatibilities between vehicles of similar mass and similar type. Both methods: in depth studies and overall statistics must be applied to solve this question.

Overall statistics can help to identify and quantify incompatibilities by using the vehicle structure data collected by INSIA (see next chapter). Several groups of different vehicle types but each with similar mass, similar structural stiffness or similar structural geometry should be defined. The accident severity of accidents between vehicles of two groups of the defined groups should be determined for each vehicle group. Different vehicle groups should show different injury severity levels. Driver gender and age as well as accident type and location should be considered to eliminate the influence of the driver.

WORKING PACKAGE STRUCTURAL SURVEY OF CARS

INSIA, the vehicle engineering institute of the politechnical University Madrid/Spain, is responsible for this working package. The survey done by INSIA is nearly completed. Minor improvements are under discussion.

__Introduction__ - The parameters which have an influence in compatibility can be divided in three main groups:

- Mass of vehicles.
- Stiffness of structure.
- Geometrical compatibility.

Conventional thinking tells us that when a smaller car collides with a larger one, the smaller car usually fares worse. In many studies was looked at a number of accidents, grouped the vehicles according to mass and then looked at the risk of injury to the occupants of the struck car and the risk to the occupants of the striking car. Perhaps unsurprisingly lighter cars seem to present less of a hazard to heavier cars.

So, the exterior risk associated with each model varied greatly within a given mass category. This conclusion illustrates that crash compatibility is not only influenced by mass but also by vehicle structure. The shape and crush stiffness of the sides and fronts of vehicles lead to intrusion problems.

The structural survey examines the geometrical features of the resistant front and side elements, as inferred from vehicle measurements. Thus, this work is spread to a total number of **75 models** which have been selected from the main vehicle manufacturers in Spain. All of them have been sold for 1997.

__Methodology__ - Detailed measurements have been taken of exterior and interior elements. Using the information available from the previous measurements in vehicles, the geometric characteristics of the main resistant elements involved in the geometric compatibility between cars have been defined. These elements are presented in the following figures (*Figure 1, 2 and 3*), and have been divided in two main groups according to the vehicle zones studied in this project.

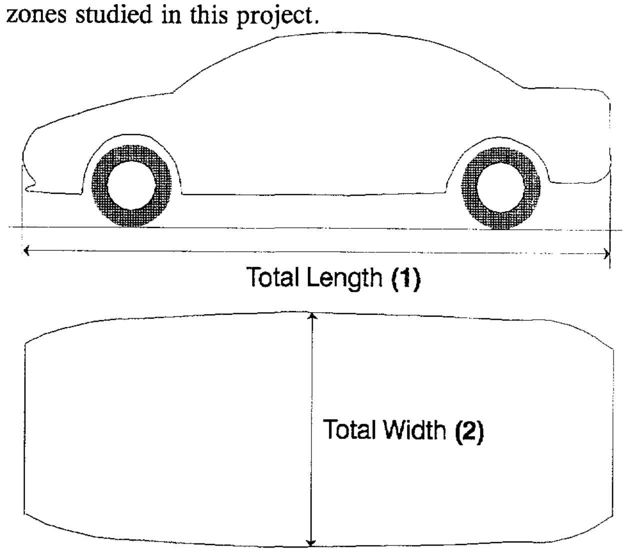

Figure 1.- Definition of the main resistant elements. General dimensions.

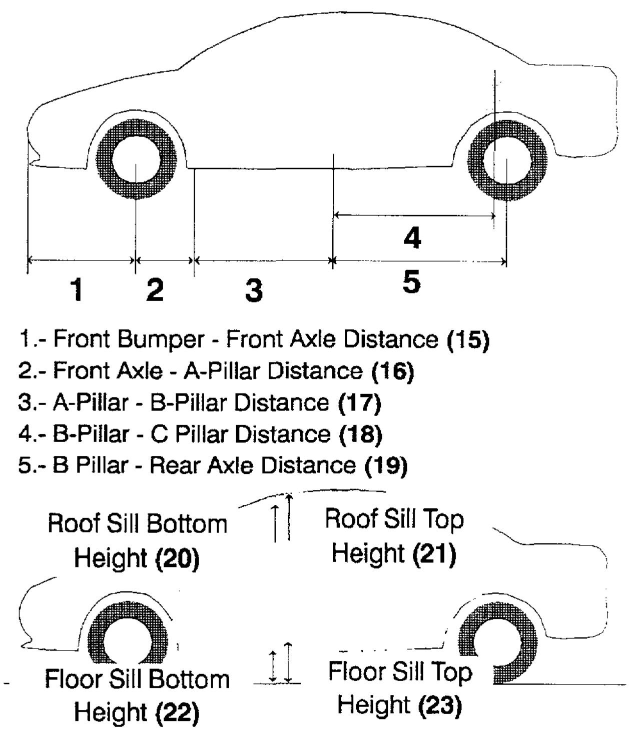

Figure 2.- Definition of the main resistant elements. Side elements.

