

## QUALITY CRITERIA FOR CRASHWORTHINESS ASSESSMENT FROM REAL-WORLD CRASHES

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### **ABSTRACT**

The need for a consumer information on car safety is growing steadily. Up to now, the consumer information about crash tested new cars has been provided, but this should be supplemented by safety ratings based on real world accidents which reflect all types of accident circumstances.

The possibilities and limits of the necessary “Quality Criteria for the Safety Assessment of Cars based on Real-World Crashes” are analysed in an EU project in cooperation of research institutes, industry and universities [1, 2].

The paper summarises the results of three major objectives within this “SARAC” project.

- The existing rating procedures world wide have been analysed and are described by their methods and the assessment criteria/crash parameters used. The output results of the different ratings are compared with respect to the correspondence of the rankings produced by each method.
- The interrelationship between prospective (for example EuroNCAP) and retrospective rating systems is being investigated. Results from Australia, US and Europe represent the first experiences available, suggesting it is likely that correlations can be established.
- The paper finally outlines possibilities to integrate the aspects of crash compatibility and vehicle aggressivity in a comprehensive overall rating system. The methods for measuring aggressivity have been tested on databases and the necessary parameters will be outlined. Possibilities for an improved international comparison of safety rating results based on real accidents and necessary future steps are discussed.

### **INTRODUCTION**

The interest of consumers in the safety of passenger cars, and particularly in their ability to protect occupants in the event of an accident, has been growing steadily during the last decade. For a number of years this protective performance of cars, known as “crashworthiness”, has been part of motor vehicle safety regulations in the United States, in Europe, in Japan, in Australia and in other countries. These regulations prescribe minimum occupant protection requirements in standard frontal and side impact crash tests.

In addition, the United States, Europe, Australia and Japan have also developed new car crash testing programmes with the aim of developing consumer interest in car safety and letting market forces, by way of consumer choice, influence car manufacturers to improve the occupant protection of their new car models. The consumer information about crash tested new cars is provided in terms of simple ratings. It is also possible, although arguably more difficult, to produce an assessment of relative car occupant protection from real world road accident data.

Crash testing programmes and real-world rating systems are complementary. Crash test programmes attempt to simulate the most likely crash types and are carried out in controlled laboratory conditions. On the other hand, assessments based upon real world accident data reflect all accident circumstances. When adjusted to control for variations in accident circumstances and other uncontrolled aspects, they can have the potential to produce reliable information about the relative safety of cars. Neither approach guarantees a perfect rating system but both have the potential to produce consistent consumer information about the relative safety of cars.

To improve knowledge on the methods and quality criteria for safety ratings, the German Insurance

Association (GDV) established an advisory group in 1994 [1] comprising experts from government, the automobile industry and universities in order to investigate the state of the art and the possibilities for an acceptable car rating system. Five workshops [3] were conducted between 1995 and 1998 involving experts from several countries who exchanged information, views and arguments regarding the requirements for a high quality car rating system, such as the influence of statistical methodology upon risk evaluation, the entrance and outcome criteria for databases and the presentation of results.

**Safety Rating Advisory Committee (SARAC)**

This initiative of the German Insurers attracted high interest by the European Commission General Directorate Transport and Energy (DG TREN) as these works offered a basis to compare results from prospective crash tests and retrospective accident analysis and to define necessary standards for future European databases.

Therefore it was decided in April 99 to formalize these activities within the European Project “Quality Criteria for the Safety Assessment of Cars based on Real World Crashes” which is directly aligned to the European Commission DG TREN. The EU project activities are coordinated by the Committee of the

European Insurers (CEA, Paris) with GDV Institute for Vehicle Safety acting as the secretariat. The SAFETY Rating Advisory Committee (SARAC) was founded by the project members from 10 countries including Europe, United States of America, Australia and Japan. The member organisations are shown in Figure 1, while the participating experts are listed in the Annex.

**Project Objectives.** Three objectives were specified for SARAC to focus its activities to help improve the quality of vehicle safety rating systems throughout Europe. These included:

1. assessing the suitability of existing retrospective data analysis systems to provide high quality safety ratings of passenger vehicles and continue to improve these systems by the identification and inclusion of new and revised key variables where feasible;
2. the use retrospective analysis of real world crash data to complement and supplement prospective crash test results where appropriate; and
3. including issues of crash compatibility and vehicle aggressivity using retrospective real world crash data.

**Comité Européen des Assurances (CEA)  
Commission of the European Communities (EC)**

**USA:**

- Insurance Institute for Highway Safety
- Highway Loss Data Institute

**Australia:**

- Monash University  
Accident Research Centre

**France**

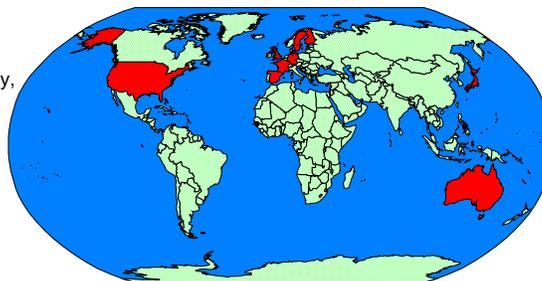
- Laboratory of Accidentology, Biomechanics and Human Behavior, PSA PEUGEOT CITROËN / RENAULT

**Japan:**

- National Organization for Automotive Safety and Victims' Aid (OSA)
- Japan Automobile Research Institute (JARI)

**Spain:**

- Instituto de Investigación Sobre Reparación de Vehículos, S.A.



