AN NCAP STAR RATING SYSTEM FOR OLDER OCCUPANTS

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ABSTRACT

The objective of the paper was to apply to the NCAP star rating system injury risk functions that are more representative of the injury tolerance of older occupants. The NASS 1998-2008 data for front outboard occupants in NCAP like frontal crashes protected by air bags and safety belts was analyzed to determine injury risks by body region and occupant age groupings. The injury rates for NCAP like crashes were calculated for each applicable body region. Alternative injury risk functions were applied to 302 NCAP tests of vehicles model year 1988-2006. NCAP injury rates were calculated and compared with NASS data. The comparison was used to select injury risk functions to be applied to 2011 NCAP tests. Selected risk functions from the literature that produced injury rates in NCAP tests like those in NCAP like crashes were substituted for NCAP 2011 chest and neck injury risk functions. When applied to the 2011 NCAP tests there was a general downward shift in the star ratings awarded to the driver. However, the number of passengers with 5 star ratings more than doubled. For both drivers and passengers there were vehicles that advanced from 4 stars to 5 stars. The application of this alternative rating system would produce added incentives for safety designs that more correctly prioritize the reduction of injuries most harmful to older occupants.

INTRODUCTION

In the United States, the number of people of 65 years of age and older is expected to rise from 40.2 million in 2010 to 72.1 million in 2030, an increase of approximately 80 percent [US Census Bureau 2008]. Globally, the elderly population is increasing due to general declines in both fertility and mortality [United Nations 2009].

When exposed to frontal crashes, the injury risks for the elderly population differ from their younger counterparts in terms of both tolerance to injury and body region most susceptible to life threatening injuries. Numerous studies have shown that the chest region is much more vulnerable to life threatening injuries for the older population [Augenstein 2005, Kent 2005, Ridella 2012]. Age dependent injury tolerances for the chest have been proposed by several researchers [Zhou 1996, Laituri 2005, Prasad 2010]. The anticipated increase in the older population and their lower tolerance to crash injuries justifies the requirement for a vehicle rating system that is relevant to the safety needs of the elderly. The availability of accident data, crash test data and injury risk functions for elderly occupants permits the development of a methodology for a vehicle rating system tailored to elderly occupants.

The application of the Combined Probability of Injury index to NHTSA's 2011 NCAP program has significant merit from the standpoint of advancing the design and performance of vehicle safety systems. However, the index is based on the risks of injury to younger occupants. This paper applies risks that are more appropriate for older occupants to the recent NCAP frontal crash tests to determine how the star ratings would change. The objective is to provide a methodology for producing alternative NCAP ratings that could be used by older consumers. To develop such an alternative, it is necessary to answer research questions regarding how to develop and apply rating factors that prioritize the reduction of injuries suffered by older occupants so that the body regions most likely to be injured receive appropriate priority in the rating system. A related question seeks to determine how the star ratings of existing NCAP test vehicles would change when a rating system more appropriate for older occupants is applied to the test data.

Beginning with Model Year 2011, NHTSA introduced a wide variety of changes to the nature and structure of the NCAP rating program [Federal Register 2008]. The more significant changes, as they apply to the portion of the program involving frontal crash protection, included:

- Substituted a Hybrid III 5th percentile female dummy for the 50% male dummy in the front right seating position;
- Expanded the body regions monitored to include the neck;
- Substituted chest deflection in place of chest acceleration to assess chest injury risk;
- Substituted a 15 ms HIC in place of the 36 ms HIC to assess head injury risk;
- Selected injury risk functions that shifted the emphasis from AIS 4+ injury risk to AIS 3+ injury risk in the case of the head, neck and chest;
- Added AIS 2+ injury risk in the case of the knee-thigh-hip (KTH) complex; and
- Created and applied a combined injury risk (CPI) metric to calculate overall injury risk to the above-mentioned four body regions.

The combined injury risk (CPI) metric was defined as follows:

CPI= 1- (1-Phead)(1-Pneck)(1-Pchest)(1-Pkth)

Where:

Phead= Prob. of an AIS3+ Head Injury based on HIC

Pneck= Prob. of an AIS 3+ Neck Injury based on Nij or Axial Force

Pchest= Prob. of an AIS3+ Chest Injury based on Chest Deflection

Pkth= Prob. of an AIS2+ Knee-Thigh-Hip Injury based on Femur Loads

To support the changes, a new set of injury risk functions was defined for use in translating the dummy responses measured in the test into injury risk. These injury risk functions can be expected to influence both the restraint hardware and frontal structure in vehicles subject to test under the new rules.