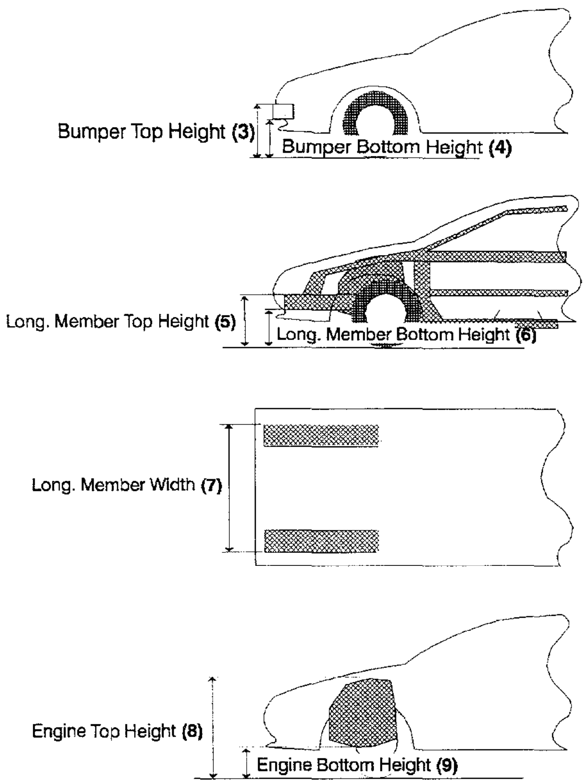

Figure 3.- Definition of the main resistant elements. Front elements.

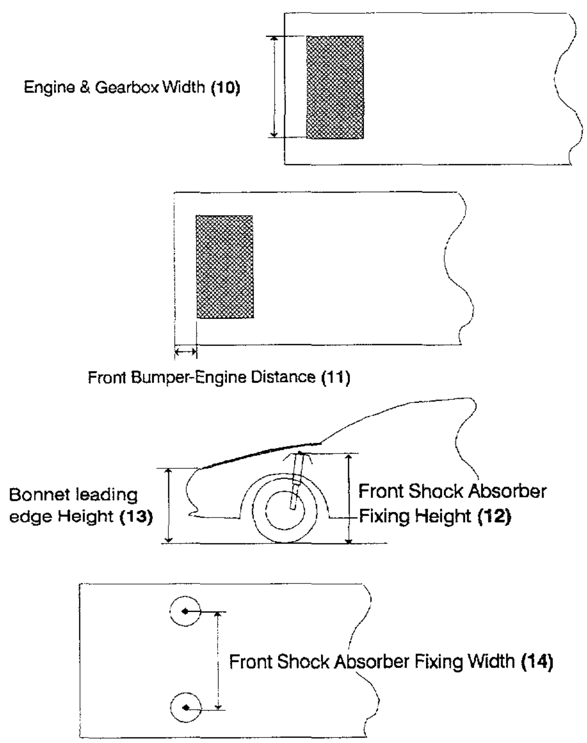

Figure 3.- Definition of the main resistant elements. Front elements (continued).

<u>**Results - Vehicles involved**</u> - As it has been presented in the previous text, this work is spread to a total number of **75 models** which have been selected from the main vehicle manufacturers in Spain. The distribution of these models according to the independent variables taken into account *-mass, length-* is shown in the following figures (*Figure 4 and 5*).

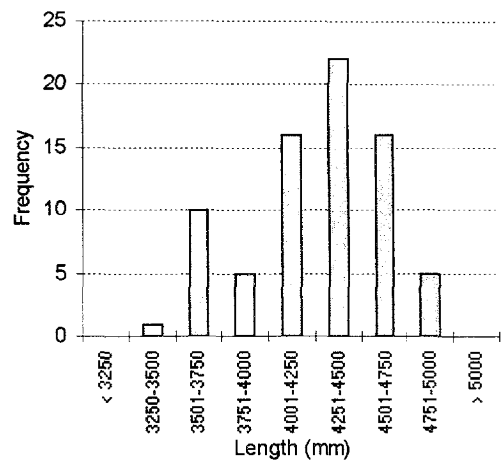

Figure 4.- Distribution of vehicle models by length.

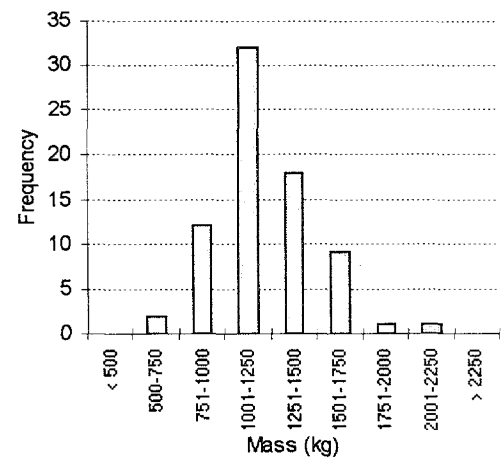

Figure 5.- Distribution of vehicle models by mass.