**Germany:**

- GDV  
Institute for Vehicle Safety
- BAST
- BMW Group
- DaimlerChrysler AG
- Ford Motor Company
- VDA
- Volkswagen

**United Kingdom:**

- Department of Environment, Transport and the Regions

**Sweden:**

- Folksam
- National Road Administration

**Finland:**

- Finnish Motor Insurers' Centre
- University of Oulu
- Ministry of Transport and Communications
- Vehicle Administration Centre

**Figure 1. SARAC worldwide co-operation.**

**Research Method.** To manage the various research tasks specified for SARAC, three working groups were formed to undertake research on a range of different sub-tasks relevant to the project's objectives (see Table 1).

Specific key issues that needed to be addressed were identified as outlined below.

- The existing rating procedures worldwide needed to be analysed and classified by their entry characteristics, assessment criteria and crash parameters. The outcome of the different rating systems needed to be compared with respect to their correspondence.
- There were a number of problem areas related to the existing retrospective ratings. The critical parameters and possible substitutes needed to be determined and analysed.
- The different ratings should be compared from their application to a common database available within this project and thus comparing the outcome on an uniform, controlled basis to provide a better understanding of the key parameters of real world rating systems.

- There are databases nationwide available from UK, France, Finland, Australia, USA and Germany. These databases needed to be compared in terms of their applicability and suitability for conducting real world crashworthiness ratings in Europe.
- The degree of correspondence between prospective safety ratings published by EuroNCAP and retrospective ratings based on real world data needed to be determined to illustrate the similarities of both systems.

The three working groups commenced their research in 1998 and are due to be finalized mid-2001. This paper summarises the present state of research from the three working groups to date, as outlined below.

**WORKING GROUP 1 - DESCRIPTION OF EXISTING SYSTEMS AND PROBLEM IDENTIFICATION**

The first working group set out to review a number of existing rating systems as a means of understanding the strengths and weaknesses of these systems and to investigate various aspects of the presentation of the results from rating systems generally. A report on the findings to date from the various subtasks follows.

**Table 1.  
SARAC Working Groups and Sub Tasks**

<b>SARAC working groups and sub tasks</b>		
<b>Working Group 1</b>	<b>Working Group 2</b>	<b>Working Group 3</b>
Description of existing rating methods and identification of problem areas	Interrelationship between prospective and retrospective rating systems	Statistical procedures, vehicle aggressivity and compatibility ratings
Sub Tasks	Sub Tasks	Sub Tasks
- Description of existing rating methods	- Correlation of data from real-world accidents and crash tests in Australia and US	- Determine critical parameters and variables
- Status report on development of existing methods	- Correlation of data from real-world accidents and crash tests in Europe	- Sensitivity analysis for key variables
- Comparative analysis of several rating systems	- Additional research to enlarge the scope of prospective tests	- Review of existing aggressivity rating systems
- Problems of defining safety in a rating system.	- Amalgamate real-world accident and crash test ratings	- Develop criteria for an aggressivity rating system
- Vehicle classification and identification	- Appropriate presentation of rating results	- Presentation of crashworthiness and aggressivity ratings
- Driver vs. front occupant ratings		
<b>Final Report</b>		

## Description and Comparison of existing rating methods

Several ratings were identified for use in this project and are shown in Table 2. The description of these systems addressed various aspects of their methodology, variables used and databases available for analysis [4].

**Database population.** In undertaking crashworthiness analyses, most of the existing rating systems are based as police data at a nationwide or State level. Only in Finland [5] and in US [6] the data of insurance companies are used as main bases: in Sweden and Australia the initial police data are matched with insurance claims.

**Safety aspects covered.** Most of the ratings aim to cover the secondary safety aspects. The

predominant rating criterion was the risk of injury and/or severe injury to the drivers of the specific car model when involved in a crash. This risk measurement is appropriate for a crashworthiness rating system. The Folksam [7], Monash [8] and UK [9] Systems not only included injury risk but also severe injury risk to the driver. Minor AIS 1 injuries are of questionable value for rating crashworthiness hence the ratio of minor, serious and fatal injuries overcomes this problem. Only the two US (IIHS and HLDI) systems measure a combination of crash involvement risk and crashworthiness and therefore they are able to indicate some aspects of primary safety. While the Oulu and UK Systems are intended to cover primary safety, too, they are still limited in their exposure entry criterion.

**Table 2.**  
**Used Rating Systems**

<b>Standardized description of existing car safety rating methods</b>				
<b>Publishing Organisation</b>	<b>Car safety aspects covered</b>	<b>General research design</b>	<b>General nature of population at risk (exposure quantity)</b>	<b>Grouping of car models when publishing rating results</b>
<b>Monash University Accident Research Center (MUARC) (Australia)</b>	secondary safety - crashworthiness	retrospective research design	accident involvements of cars	Car models are grouped by eight different "market groups" related to mass, size and cost.
<b>Department of Transport (DETR) (UK)</b>	secondary safety - crashworthiness - aggressivity - primary safety <sup>1)</sup> - involvement in injury accident	retrospective research design (although only two-car accidents are considered data analysis is not based on the matched pairs concept)	accident involvements of cars - two-car accidents - injury accidents	Car models are grouped by four different categories according to size of car.
<b>Folksam Research (Sweden)</b>	secondary safety - crashworthiness	retrospective research design based on the matched pairs concept	accident involvements of cars - two-car accidents - accidents where at least one driver or front seat passenger was injured	Car models are grouped by four different categories according to size of car.
<b>University of Oulu (Finland)</b>	secondary safety - crashworthiness - aggressivity - total safety - primary safety <sup>1)</sup> - involvement in injury accident	retrospective research design based on the matched pairs concept	accident involvements of cars - two-car accidents	Car models are grouped by five different mass categories.
<b>Insurance Institute for Highway Safety (IIHS) (USA)</b>	primary safety - involvement in accident with death to driver	retrospective research design	"vehicle years" of registered vehicles (cars)	Car models are grouped by seven body style categories and within each body style group according to three vehicle size groups. Within each group car models are ranked according to the model-specific relative driver death rate. In addition, each car model is assigned to one of five (ordered) car safety categories.