The success of the New NCAP process hinges on the fidelity of the injury risk functions in predicting today's accident environment with the current demographics and the projected demographics ten to twenty years in the future. If the injury risk functions utilized in the rating scheme prioritize incorrectly, the resulting vehicles may not be responsive to the real-world safety needs of today or the future even for the highest rated vehicles.

The chest risk function for the New NCAP appears on page 40026 of the 2008 Federal Register Notice. When compared to age related risk curves developed by Laituri, the New NCAP curve corresponds to a 35 year old male [Laituri 2005].

Two examinations are necessary when considering the safety needs of older vehicle occupants. First, are the risk functions used for each body region representative of the injury tolerance of older occupants? Second, do the risk functions, when applied to the CPI and the resulting star rating, prioritize the body regions so as to optimize the restraint systems for older individuals? A purpose of this paper is to examine these two requirements in conjunction with the development of a rating system for older occupants. The suitability of an older occupant rating system for the NCAP test severity, its test procedures and the crash dummies employed are beyond the scope of this analysis. Earlier papers have indicated that a lower severity test would encourage better safety systems for older occupants [Digges 2007]. However, since test data at NCAP severity is available, the rating system will be applied to the 56 k/hr crash test data.

METHODOLOGY AND DATA SOURCES

In the sections to follow, the NASS data restricted to NCAP like crashes was used to determine the injury rates for each applicable body region and age grouping. Alternative injury risk functions from the literature were applied to 302 NCAP tests of vehicles model year 1988-2006. The resulting injury rates for the 302 NCAP vehicles were calculated and compared with the injury rates for NCAP like crashes in NASS. The comparison were used to select injury risk functions to be applied to 2011 NCAP tests. The selected risk functions from the literature were substituted for NCAP 2011 chest and neck injury risk functions and the changes in star ratings and injury priorities were determined. The approach was based on a research project conducted by D.J. Dalmotas Consulting, Inc. [Dalmotas 2011].

The 1988-2008 NASS data were searched for airbag equipped passenger vehicles that were involved in frontal collisions where at least one front outboard-seated adult occupant was restrained with a 3-point belt system. The study included impacts where the primary damage involved either the front of the vehicle or the primary damage involved the front left or right side of the vehicle forward of the passenger compartment and the direction of force was between 10 o'clock and 2 o'clock. Secondary impacts were permitted, but only if the damage extent number associated with the secondary side impact was less than CDC extent 3, indicating negligible interior compartment damage [SAE J224]. Rollovers were excluded.

The occupant sample was restricted to belted drivers and belted right front passengers who were seated in a position equipped with an airbag. Occupants restrained by a conventional, manual 3-point belt were included in the sample. Automatic seat belt systems, including door-mounted 3-point belt systems were excluded. As a minimum, the gender, age, and NASS MAIS rating had to be known.

For occupants with an MAIS rating between 0 and 2, the associated NASS collision weighting factor had to be less than 2,500. In the case of occupants with MAIS $\geq$ 3, the associated NASS collision weighting factor had to be less than 200. This was done to minimize distortions in the MAIS $\geq$ 3 injury frequencies which occur if filtering is confined only to collisions with very elevated NASS collision weights.

The above-mentioned selection criteria resulted in a frontal sample consisting of 19,907 front outboard occupants representing, when weighted, 6,109,236 occupants. The composition of the sample, in terms of vehicle damage assignments and Delta-V reporting are given in Table 1. Approximately 30% of the sample in Table 1 has unknown crash severity (delta-V).