<u>**Results - Measurement Analysis:**</u>

<u>Linear Regression.</u> This phase consists of analysing the relations among the variables considered (resistant elements) and the independent variables: *mass and length.* This analysis has been developed by means of the following statistics:

- Linear parameters (least-squares coefficients): slope (B_1) and intercept (B_0).
- Standard error of the estimate (SEB_i).

- *Testing hypothesis:* a frequently tested hypothesis is that there is no linear relationship between X and Y. The statistic used to test this hypothesis is *t*, which distribution, when the hypothesis of no linear is true, is Student's t distribution with N-2 degrees of freedom. The significance level is 0.00005:

$$t = \frac{B_i}{SEB_i}$$

Taking into account these parameters, following linear relations have been found (*Table 1*).

Table 1.
Linear relations among variables - (*): transverse configuration engine; (**): four/five-door models

INDEPENDENT VARIABLE: LENGTH											
		Value	SEBi	t	Sig. level			Value	SEBi	t	Sig. level
(10)(*)	B_1	0.103	0.020	5.031	0.0000	(15)	B_1	0.191	0.016	11.8	0.0000
	B_0	441	86	5.115	0.0000		B_0	31	69	0.45	0.6575
(11)	B_1	0.141	0.027	5.124	0.0000	(16)	B_1	0.12	0.026	4.56	0.0000
	B_0	-109	117	-0.93	0.3557		B_0	31	110	0.28	0.7810

INDEPENDENT VARIABLE: MASS											
		Value	SEBi	t	Sig. level			Value	SEBi	t	Sig. level
(8)	B_1	0.113	0.023	4.84	0.00	(19)(**)	B_1	0.319	0.064	5.01	0.00
	B_0	675	29	23.17	0.00		B_0	672	86	7.84	0.00
(15)	B_1	0.206	0.030	6.81	0.00	(23)	B_1	0.089	0.014	6.25	0.00
	B_0	593	38	15.65	0.00		B_0	235	18	13.19	0.00

<u>Results - Measurement Analysis:</u>

Mean values. In this case, the dependent variables which do not show linear relation with length or mass are considered. Then, the mean values and the standard deviations are calculated. Afterwards, the different variables are compared, evaluating the relative position between them in case of collision (*Tables 2 and 3*).

Table 2.
Relative distance between mean values of dependent variables. Horizontal dimensions.

Mean		(7)	(10')	(14)	(17)	(17')	(18)	(19)
value		1084	457	1083	1122	984	758	837
(7)	1084	0	-627	-1	38	-100	-326	-247
(10')	457	627	0	626	665	527	301	380
(14)	1083	1	-626	0	39	-99	-325	-246
(17)	1122	-38	-665	-39	0	-138	-364	-285
(17')	984	100	-527	99	138	0	-226	-147
(18)	758	326	-301	325	364	226	0	79
(19)	837	247	-380	246	285	147	-79	0

Table 3.
Relative distance between mean values of dependent variables. Vertical dimensions.

Mean		(3)	(4)	(5)	(6)	(9)	(12)	(13)	(20)	(20´)	(21)	(21´)	(22)
values		543	382	522	411	192	836	723	1292	1555	1369	1667	222
(3)	543	0	-161	-21	-132	-351	293	180	749	1012	826	1124	-321
(4)	382	161	0	140	29	-190	454	341	910	1173	987	1285	-160
(5)	522	21	-140	0	-111	-330	314	201	770	1033	847	1145	-300
(6)	411	132	-29	111	0	-219	425	312	881	1144	958	1256	-189
(9)	192	351	190	330	219	0	644	531	1100	1363	1177	1475	30
(12)	836	-293	-454	-314	-425	-644	0	-113	456	719	533	831	-614
(13)	723	-180	-341	-201	-312	-531	113	0	569	832	646	944	-501
(20)	1292	-749	-910	-770	-881	-1100	-456	-569	0	263	77	375	-1070
(20´)	1555	-1012	-1173	-1033	-1144	-1363	-719	-832	-263	0	-186	112	-1333
(21)	1369	-826	-987	-847	-958	-1177	-533	-646	-77	186	0	298	-1147
(21´)	1667	-1124	-1285	-1145	-1256	-1475	-831	-944	-375	-112	-298	0	-1445
(22)	222	321	160	300	189	-30	614	501	1070	1333	1147	1445	0

(10'): longitudinal configuration engine;
(17): two/three-door models;
(17'): four/five-door models;
(20): without Off-Road, Commercial, MiniVan;
(20'): only Off-Road, Commercial, MiniVan
(21): without Off-Road, Commercial, MiniVan;
(21'): only Off-Road, Commercial, MiniVan

<u>Structural Survey Conclusion</u> - With the obtained results, the next conclusions are considered:

- There are only a few variables that show linear relation with length and mass.
- Using the mean values in case of lack of linear relation, the relative position between the different resistant elements considered can be analysed (collision).