<sup>1)</sup> Not investigated in SARAC

**Database exposure characteristics.** The databases used in these analyses vary substantially. Only Oulu and Monash have a material damage criteria for entry into the database which is necessary for analysing the risk of injury from an absolute basis. While there is a clear relationship between crash severity (delta-V) and injury severity, in the long term, the injury entry criterion has to be reviewed. In other rating systems as described in Table 2, the entry criterion comprised “at least one minor injury to driver or occupants of the cars involved”. A material damage entry criterion avoids this problem to some degree but may cause problems of comparison between the cars.

A major difference was found in accident configuration. Oulu, UK and Folksam are based on the injury outcomes in two car crashes only involving the specific model cars. Only the Monash, IIHS, HLDI and VW systems collect all accidents with involved model cars. This extended entry criterion allows for the inclusion of “single vehicle accident” to be covered in the database.

Even so, in all these cases, the reference criterion is crash involvement and the analysis of crash involvement systems is not yet possible. Only IIHS and HLDI databases offer the reference criteria “registered cars” or vehicle years of insurance.

**Adjustment factors.** The existing differences in crash exposure, e.g. driver age, mass of other colliding car, have to be adjusted to reflect the factors of injury protection of a specific car model independent of the car fleet environment and specific user characteristics. The adjusted factors are shown

in Table 3 below; these factors and the methods used to make the adjustments still vary considerably.

**Categorizing of car models.** Table 2 also shows that the grouping of the car models caused by the historical development of the ratings and continued by the need of comparison within the rating system both the parameter “size” or “weight” are used and the categories vary from 4 to 8 groups. For car identification, different groupings do not cause a problem as these are mainly defined by manufacturer, model, year and engine capacity. However, for comparison across countries, different groupings do cause problems when comparing relative performance.

### Comparative Analysis of Several Rating Systems

The project group agreed that there would be merit comparing the outcome of rating procedures using the two databases available (the US data from 3 States and the Oulu/Finland database). [10]

Due to the parameter availability in these two databanks, four rating methods and a benchmark “Maximum Data Model” system (which makes maximum use of the crash data available to rate crashworthiness) were calculated for 20 defined vehicle models in US. The result is shown in Table 4 from findings in Cameron et al [10]. Generally the rank order of the cars calculated with use of the different rating methods was similar, but some cars are ranked very differently. The best and the worst rankings seem to be very consistent whereas in the middle the ranking varied sometimes by 7 to 9 positions pushing the cars from the second quarter to the last one and vice versa.

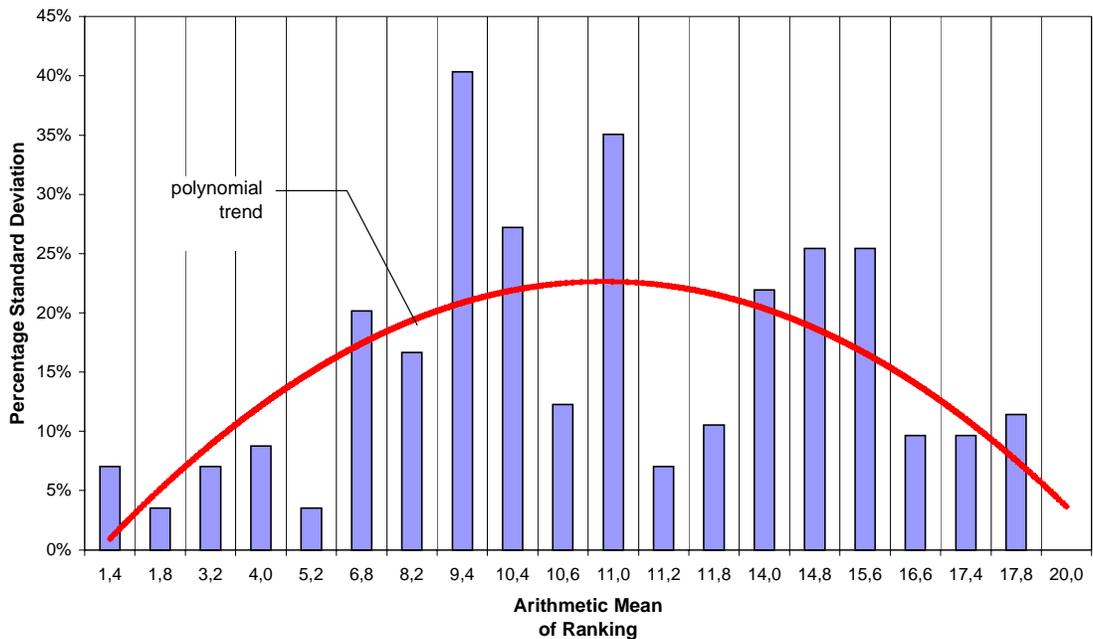
**Table 3.**  
**Rating Systems: Adjustment Factors**

Method	MUARC	DETR	FOLKSAM	UNIVERSITY OF OULU	VW method *
<b>Adjustment factors</b>	<ul style="list-style-type: none"> <li>- Driver sex</li> <li>- Driver age</li> <li>- Speed limit</li> <li>- Number of vehicles involved</li> <li>- State</li> <li>- Year of crash</li> </ul>	<ul style="list-style-type: none"> <li>- Speed limit</li> <li>- Driver sex</li> <li>- Driver age</li> <li>- First point of impact</li> </ul>	<ul style="list-style-type: none"> <li>- Case car mass (also used to adjust for presence of front seat passengers)</li> <li>- Crash year</li> </ul>	<ul style="list-style-type: none"> <li>- Driver age</li> <li>- Driver sex</li> <li>- Speed limit</li> <li>- Driver guilt</li> <li>- Accident type</li> <li>- Injury severity</li> </ul>	<ul style="list-style-type: none"> <li>- Velocity change</li> <li>- Use of seat belt</li> <li>- Angle between vehicles</li> <li>- Type of collision opponent</li> <li>- Velocity of case car</li> <li>- Height of driver</li> <li>- Age of driver</li> </ul>