Table 1.
Composition of Weighted and Unweighted NASS Belted Occupant Samples as a Function of Vehicle Damage

Primary Damage			Total Sample	
GAD	**SHA**	**PDOF**	**Weighted**	**Raw**
F	**C, D, L,R,Y,Z**	**Any**	5,684,747	18,746
L	**F**	**10, 02**	166,601	447
		11, 12, 01	73,664	212
R	**F**	**10, 02**	119,640	311
		11, 12, 01	64,583	191
All	**All**	**All**	6,109,236	19,907

The GAD in Table 1 is the direction of the General Area of Damage – Front, Left and Right. The SHA is the Specific Horizontal Area of the damage. The PDOF is the clock direction of the impact, as determined from the damage. These damage specifications are contained in the Collision Damage Classification (CDC) as defined in a standard from the Society of Automotive Engineers [SAE J224]. The six SHA designations for a frontal (F) GAD allow all crashes with frontal damage to be included in this classification. For the GAD left (L) and right (R), only damage to the front fender at the PDOF clock directions shown in the Table are included. These populations are considered frontal crashes.

The composition of the weighted occupant sample as a function of the occupant's "NCAP classification" and MAIS is depicted in Table 2. For the purposes of classifying occupants in the present study, an occupant was classified to have sustained an "NCAP" injury if he or she sustained one of the following:

- A head or facial injury rated as AIS 3+
- A neck or spine (any) injury rated as AIS 3+
- A chest injury rated as AIS 3+ or
- A lower extremity injury to the knee-thigh-hip complex rated as AIS 2+.

Of the 6,109,236 individual occupants represented in the weighted frontal sample, 109,523 of the occupants sustained at least one of the above-mentioned NCAP related injuries, yielding an overall occupant injury rate of 1.793% across all severities, independent of whether or not the Delta-V for the occupied vehicle was reported. Among occupants in the frontal sample rated as MAIS 4+, the percentage who sustained at least one NCAP injury was 97.5%. The only individuals excluded were those who sustained isolated injuries to the abdomen at the AIS 4+ level. In the case of occupants in the frontal sample rated as MAIS 3+, the percentage who sustained at least one NCAP related injury was reduced to 63.9%. The excluded occupants took the form of individuals whose AIS 3+ injuries were confined to the abdomen, to the upper extremities and to the lower extremities below the knee. The distribution of the individual injuries represented in frontal sample as a function of body region injured and the associated AIS severity level is provided in Table 3.

In Table 3, the 3+ injuries include AIS 3, 4, 5, and 6. These AIS classifications rank injuries with increasing severity from 3 (serious) to 6 (fatal). The AIS 7 classification specifies injuries with the extent unknown. AIS 7 injuries were not included in the 1&2 or 3+ categories but are included in the totals.

Table 2.
Composition of Weighted NASS Belted Occupant Sample as a Function of NCAP Classification and Maximum AIS Level

Injury Severity	Delta-V Unknown	Delta-V Known	% with NCAP Related Injuries
MAIS 0	965,091	2,010,176	0.00%
MAIS 1	650,174	2,104,713	0.00%
MAIS 2	58,563	250,364	19.40%
MAIS 3	16,433	39,895	63.90%
MAIS 4+	5,485	8,341	97.50%
All	1,695,747	4,413,489	1.79%

The distribution of all of the individual injuries in the "NCAP" occupant subset of the frontal occupants as a function of body region injured and associated AIS level is summarized in Table 4. In the Table AIS 7 injuries are included only in the "All" column.

The subset of the injuries in Table 4 which are NCAP-related are described in Table 5. Collectively we can see that the 109,523 (1.79% in Table 2) individuals designated as NCAP occupants in the weighted frontal subset sustained a total of 747,952 individual injuries, 173,024 of these being NCAP-related injuries.

Table 3.
Distribution of Individual Injuries Sustained by Occupants in the Frontal Sample as a Function of Body Region Injured and AIS Severity Level

Body Region	AIS 1&2	AIS 3+	All
Abdomen	409,422	6,970	421,263
Back	372,502	2,571	375,072
Chest	1,071,751	30,018	1,103,893
Face	1,203,236	1,744	1,205,031
Head	346,866	25,609	375,364
L Ext	2,037,155	46,628	2,084,322
Neck	767,939	4,552	772,855
U Ext	2,475,157	25,060	2,500,858
Unknown	35,414	41	35,542
Whole Body	1,291	0	1,291
All	8,720,733	143,193	8,875,491

Table 4.
Distribution of Individual Injuries Sustained by "NCAP" Occupants in the Frontal Sample as a Function of Body Region Injured and AIS Severity Level