WORKING PACKAGE CRASH TESTING

TRL is responsible for this working package.

Introduction - TRL and BASt will carry out exploratory crash tests till mid 1998. In the second half of 1998 the generally agreed crash test programme will be commenced. Initial testing activities have focused on identifying the major factors which influence compatibility and determining the extent to which they might influence injury outcome. This work has been supplemented with exploratory testing with the aim of establishing possible, and practical, assessment methods.

Car to Car Frontal Impact

Interface Force - Theoretical proposals are emerging as to possible ways of creating a compatible fleet. Many of these are in some way based around the control of the vehicles stiffness. In order to be able to assess the usefulness of these proposals, it is necessary to be able to quantify the characteristics of the vehicles global dynamic stiffness. One of the more useful measures of a vehicles stiffness is the level of interface force between impacting cars.

Interface force can be obtained through the use of a load cell wall or the measurement of the deceleration of the constituent parts of the vehicle. Both of these methods have been explored under this programme and for barrier tests have been shown to be in good agreement. In order to calculate the interface force from the car's deceleration, it is necessary to select and instrument discrete components and areas of structure. The selection is made based upon how it is believed these discrete areas of the vehicle will move and deform during the impact. It is assumed that the selected area will act as a lumped mass and the deceleration force for each lumped mass can be calculated from its associated deceleration. The summation of these forces gives the overall interface force (Figure 6.)

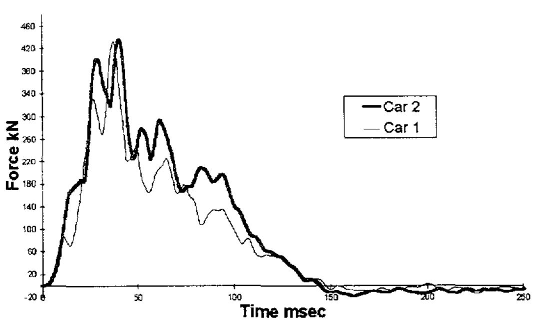

Figure 6.- Interface force calculated in car to car offset impact.

Now that this capability has been established, it will be used to gain an understanding of current interface force levels between impacting cars. In addition, it is envisaged that an assessment method will be created in order to validate the theoretical proposals developed to achieve a compatible fleet.

The interface work described above assumes that the fronts of vehicles interact well and that the 'average' stiffness which can be obtained from the interface force is sufficient. It is well known that the fronts of vehicles often have small areas of stiff structures within a larger area of weaker structure. For this reason it may well prove important to control the distribution of frontal stiffness, an area of research which is currently being undertaken to form part of the EC Compatibility Programme.

Structural Interaction - The control of the distribution of frontal structure is key to geometrical compatibility. Geometry, and how vehicles fronts interact, is one of the factors which influence vehicle compatibility along with vehicle mass and stiffness. However, the relative importance of each characteristic have yet to be established. Work has recently started to isolate and quantity the importance of each factor, starting with geometry.

In order to study the importance of structural compatibility, tests had to be conducted which had the sole variable of geometry. The first test carried out consisted of a medium size, car to car offset test. This was performed using identical vehicles, at the same test weight, but having undergone modifications to their ride heights. The vertical difference in height was 100mm, well within the fleet variations for this segment of car (5). The most noticeable difference in structural deformation of the two vehicles could be seen in the upper load path. In the lowered car, the struck side suspension turret had been displaced 480mm rearwards. By contrast, the suspension turret of the higher car moved rearwards by only 295mm.

In this test the vehicle's mass, stiffness and occupant compartment strength were matched. However, the 100mm vertical height difference was sufficient to noticeably change the vehicles structural response. When considering that the vertical height difference of the two vehicles was less than the height of the bumper beam, these results become significant. These preliminary observations have been obtained at the beginning of a testing programme, it will not be until further research has been conducted that any conclusions may be drawn. However, it is believed that until vehicle designs enable structures to interact better in car to car impacts, any compatibility improvements in mass ratios, or stiffness matching, are unlikely to be fully realised.

WORKING PACKAGE MATHEMATICAL MODELLING

TNO is responsible for this working package. TRL and TNO are carrying out research work in this field. Their different approaches are described below.

TRL-Approach - Introduction - Initial research has focused on identifying the major factors which influence compatibility and determining the extent to which they might influence injury outcome. For frontal impact, the modelling work has studied how non-contact, deceleration related injuries might be minimised by optimising the deceleration pulse. For side impact, full car finite element models have been used for parametric studies to aid out understanding of the effects of the bullet vehicle mass, geometry and stiffness. This will help us to identify characteristics for more compatible car designs. Further details of the modelling approach and results are reported below.