\*) Ratings method based on non-linear regression analysis)

**Table 4.**  
**Rank Order of Crashworthiness Ratings for each Vehicle Model (US Data)**

IIHS Vehicle ID	3263	2902	3108	256	127	3128	208	223	401	1626	2308	619	209	108	2941	2310	139	255	138	1603
<b>Folksam</b>	3	1	2	6	5	4	8	7	14	13	15	12	11	10	9	19	18	17	16	20
<b>DETR</b>	1	2	3	4	5	7	8	6	9	11	14	10	12	13	15	18	16	19	17	20
<b>MUARC</b>	1	2	4	3	5	10	12	6	8	9	7	11	14	19	16	13	15	17	18	20
<b>MUARC (Newstead)</b>	1	2	3	4	6	5	7	13	8	10	12	11	11	14	16	15	17	18	19	20
<b>MDM*</b>	1	2	4	3	5	8	6	15	13	10	7	12	11	14	18	13	17	16	19	20
<b>Best Rank</b>	1	1	2	3	5	4	6	6	8	9	7	10	11	10	9	13	15	16	16	20
<b>Worst Rank</b>	3	2	4	6	6	10	12	15	14	13	15	12	14	19	18	19	18	19	19	20
<b>Arithmetic Mean of Ranking</b>	1,4	1,8	3,2	4,0	5,2	6,8	8,2	9,4	10,4	10,6	11,0	11,2	11,8	14,0	14,8	15,6	16,6	17,4	17,8	20,0
Standard Deviation (Max. = 9,12)	0,64	0,32	0,64	0,80	0,32	1,84	1,52	3,68	2,48	1,12	3,20	0,64	0,96	2,00	2,32	2,32	0,88	0,88	1,04	0,00
Percentage Standard Deviation (100% = max. deviation = 9,12)	7%	4%	7%	9%	4%	20%	17%	40%	27%	12%	35%	7%	11%	22%	25%	25%	10%	10%	11%	0%



**(FIGURE CORRESPONDING TO TABLE 4)**

(\* MDM = Maximum Data Model)

Thus even if good comparability is offered, the rating systems still seem to be sensitive to the crash entry criterion (all crashes or injury crashes), the crash type (two car or all accidents including single car crashes), and possibly atypical occupant and/or injury combinations. There is still major analysis and interpretation work necessary to understand the interactions better and arrive at consolidated ratings with smaller differences. But as a first step it is encouraging that considerable similarity was apparent

and with continued cooperation, beneficial improvement for all parties across different data entry criteria and adjustment methods seem achievable.

#### **Vehicle Categorization – A Proposed New System**

A clear identification is a prerequisite for every categorization procedure with respect to safety rating. All safety rating systems use the normal description criteria of manufacturer, car make and model, year of registration. Only in the accident material of

MUARC and the Insurance Institute for Highway Safety was the Vehicle Identification Number (VIN) available and used for car identification. Unfortunately, VIN is neither widely available nor used in rating systems which limits the identification of specific safety features and control of extraneous variables.

The way that cars are categorised between systems is also not consistent; a new method for categorising vehicles would also be desirable for rating crashworthiness. [11] The various systems of today use different vehicle parameters such as vehicle length, weight, mass, structure, and car market definitions for classification. The project reviewed current methods of rating vehicle category and showed little consistency among existing systems. These differences limit the comparability across systems. Most ratings reflect if the car's values are better or worse than the group average, and therefore due to the categorization, confusing results may occur.

Vehicle size is a common category in use today. However, some newer vehicles tend to be wider than others common in the size class (eg; Fiat Multipla). Others such as Ford Ka, have a much longer wheelbase for driving comfort in a short vehicle. The Renault Megane is considerably higher than others in

its size category to achieve more leg room. In addition there is increasing trend with SUV etc.

Market category is another popular categorization method used by some systems, such as MUARC. An advantage is that it is relevant for competing vehicles but it is not very well defined. Market categories also vary across countries and cultures. Curb weight as a classification parameter contains problems with the various weight spread of different vehicle models. Some car models have a large difference, for example Mercedes E-class which differ 425kg, Renault Megane 335kg or VW Polo which varies 250kg between lightest and heaviest model. One possibility is to use curb weight from the base model or the most sold model. However base models and most sold models can be difficult to define for different countries and markets. Interior measurement is a fair criterion to classify sizes of models but these data are rather uncommon in national databases.

This subtask set out to develop a new categorization system that could be the basis of generally available parameters, relevant for the different types of vehicles. The proposal shown in Figure 2 includes passenger cars according to the EU group M1. It creates three main groups, i.e. SUV and MPVs, ordinary passenger cars and sports cars. The first classification of vehicle types is defined by a total height greater than 155cm.