Body Region	AIS 1&2	AIS 3+	All
Abdomen	35,529	4,866	40,497
Back	20,459	2,571	23,029
Chest	59,611	30,018	89,905
Face	68,935	1,744	70,679
Head	24,654	25,609	50,352
L Ext	268,867	38,652	307,519
Neck	21,183	4,552	25,909
U Ext	129,471	9,608	139,079
Unknown	874	41	915
Whole Body	68	0	68
All	629,651	117,661	747,952

Table 5.
Distribution of Individual "NCAP" Injuries Sustained by "NCAP" Occupants in the Frontal Sample as a Function of Body Region Injured and AIS Severity Level

Body Region	AIS 2	AIS 3	AIS 4+	All
Chest	0	18,645	11,373	30,018
Head-Face	0	15,522	11,832	27,354
KTH	78,602	29,517	411	108,530
Neck-Spine	0	5,938	1,184	7,122
All	78,602	69,623	24,800	173,024

In order to compare the priorities for protecting different body regions as related to occupant age, Table 6 was developed. The predominance of head and chest injuries is reflected in the distribution of individual AIS 4+ injuries as a function of the body region in the frontal occupant sample. Table 6 displays the relative ranking of the head and chest as related to the age of the occupant. Among younger occupants, those in the 15 – 43 years bracket, AIS 4+ head injuries can be seen to clearly predominate. In the case of the 44+ aged occupants, AIS 4+ chest injuries can be seen to predominate. The percentage of AIS 4+ injuries involving the neck-spine region among all three age groups was low, of the order of 4%.

Table 6.
Distribution of Individual AIS 4+ Injuries in Frontal Sample as a Function of NCAP Body Region and Age of Occupant

Occ. Age	Chest	Head-Face	KTH	Neck-Spine
15-43 Yrs	29.8%	55.8%	1.9%	4.2%
44-64 Yrs	**51.5%**	31.9%	1.4%	4.6%
65-97 Yrs	**51.2%**	37.1%	0.7%	4.1%
All	41.7%	43.4%	1.5%	4.3%

NASS DATA RESULTS

The objective of this analysis was to develop NASS data based injury rates by body regions for NCAP related injuries. The injury rates can be used to guide priorities for reducing injuries by body region and age groupings. Age groups and body regions with the higher injury rates suggest a higher priority for mitigation.

In order to assess the injury rates in field collisions at crash severities represented by the NCAP 56 km/h full frontal rigid barrier test, the NCAP injury data as described in Table 5 was used. Lower and upper bound injury rate estimates were computed from the NASS data using the Delta-V interval 49-64 km/h to provide the lower bound estimate and the Delta-V interval 56-71 km/h to provide the upper bound estimate. Table 7 shows the results. The lower bound injury rate estimate corresponds to 16.7%, while the upper bound estimate corresponds to 25.1%. A mid-point estimate of 20.9% was also listed

Table 7.
Injury Rate by Body Region: Any NCAP Injury / Bounded Estimates

	Field Data (NASS)		
Severity	49-64 km/h	56-71 km/h	M1d-point
Body Region	Lower Bound	Upper Bound	Mid-Bound
Neck-Spine	0.7%	0.7%	0.7%
Head-Face	2.4%	4.0%	3.2%
Chest	7.7%	13.6%	10.6%
KTH	11.3%	16.7%	14.0%
NCAP (Any)	16.7%	25.1%	20.9%

Table 8.
NCAP Injury Rates, All Crash Severities, as a Function of Occupant Age

Occupant Age Groups	Head-Face	Neck-Spine	Chest	KTH
	AIS 3+	AIS 3+	AIS 3+	AIS 2+
	MALE			
15-43 Yrs	0.15%	0.06%	0.23%	1.43%
44-64 Yrs	0.25%	0.12%	0.54%	1.51%
65-97 Yrs	0.33%	0.19%	1.09%	1.91%
All	0.19%	0.08%	0.37%	1.49%
	FEMALE			
15-43 Yrs	0.10%	0.03%	0.18%	1.27%
44-64 Yrs	0.33%	0.22%	0.64%	1.69%
65-97 Yrs	0.28%	0.38%	0.84%	1.44%
All	0.17%	0.10%	0.34%	1.38%