TRL-Approach Car to Car Frontal Impact - There is virtually universal agreement amongst accident investigators that occupant compartment intrusion is a major cause of fatal and serious injuries to restrained occupants (1). In the future it is envisaged that car's occupant compartments will become stiffer so that there will be less intrusion in accidents. This is being driven by the introduction of Offset Barrier legislative and consumer impact tests. A probable outcome of this will be that there will be a reduction in the number of 'contact' related injuries and an increase in restraint system induced injuries. For this reason a study was initiated into the influence of the deceleration pulse on restraint related injuries, with the aim of modifying the pulse to minimise this type of injury. Having identified the most desirable shape we will, in later work, assess if it is possible to achieve such a pulse in real cars in a compatible fleet.

Computer simulation was selected as the most appropriate method by which to address this question. The MADYMO software package was used to simulate the deceleration of the occupant compartment (Figure 7).

Various simple shaped, analytical and experimental deceleration pulses were applied to the model in the fore aft direction. Chest injury criteria were monitored as the chest is directly loaded by the seat belt.

The results from this study, which are supported by previous work (2), indicate that:

1. Chest injury is minimised by maximising ridedown distance.
2. Chest injury is minimised by having a passenger compartment deceleration pulse profile that is constant in shape as opposed to triangular back loaded.

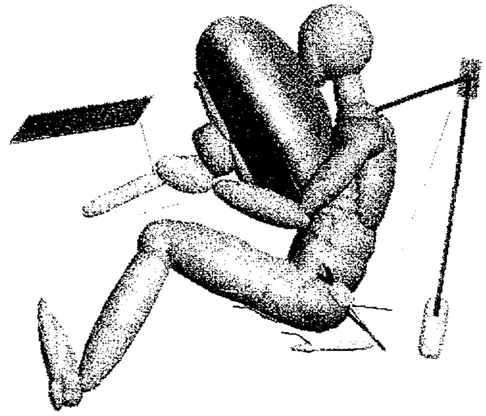

Figure 7.- Occupant compartment model; HYBRID III dummy held by a typical restraint system.

These findings have been demonstrated with deceleration pulses abstracted from experimental car crashes as well as analytical pulses.

It has also been shown that the deceleration pulse abstracted from a car to car 50 percent overlap impact, causes higher chest injury than the pulse from an ODB test. The reason for this is that the higher deceleration at the beginning of the car to car pulse means the occupant contacts the airbag with a higher velocity. This results in a high sternum to airbag load causing higher chest loading. A possible explanation for this is that the restraint system is 'tuned' to perform well in the ODB test. Manufacturers should be aware that the additional deceleration at the beginning of a car to car pulse compared to an ODB pulse can cause the occupant to contact the airbag with a greater velocity and hence induce higher chest compression. This would be difficult to compensate for in the adjustment of airbag trigger time as the beginning of the two pulses are very similar in shape.

TRL-Approach Car to Car Side Impact - The purpose of this study was to understand the effect of changing bullet vehicle parameters on the impacted cars structure and dummy response. In order to undertake such a parametric study, the European Mobile Deformable Barrier (MDB) was chosen as the bullet vehicle. It was assumed that changing the MDB characteristics would indicate trends similar to those from changing the characteristics of an impacting car.

The FE model of the small four door car, EUROSID and MDB, used for the study is shown (Figure 8). The model was validated for an European side impact test and shown to give reasonable agreement.

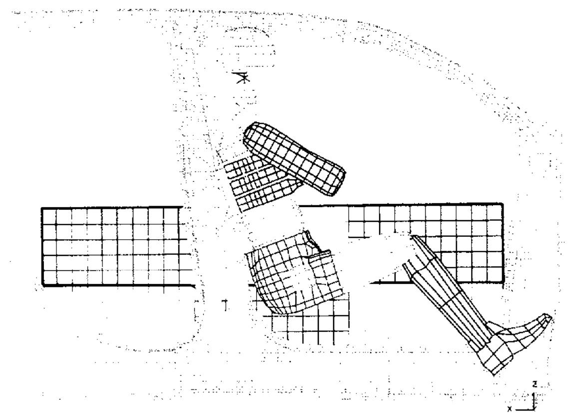

Figure 8.- Relative positions of MDB, EUROSID and car structure in European side impact test.

A number of parameter sweeps were performed changing the following barrier characteristics:

1. Barrier centre impact point.
2. Barrier mass.
3. Barrier front face geometry.
4. Barrier stiffness.

Moving the barrier impact point down significantly reduced the EUROSID injury criteria as this gave better structural engagement with the sill. Raising the barrier had the opposite effect. Moving the barrier fore and aft did not have such a large effect on the injury criteria. This was an expected result as the amount of structural engagement did not change greatly.

Changing the barrier mass did not effect the injury criteria significantly as seen by other researchers (3). The reason for this is that most injury criteria peak before 40 ms whereas the momentum transfer is not complete until 80 - 100 ms. Also, the simple geometry changes made such as changing the barrier to have a planar front, did not significantly effect the injury criteria.