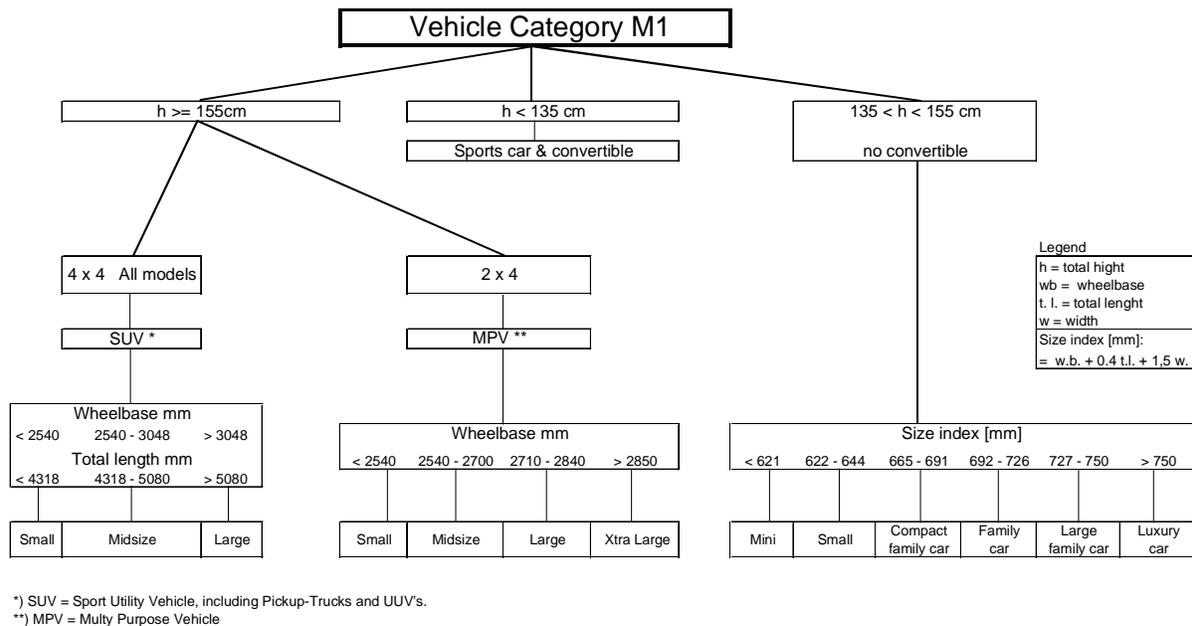


Figure 2. Vehicle Categorization – A Proposed New System [11].

SUVs and MPVs are subdivided according to their wheelbase. Ordinary passenger vehicles are given into a group with total height between 135-155 cm. The formula to divide this group of vehicles into different size classes is:

$$VC = Wb + 0.4tl + 1.5w$$

where, Wb = wheelbase  
tl = total length  
w = width of car (mirror excluded)

Station wagon models are not categorized by this formula. They belong to their corresponding four/five door models, as due to their sometimes much longer length as the basic models the station wagons could be categorized in the wrong size class. Sports cars and convertibles are in the group with a height less than 135cm. This proposed categorization system will be tested and proposed to ISO as the international standard for accident research.

### **Summary of Working Group 1 Activities**

Working Group 1 set out to review a number of existing rating systems as a means of understanding the strengths and weaknesses of these systems and to investigate various aspects of the presentation of the results from rating systems generally. Seven existing systems were critically analysed including the databases available for each of these systems. Exposure and adjustment factors available for control varied considerably across systems, leading to variations in their findings when applied to a common database.

Several problems were identified in the presentation of results and the ability to compare ratings across different systems and databases. The way vehicles are classified and categorised seemed to be a major difficulty when attempting to compare ratings across systems and countries. A new proposed system of vehicle categorisation was developed to address this inconsistency.

### **WORKING GROUP 2 – CRASH TEST AND REAL-WORLD ACCIDENT RATING SYSTEMS**

Working Group 2's responsibility was to examine the degree of similarity between ratings by crash tests and historical crashworthiness systems and other associated issues, as described below.

### **Correlation of data from real-world accidents and crash tests in Australia and US**

The Monash University Accident Research Centre completed two studies of the correlation of the Australian NCAP results with its own crashworthiness ratings, and a third correlation of US NCAP-type test results with real crash data in conjunction with IIHS [10]. This sub-task set out to summarise the findings from those studies, review the implications of measuring injury risk by the relative injury risk measure based on two-car crashes, as used in the European crashworthiness rating systems, and investigate the available European crash databases regarding their suitability for studying the correlation with EuroNCAP results.

Key elements of this report included a review of suitable European real crash databases for use in a correlation analysis of real-world crash data and crash tests in Europe [13] and a review of analysis methods used in the Australian and US studies of relationships between real crash outcomes and crash barrier test results. A short report on the implications of real crash database coverage on study viability was also included. This report will be available later this year through GDV in Munich.

### **Correlation of data from real-world accidents and crash tests in Europe**

The next task in Working Group 2's activities was to undertake a correlational analysis in Europe, similar to those already conducted in Australia and USA. Two European crash databases were selected for the analysis (Police accident reports held by DETR in the UK and LAB in France) and data was obtained covering the crash years of the car models tested in the EuroNCAP program. For the U.K., the full STATS19 data covered the period 1993-1998 and included over 1.4 million crashes involving over 2.4 million traffic units with at least one person who was injured in the crash. Of the 2.4 million traffic units, 1.96 million of these were coded as passenger cars with 921,000 of these involved in a crash between two passenger vehicles only. The French GNP crash data covered the period 1993-1998 also and contained information on 660,000 passenger cars involved in crashes where at least one person was injured. Of these vehicles, 373,000 were involved in a crash between two passenger vehicles only. These data were used for estimation of real crash injury measures. Table 5 and 6 show the various vehicle makes and models of the vehicles possible from the databases provided and from EuroNCAP crash tests included in these analyses.