The variation in the NCAP body region injury rate for all crash severities as a function of occupant age is shown in Table 8. The greatest change is the increase in chest injury risk for the age 65+ male and female occupants – up by a factor greater than four when compared to the 15-43 age group. For the 65+ age groups of males and females, the AIS 3+ chest injury rate is at least three times the magnitude of the AIS 3+ head injury rates. The chest injury rates for 65+ men are at least 5 times higher than their neck injury rates. However, for 65+ women, their AIS 3+ chest injury rate exceeds the AIS 3+ neck injury rate by a factor greater than 2. These results suggest the need to increase the priority of protecting older occupants from chest injuries.

The change in chest injury risk with crash severity for the 65-97 year old group is displayed in Figure 1. Both weighted and unweighted NASS data are displayed in the Figure 1. The data was smoothed using an 11 point moving average. Both weighted and unweighted data show a sharp increase in injury risk at crash severities greater than 48kph. Figure 2 shows data similar to Figure 1 but for the population age 15 to 43. This is the population that is best represented by NCAP injury risk functions.

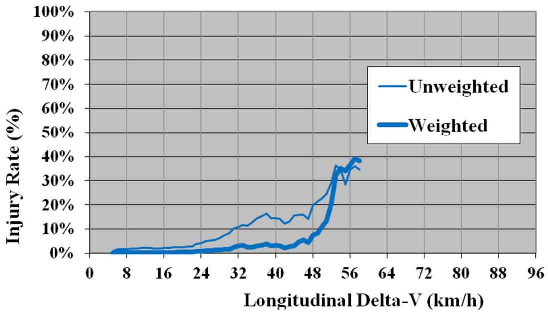

*Figure 1***.** Chest AIS >= 3 injury rate as a function of longitudinal delta-v front outboard occupants of light-duty passenger vehicles adults 65+ yrs / NASS: 1988-2008.

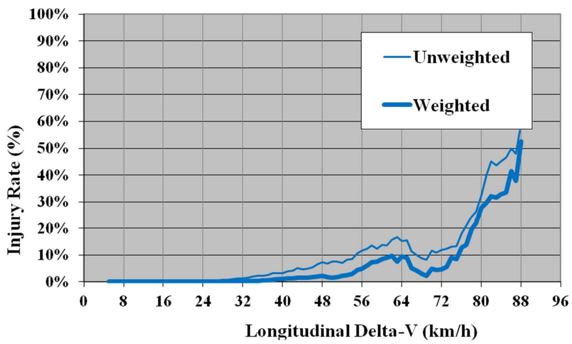

Figure 2. Chest AIS >= 3 injury rate as a function of longitudinal delta-v front outboard occupants of light-duty passenger vehicles adults 15 - 43 yrs NASS: 1988-2008**.**

ALTERNATIVE RISK FUNCTIONS

In selecting risk functions to be used in a rating system for older occupants, the relative magnitude of the injury rates presented in Tables 7 and 8 need to be used for guidance. Table 7 shows that, for the older population, the chest has the largest increase in injury rate. Consequently, chest injury risk curves that are representative of the older population should be employed.

In the case of the chest, NHTSA elected to employ an injury risk curve normalized to a 35 year-old occupant on the basis that this corresponds to the mean age of the U.S. driving population. As shown in Table 8 and Figures 1 and 2, the risk of chest injury varies greatly as a function of age. The injury rate of belted male and female occupants between 44 and 64 years of age is greater than twice that of occupants between 15 and 43 years of age. For the oldest segment of the population (65+) the increased risk is greater than 4. Of the chest injury risk curves already defined in the published literature, the "older male" proposed by Prasad et al. [2004, 2010] was selected to represent the older population with increased chest injury risk. Figure 3 displays the age related chest injury risk curves proposed by Prasad. [Prasad 2010]. The figure also shows the risk curve used by the 2011 NCAP rating system [Prasad 2010].