Changing the barrier stiffness had a significant effect. Stiffening the whole of the barrier increased all of the injury parameters, stiffening just the top of the barrier caused an even larger increase, but stiffening just the bottom of the barrier reduced chest injury.

In summary, the results of this study indicate that in order to improve compatibility for side impact, the bullet vehicle should be designed such that it engages the structure of the target vehicle more effectively through improved geometrical interaction. However, this should be achieved without compromising the intrusion profile, causing any unnecessary delay in the occupants acceleration (4), or causing excessive roll in the target car. It is believed that excessive roll in the impacted vehicle may lead to head impact on the cant rail. Stiffening of the bullet cars upper load path without stiffening the lower path should be avoided as this will increase occupant injury. It should be noted that these conclusions have yet to be validated by experimental test.

TNO Approach - Objective - The objective of the workpackage Mathematical Modelling of Vehicles and Car Occupants is directly linked to the general objective of the research program, which is: to define optimal structural characteristics of a car fleet in order to get a minimum risk for getting seriously injured in the selected distribution of car to car collisions (front and side).

TNO Approach - Contents - The task Mathematical Modelling is subdivided in three subtasks:

I. Vehicle modelling with Finite Element Methods: The objective of the numerical simulations with vehicle (FEM) models, is to understand in depth what principle mechanisms are involved during car to car crashes in terms of the interaction of the energy absorbing structures of the collision partners. In car to car crash tests only the post crash situation can be studied, as it is impossible to watch every single detail of the structure by means of high speed films or transducers. With these modelling techniques a tool is available to study different types of cars and many impact situations without additional costs for buying the cars and using test facilities. Even after finishing the project the models would be available to be used in subsequent studies on this subject. Additionally the models will be used to derive the characteristics of the structural parameters to be used in the lumped mass approach. TRL is the executing party for this part of the working package.

II. Vehicle modelling with lumped mass models, occupant modelling and optimisation: The objective of using lumped mass models for the vehicle and the occupant is to run optimisations to define the optimum structural characteristics to get minimum risk for getting seriously injured for the selected distribution of accidents in the field. The reason for using lumped mass models is that current computer power to run optimisations with complete FEM models is not sufficient. TNO is the leading party for this part of the working package. The status is reported below.

III. Verification of optimisation and findings from tests and accident investigations with FEM models.
Finally the new structural characteristics, have to be translated back to the structure by proposing design modifications that meet these new parameters. These modifications and modifications resulting from tests and accident investigations, can be build into the FEM models and verified for their actual performance in the car to car crashes.

TNO Approach - Lumped mass Modelling detailed description and progress

Create very simple linear spring mass models

Objective:
Study mass and global stiffness influence on compatibility. Increase the understanding on compatibility for frontal impacts only. For very first impressions on global stiffness and mass influences this approach is valid since from literature (6,7). It is known that indeed the global front stiffness of a car can be approximated roughly by a linear force deflection characteristic.
Model specifications:
A vehicle model consists of only one mass and one spring. The equations of motion can be solved analytically. The model can be used quite simple in a spreadsheet program and modifications of masses and stiffnesses can be entered easily.

Status:
The models give very quick the consequences of changing global vehicle parameters like stiffnesses, masses but also velocities, for the two vehicle models involved. The models can give an answer on the pre-assumptions that are made for what would mean, design a car for compatibility. The results show that it is very well possible to balance the global load levels of different mass vehicles for compatibility.
The final answer on this item has to follow from this EEVC study.

TNO Approach - Create simple lumped mass models

Objective:
Study mass and global stiffness influence on compatibility for front and side impacts.

Model specifications:
The front models should be capable to describe the global front stiffness, engine bay layout, contact engine to firewall, compartment stiffness and intrusion by engine, delivering realistic crash pulses for car to car frontal impacts.

Status:
General models have been created. Studies with model parameter variations have not been carried out yet. The model types have been proven to be valuable for the purpose they have to serve.

Create complex 3D frame models

Objective:
Include geometric incompatibility studies capability into the models. Study mass and global stiffness influence on compatibility. In the end, the models have to be used in optimisation runs where the safety level for the whole car population is optimised for the vehicle parameters, which are relevant for compatibility.

Model specifications:
The model should be capable to describe the interaction between vehicles. This means a detailed 3 D modelling of the front. "Hooking" should be described, however, it is not realistic to have the same level of detail as for FEM models to describe the contacts. The contacts and structural detail should be defined for a pre defined configuration and not for a general case.

The front-structure behaviour must be simulated correctly which means the major mechanisms of the structural elements must be simulated correctly. The occupants compartment intrusion must be simulated which means adequate surface description of the footwell, dashboard and steeringwheel behaviour must be simulated. As the models contain more detail the characteristics can be defined more in detail as well. For this purpose component calculations by means of FEM could be carried out or component tests can deliver the desired characteristics. For the side models the same models as in the simple models phase are applicable. In case FEM models give more information during the progress of the project, new details and information can be incorporated into the models. The interior of the car is part of the model including a HIII dummy. This dummy can be exchanged by different dummy sizes for studying the influence of measures and parameter changes to the dummy criteria.