**Table 5.**  
**Correlation of EuroNCAP tested vehicles with crash data from the UK**

Fiat - Punto 55S	Nissan – Primera 1.6GX	Toyota – Corolla 1.3 Sportif (LHD)
Ford - Fiesta 1.25LX 16V	Peugeot - 406 1.8LX	Volkswagen – Golf 1.4 (LHD)
Renault - Clio 1.2RL	Renault – Laguna 2.0RT	Vauxhall Omega 2.2GI/GLS (LHD)
Rover – 100	Rover - 620 Si	Vauxhall - Astra 1.6i Envoy (RHD)
Vauxhall – Corsa 1.2LS	Saab - 900 2.0I	Ford - Escort 1.6 LX
Volkswagen – Polo 1.4L	Vauxhall – Vectra 1.8LS	Nissan - Almera 1.4GX
Audi - A4 1.8	Volkswagen – Passat 1.6L (LHD)	Peugeot - 806 2.0 (LHD)
BMW - 316 i	Fiat - Brava 1.4S	Volkswagen – Sharan TDI (LHD)
Citroen - Xantia 1.8i Dimension	Honda - Civic 1.4i	Ford – Ka
Ford - Mondeo 1.8LX	Peugeot - 306 1.6GLX	
Mercedes - C180 Classic	Renault – Megane 1.6RT (LHD)	

**Table 6.**  
**Correlation of EuroNCAP tested vehicles with crash data from France**

Citroen - Xantia 1.8i Dimension	Opel - Corsa 1.2LS	Renault - Clio 1.2RL
Fiat - Punto 55S	Opel - Vectra 1.8LS	Renault Espace 2.0RTE (LHD)
Ford - Fiesta 1.25LX 16V	Opel – Astra 1.6i Envoy (RHD)	Rover - 100
Ford - Escort 1.6 LX	Peugeot - 406 1.8LX	Toyota – Corolla 1.3 Sportif (LHD)
Ford - Mondeo 1.8LX	Peugeot - 306 1.6GLX	Volkswagen - Polo 1.4L
Honda - Civic 1.4I	Renault - Laguna 2.0RT	Volkswagen - Golf 1.4 (LHD)
Nissan Micra 1.0L	Renault - Megane 1.6RT (LHD)	Volkswagen - Passat 1.6L (LHD)

Comparison of EuroNCAP measures and real crash outcomes in Europe will be based on the methods established in the Australia and US correlation studies. Analysis will centre on comparing the broad consistency of EuroNCAP ratings and real crash outcomes through descriptive statistical techniques such as correlation analysis. More in depth analysis will then be carried out to identify the specific EuroNCAP measures or combinations of measures that relate most closely to real crash outcomes using techniques such as logistic regression. All real crash types will be considered in the study along with real crashes involving frontal and side impacts, crash types examined specifically in the EuroNCAP program

### **Summary of Working Group 2 Activities**

Working Group 2’s overall activities are focussed on comparisons between prospective (crash test) results and retrospective (real-world crash data) ratings of vehicle crashworthiness. In addition, several aspects related to the presentation of these results are being considered.

Correlations were found between the two sets of ratings using crash tests and ratings available in Australia and the USA and the same methods are being used to examine correlations with EuroNCAP. The findings to date offer some re-assurance that these two rating methods have a degree of consistency and hence, useful for providing consumers with safety information on new and

second-hand vehicles. To avert the possibility of confusion from differences in the relative ranking of a particular vehicle in each system, a number of options are being considered for presenting a single (combined) crashworthiness rating.

### **WORKING GROUP 3 - AGGRESSIVITY AND ITS RELATIONSHIP TO CRASHWORTHINESS**

The third Working Group set out to examine the issue of vehicle aggressivity, methods of rating how aggressive a vehicle is to others on the road and its relationship with its crashworthiness. Members of this working group undertook a number of subtasks and these are described. Possibilities for an improved international comparison of safety rating results based on real accidents and necessary future steps are also discussed

#### **Determine critical parameters and variables**

The aim of this subtask was to present a review of possible influential parameters and variables affecting aggressivity of cars in two car crashes. Aggressivity and compatibility are, however, more complex than crashworthiness, because accident involvement risk, the design features of the focus car model and the injury outcomes are necessarily combined with those of the opponent vehicle. Thirty-four different aggressivity exposure variables were identified and classified into four different categories: crash, vehicle, occupant and environment variables according their influences on accidents.

The identified variables were also categorised based on their importance for the later sensitivity analysis. Unfortunately there are many variables and exposures that are not recorded systematically in most crash databases. It seemed, however, that vehicle mass, age and sex of the drivers, speed zone, injury severity and accident type would be the most relevant variables for the sensitivity analysis of aggressivity. Also mass-ratio, crash severity and crash location could be regarded as essential parameters. A report has been prepared examining the critical parameters and variables for aggressivity ratings and analyses their advantages and drawbacks.

#### **Sensitivity analysis for key variables**

The sensitivity of the key parameters of aggressivity was investigated applying logistic regression on VALT/Oulu and IIHS data sets. The logistic regression analysis was used to calculate variable estimates, their confidence limits, statistical significance and odds ratios. The aggressivity rating of vehicle models was calculated with method used at

MUARC. The sensitivity of the variables was interpreted analysing statistical significance level of the variable, odds ratio value and rating/ranking of vehicle models when a variable was excluded from the entire model.

According to the odds ratio, the most sensitive variables of aggressivity are age and sex of the other vehicle driver, speed limit at the crash site, and damage severity of the other vehicle for injury risk. For injury severity the most sensitive variables are age and sex of the other vehicle driver, vehicle damage of the other vehicle, speed limit at the crash site and crash location when the vehicle damage variable was excluded from the analysis. All these variables were also significant predictors of injury risk and injury severity at the 95% significance level in each risk calculation.

An aggressivity rating was computed with the entire model and all sub-models, which were calculated excluding one variable at a time from the analysis. The age and sex of the other vehicle driver, weight of the subject vehicle, crash year and injury severity variables caused statistically significant differences in the rating/ranking of the vehicle models in the VALT/Oulu data set. On the other hand, none of the investigated variables caused significant differences in rating/ranking of the vehicle models in the IIHS data set.