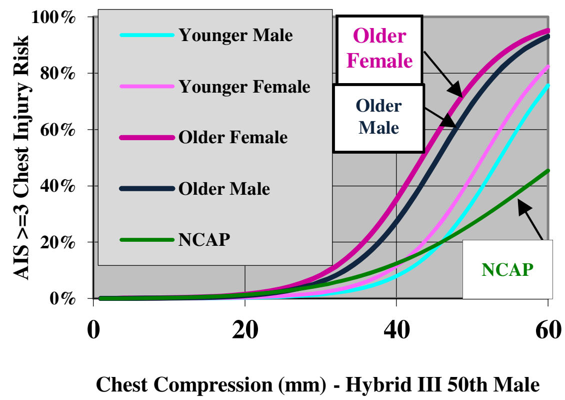

*Figure 3***.** Alternative chest deflection injury risk curves for 50% male Hybrid III dummy.

In the case of neck injury, the 2011 NCAP employed a risk curve that retained a residual risk of approximately 4% at zero value of Nij. The NCAP neck injury risk curve is displayed in Figure 4. Also shown in Figure 4 are neck injury risk curves with and without muscle tone suggested by Mertz [2003]. Table 5 indicates that the risk of neck/spine injury in NCAP like crashes is less than 1%. Consequently, the NCAP neck injury risk curve is expected to overstate the injury risk at lower values of Nij.

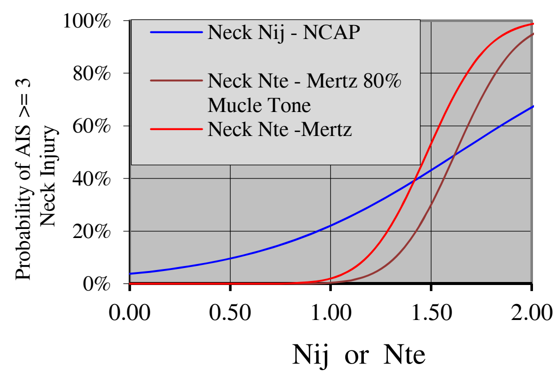

Figure 4. Alternatives Nij injury risk curves for 50% male Hybrid III dummy.

Another neck injury risk curve used by NHTSA is applied to out-of-position occupants exposed to air bag deployments. The neck tension and compression are used as injury measurements in these applications. Figure 5 shows this NHTSA neck tension/compression risk curve. Also shown in Figure 5 are neck injury risk curves with and without muscle tone, proposed by Mertz [2003].

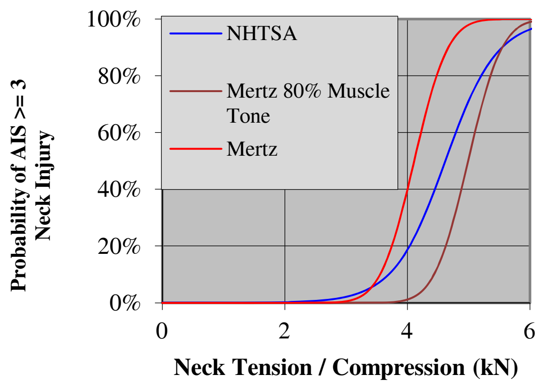

Figure **5.** Alternative neck tension/compression injury risk curves (N_{te}) for 50% male Hybrid III dummy.

INJURY RISK CALCULATIONS FOR NCAP VEHICLES MODEL YEAR 1988-2006

To explore how body region injury rankings generated by the injury risk functions used in NCAP correlate with field data, a retrospective review of NCAP tests previously performed by NHTSA was undertaken. Data for a total of 456 NCAP tests were secured and processed using the injury risk functions that are used in the 2011 NCAP program. This total included 302 tests of model year (MY) 1988 to 2006 passenger vehicles. This subset of tests was judged to most closely represent the vehicle population in the NASS database.

This group of 302 vehicles tested by NCAP was used to assess how well alternative risk functions predict the injury rates in NCAP type crashes. First, the 2011 NCAP injury curves were applied to the 302 vehicles and the mean injury rates for each body region were calculated. Second, alternative injury curves were applied to the same 302 vehicles. The results of the two calculations were compared with the injury rates observed in NASS field data for NCAP severity crashes. The results are shown in Table 9.