The car models should be in three different car classes: light, medium heavy and one with clear geometric incompatibility characteristics. As it is very difficult to obtain data from the industry, car FE models which are available from NHTSA will be used to create the following car models.

1 Chrysler Neon
2 Ford Taurus
3 Geo Metro
4 Ford Explorer

This range of cars is estimated to be representative sample of the car population to study different phenomena, like mass dependency geometric influence and stiffness influence.
Both frontal and side models will be created.

Status:
The Chrysler Neon has been started as a common project between TNO and NHTSA. Figure 9 shows a representation of the undeformed geometry of the model of the vehicle only. The model has been validated for US NCAP frontal impact 35 mph including a HIII dummy. Figure 10 shows the vehicle and dummy model at 100 ms in a side view. For the vehicle results validation, see Figure 11 For the dummy results validation, see Figures 12,13,14. The HIC value in the test appeared to be 610 and in the simulation 547. For the current simulation still insufficient data for the airbag were available. Although already close, it is expected the end result will be even closer to the test.

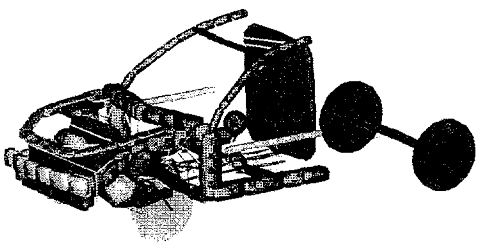

Figure 9.- Undeformed Geometry of 3D Frame model of Chrysler Neon

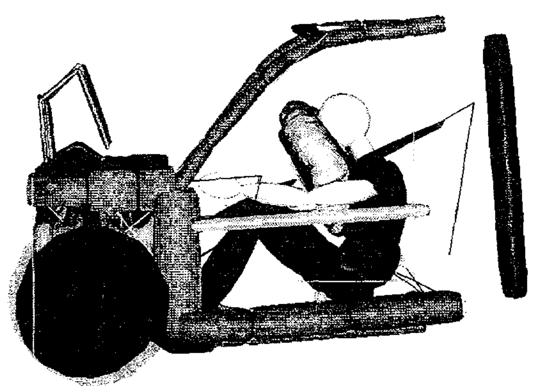

Figure 10.- Vehicle and HIII dummy model at 100 ms

The figures show an excellent model performance for this test configuration. Next step is to make the model use full for deformable offset and car to car (front and side) configurations.