The differences between these results may be caused by different selection criteria of vehicle models into the data sets (VALT/Oulu >200 crashes, IIHS >2000 crashes). Furthermore, the more crashes a vehicle model is involved, the better estimates for the vehicle models the logistic regression method gives. If there are equally strong predictors of injury risk or injury severity compared to the excluded variable, the rating/ranking of the vehicle models might not be changed significantly. In addition, the existence of interaction effects may stabilise the model and therefore reduce the effects that a variable has on rating/ranking of the vehicle models.

#### **Review of existing aggressivity rating systems**

A review of existing, published, aggressivity rating systems was undertaken as a subtask. Four proposed methods of rating aggressivity were critically analysed during this review, namely those proposed by Jeremy Boughton of TRL in the UK, Cameron and his colleagues in Australia, Hollowell and Gabler in the USA, and Ernvall at the University of Oulu in Finland. Les and others also devised a fifth (new) system during this review. These systems compared the risk of injury of drivers in two car crashes as a measure of aggressivity of the vehicles involved. The

degree of exposure control and the entry level of injury differed across the four systems which influenced the final results.

A report has been established which presents an analysis and review of existing aggressivity rating systems and is expected to be available soon.

**Develop criteria for an aggressivity rating system**

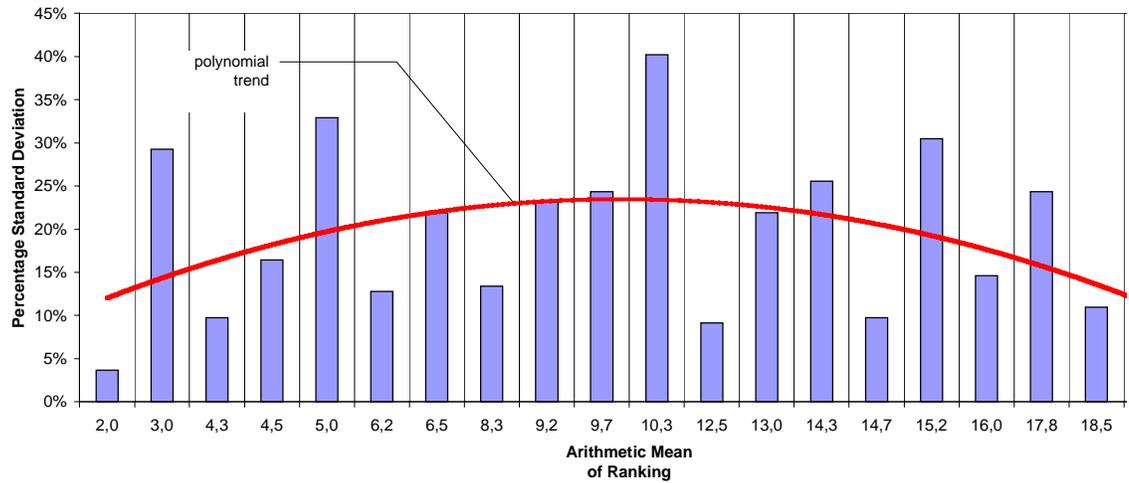
This subtask set out to compare the findings of each of the existing systems using a common database. The crash data file from three states in the USA noted earlier was used for the comparison of aggressivity rating methods. The rating criteria used by TRL,

Oulu and MUARC were applied in their raw form as well as adjusted to control for crash exposure differences. In addition, three new aggressivity rating criteria developed by MUARC as part of the SARAC project were compared in unadjusted and adjusted form. Comparisons were presented graphically and by rank correlation coefficients [13]

A comparison of the adjusted ratings for the 20 most commonly crashing vehicle models is shown in Table 7 below.

**Table 7.**  
**Rank Order of Aggressivity Ratings for each Vehicle Model (US Data)**

IIHS Vehicle ID	241	131	1219	245	613	946	3236	630	3823	522	3817	950	226	3077	3046	3259	107	3006	3267	
Aggressivity ratings low ranking values signify low injuries in opponent car	Modified Folksam	2	1	5	4	3	6	8	9	11	7	10	13	12	17	14	16	15	20	19
	TRL	2	5	4	1	8	3	11	6	12	10	7	13	9	16	14	18	15	20	17
	MUARC 1	1	9	2	5	11	8	6	7	4	16	3	10	13	12	14	19	15	18	17
	MUARC 2	3	1	5	4	2	7	6	9	10	8	11	13	12	17	14	16	15	20	19
	MUARC (Newstead)	2	1	5	7	3	6	4	9	10	8	14	13	16	12	17	11	18	15	20
	Maximum Data Model	2	1	5	6	3	7	4	10	8	9	17	13	16	12	15	11	18	14	19
	Worst Rank	3	9	5	7	11	8	11	10	12	16	17	13	16	17	17	19	18	20	20
	Best Rank	1	1	2	1	2	3	4	6	4	7	3	10	9	12	14	11	15	14	17
	Arithmetic Mean of Ranking	2,0	3,0	4,3	4,5	5,0	6,2	6,5	8,3	9,2	9,7	10,3	12,5	13,0	14,3	14,7	15,2	16,0	17,8	18,5
	Standard Deviation (Max. = 9,12)	0,33	2,67	0,89	1,50	3,00	1,17	2,00	1,22	2,11	2,22	3,67	0,83	2,00	2,33	0,89	2,78	1,33	2,22	1,00
Percentage Standard Deviation (100% = max. tolerance = 9,12)	4%	29%	10%	16%	33%	13%	22%	13%	23%	24%	40%	9%	22%	26%	10%	30%	15%	24%	11%	



(Figure corresponding to Table 7)

The University of Oulu is completing a subsequent analysis using the Finnish VALT/Oulu database to further extend this work. A report on the research is currently being prepared and will be available through GDV by the end of this year.