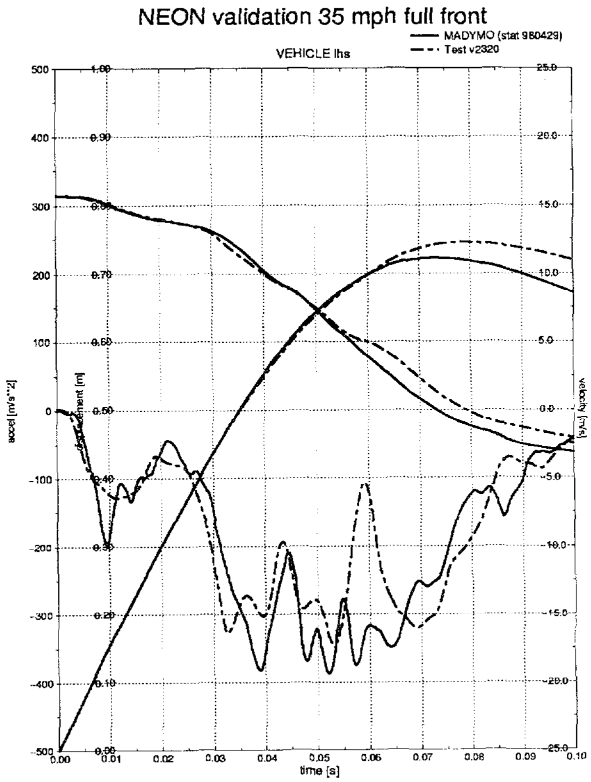

Figure 11.- Vehicle validation US NCAP

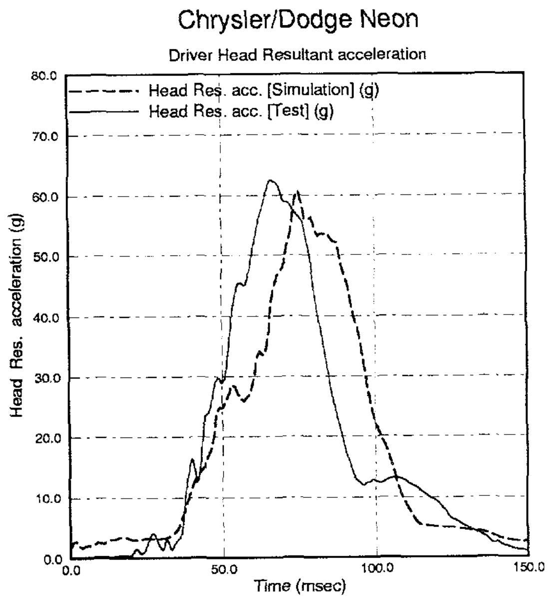

Figure 12.- Validation Resultant Head Acceleration

The work on the Ford Taurus has been started. The principle vehicle model is ready. Creation of the input characteristics for the deforming parts of the model still has to be carried out.

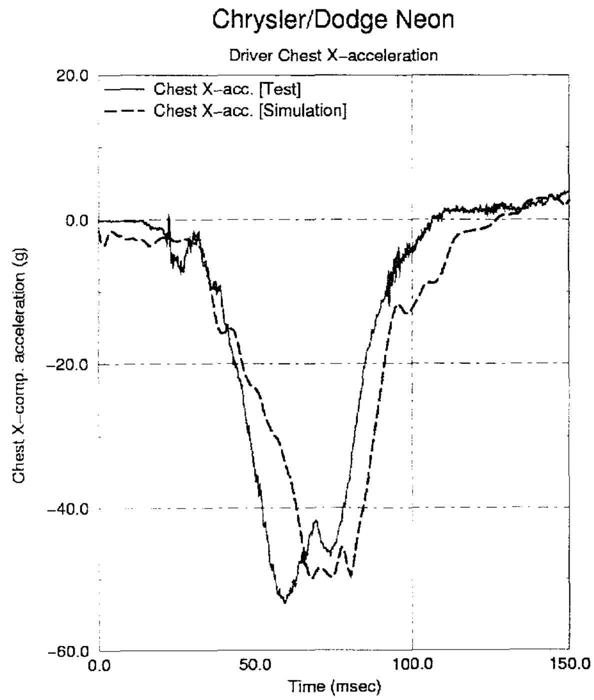

Figure 13.- Validation Resultant Chest Acceleration

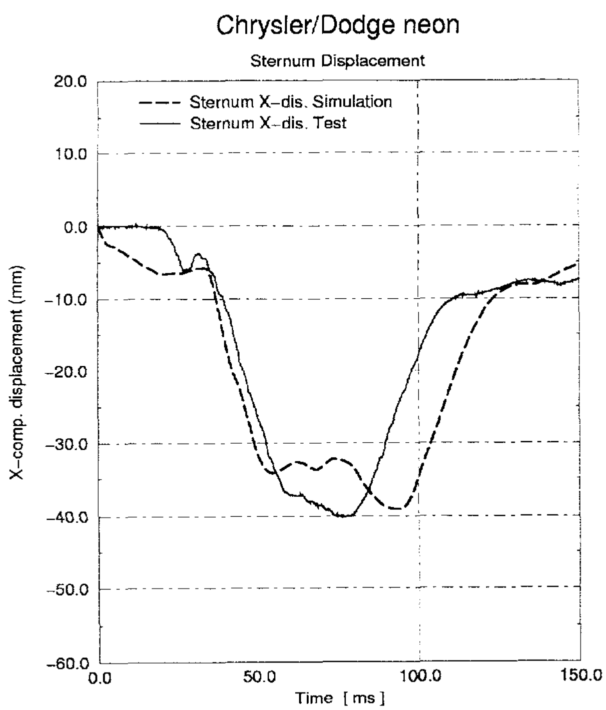

Figure 14.- Validation Sternum deflection

Side impact:
It is proposed to use frame models for the side structure for the side impact target cars. These models have proven validity in studying crash parameters (8). The model will be equipped with a Eurosid dummy model of the package MADYMO.
It is proposed to create models in four different type of weight classes conform the methodology in (9).

Status:
A 3D MADYMO frame model is presented in the MADYMO application manual (MADYMO 5.2). This model is used to study the influence of barrier mass and stiffness on the injury criteria of the Eurosid dummy. It was found that an increased stiffness of the barrier causes higher dummy loading in the thorax area, due to the dynamic behaviour of the side wall which is hit harder in case of a stiffer barrier. The higher mass has mainly effect on the final intrusion into the struck vehicle.

CONCLUSION

First research work in the field of compatibility between cars has shown that analysing crash compatibility is an extremely complicated matter. It can be expected however that the multidisciplinary approach as established in this project will lead to substantial progress in understanding arising from vehicle incompatibility.

Besides studies in this research project the EEVC Working Group 15 (Compatibility) provides scientific input to the IHRA working group on the same topic. A close co-operation with a BRITE-EURAM project working also at the problem of vehicle compatibility is established. About this project a presentation is given at the same session of this ESV-Conference.

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