### **Summary of Working Group 3 Activities**

Working Group 3 set out to examine the issue of vehicle aggressivity, methods of rating how aggressive a vehicle is to others on the road and its relationship with its crashworthiness. Database variables available for assessing vehicle aggressivity were identified and prioritised in terms of their usefulness. A sensitivity analysis was also performed to indicate their actual influence in aggressivity ratings.

A review of existing aggressivity rating systems was also undertaken and the candidates were analysed in terms of their strengths and weaknesses. These and other systems were then applied to a common database to illustrate any differences and improve knowledge of requirements for a high quality system. Presentation methods of aggressivity ratings are being reviewed along with how they could be published in conjunction with crashworthiness ratings.

### **DISCUSSION**

Safety rating systems for passenger cars based on information from real-world accidents have been known for many years. In several countries, insurance institutes, universities or government offices collect and process accident data from police and/or insurance files and publish the results at regular intervals. Each of these systems has been developed and refined over time on the basis of available datasets and of certain assumptions regarding the choice of vehicle type safety indicators as well as the calculation procedures and presentation schemes.

Considering this background it is obvious that there are considerable and even fundamental differences between existing rating systems. On the other hand, there is a growing public demand for information on passenger car crashworthiness and it has been recognised that rating systems based on real-world accidents may provide such information as a complement to results from standardised crash tests.

The main objective of the CEA/EC research project and the activities of its SARAC committee is therefore to investigate the potential of such rating systems for providing valid safety information and to indicate the possibilities of arriving at improved crashworthiness assessment procedures.

In a preliminary stage of this programme [1], five workshops involving experts from all relevant sectors and institutions were conducted between 1995 and 1998. They provided a thorough knowledge of all problems associated with accident investigation and data processing and also resulted in a table of exposure items grouped according to their priorities.

The CEA/EC research project commenced in 1999; the main areas of work are discussed below.

- The first section consisted of a description and analysis of seven existing rating systems. It has become evident that the systems exhibit considerable differences in their main elements, such as safety aspects, accident data, safety indicators and their adjustment as well as presentation by vehicle categories. In order to demonstrate the consequences of this situation, the material from two databases, covering 20 vehicle types, was fed into five rating systems. A first evaluation shows that best and worst rankings seem to be consistent whereas there are considerable differences in the rating of vehicle types in the middle range.
- The problem of vehicle classification and identification has been addressed in a separate sub-task. A proposal has been developed which would classify vehicles by categories, such as passenger cars, SUVs and MPVs and by dimensions such as wheelbase, and exterior dimensions. It remains to be seen whether this model reflects actual market categories as they are perceived by the consumer. In addition, a survey has been conducted regarding the role of the Vehicle Identification Number (VIN) as a means for vehicle description.
- The main objective of the second section is the correlation between the results of standardised frontal and side impact tests and crashworthiness assessments based on real-world accidents. This exercise, which is highly significant from the point of view of consumer information policy, has been carried out in several stages, correlating crash test and accident data in Australia and the United States in earlier pre-SARAC studies, and following similar procedures in Europe. It must be borne in mind that crash tests cover clearly defined impact configurations whereas real-world accidents occur in a multitude of conditions; in addition, the different ways of accident coverage, e.g. all injury crashes or two-car injury crashes, as well as the data processing methods used by the respective rating systems, must be taken into account. In general, a degree of correlation has been observed to date but it

seems that more work has to be done to arrive at satisfactory conclusions.

- The principal aspect of the third section is aggressivity and its relationship to crashworthiness. Five existing aggressivity rating systems have been reviewed and analysed in a report which can be considered as a complement to the description and analysis of crashworthiness rating systems. Using two databases a detailed analysis has been carried out to determine critical parameters and variables which affect aggressivity, departing from the table of exposure item priorities prepared in the initial workshops. This resulted in a new classification of variables, parameters and exposures; each of these can be assigned to one specific area: The crash, the vehicle, the occupant and the environment. In addition, a sensitivity analysis of the key parameters has been performed using two databases which cover two-car crashes. Age and sex of the driver of the other vehicle, mass of the subject vehicle and damage to the other vehicle have been determined as the most sensitive variables and also as significant predictors of injury. Present aggressivity rating systems address only car occupants; it would be interesting to consider also unprotected road users, such as pedestrians and cyclists, provided that suitable accident data are available.
- Improved consumer information is one of the basic objectives of passenger car safety ratings. The project therefore is trying to identify ways and means for presenting rating results to the public in an effective manner. The first step of

this exercise consisted in a survey of existing presentation schemes, both for crash test and for accident crashworthiness ratings. Further work will be necessary to find presentations which would indicate simple scale ratings and at the same time provide sufficient information for the consumer to understand the rating procedures. This task is even more difficult when it comes to presenting ratings from different safety areas for the same type of vehicle, such as crash test and real-world accident ratings or crashworthiness and aggressivity ratings.

In summary the SARAC project provides useful and detailed information about safety rating methods based on real-world accidents. However, the fact remains that there are differences among existing rating systems as to their databases and calculation procedures. A particular difficulty from the consumer's view is the lack of an universally accepted definition of safety as described by injury risk and injury severity.

If safety ratings based on real-world accidents are to be put on an equal basis with ratings based on standardised crash tests it would be advisable to proceed towards harmonisation of existing methods and, where necessary, to improve statistical procedures. Databases and calculation methods should be reviewed to arrive at consistent and comparable results. Further research work will be necessary to explore the areas where this is possible. The structures established by the CEA/EC project and the international cooperation and teamwork by SARAC members would constitute a firm basis for this work.

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## APPENDIX A

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## APPENDIX B

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