Table 9 displays the mid-estimate of injury risk that is representative of NCAP like crashes, based on NASS data. This mid-estimate was previously displayed in Table 7. The application of NCAP risk functions to the 302 NCAP vehicles that are representative of vehicles on-the-road is displayed in the third column of Table 9. The right column of Table 9 displays the injury rates when alternative risk functions were applied to the 302 NCAP vehicles. The alternative risk functions replaced the NCAP Nij risk with the Mertz N_{te} risk (neck with no muscle tone, Figure 5) and the NCAP chest risk function with the Prasad older male risk (Figure 3). Table 9 provides a comparison of actual injury risks in NCAP like crashes in NASS field data with calculated injury risks based on NCAP test data of 302 vehicles that are representative of vehicles on-the-road.

Table 9.
Comparison of Injury Risks Derived from NASS Field Data with Those Derived from NCAP tests (Driver Only)

Body Region	Field Data	NCAP Test Data	
	NASS Mid-Bound	NCAP 2011 Risk Functions	Elderly Risk Functions
Neck-Spine 3+	0.70%	7.90%	0.55%
Head-Face 3+	3.2%	2.3%	2.3%
Chest 3+	10.6%	6.8%	12.5%
KTH 2+	14.0%	4.9%	4.9%
NCAP (Any)	20.9%	20.1%	20.2%

DISCUSSION

A comparison of the injury probabilities the injury rates for the human driver derived from the NASS analyses and for the hybrid III driver derived from the series of 302 tests is presented in the center two columns of Table 9. A comparison of these two columns shows a general agreement between the NCAP tests and the NASS field data with respect to the combined probability of injury value, as well as for the risk of AIS 3+ injury to the head-face body region. However, the risk of neck injury calculated from the NCAP test data is grossly overstated. The risks to the chest and the knee-thigh-hip are understated. These differences in neck and chest injuries can be traced to the choices of injury risk functions selected for the 2011 NCAP program.

The lack of correlation between the NASS neck injury rates and the NCAP 2011 neck injury rates can be largely attributable to the shape of the Nij injury risk function (Figure 4). The risk function has a non-zero risk intercept for zero Nij (4%) and has a shallow rising slope. Consequently, it can be expected to overstate neck injury risk for Nij values below 1. Eliminating the NCAP Nij and employing only the neck axial force injury risk curve, Figure 5, to compute neck injury risk reduces the 1998-2006 NCAP driver risk from to 7.9% to 0.55%. The revised risk value compares favorably with the 0.7% rate for the neck-spine calculated from the NASS field data.

The right column in Table 9 shows the result of substituting alternative injury risk curves for the neck and chest injury measures. The risk functions used were the Mertz N_{te} neck with no muscle tone (Figure 5) and the Prasad chest function for the older male risk (Figure 3). A comparison of the calculated injury rates using the alternative risk functions and the NASS generated injury rates shows better agreement for the neck and chest injury rates. The alternate chest injury rate is higher than the NASS rate for the population of all ages. However, as shown in Table 6, the chest of older occupants is more vulnerable to injury and increased priority is warranted.

Table 9 shows that 2011 NCAP underestimates the injury rate for chest injuries. The chest injury function applied by NCAP is for a 35 year old male. Figure 2 indicates that this population sustains a risk of AIS 3+ chest injuries in the range of 5% to 10% at NCAP crash severity. Consequently, the 6.8% predicted by NCAP 2011 is in reasonable agreement with the risk to the young population. However, as shown in Figure 1, the older population sustains a much higher injury risk at the NCAP crash severity. Several researchers have noted the substantial increase in chest injury rates with age [Augenstein 2005, Kent 2005]. Most recently, Ridella studied age related injury risks by crash mode and body region and found that the largest age effect was to the thorax in frontal crashes [Ridella, 2011]. Table 6 shows how chest injury rates increase with age and further illustrates the need to prioritize the protection of the chest increases for the older populations. These observations justify the use of chest injury risk functions for older occupants in the revised NCAP rating system.

The lower limb injury rates from the NCAP 2011 risk functions are considerably below the rates in NASS data. However, as shown in Table 5, more than 75% of these the injuries are at the AIS 2 level. When considering the most severe injuries (AIS 4+), as shown in Table 5, the lower extremities represent less than 2% of these injuries. Consequently, the priority for preventing these injuries should be lower than that for preventing serious head, neck and chest injuries. Table 8 indicates that of all the NCAP body regions, the lower limb injury risk is the least sensitive to age. Based on these observations, the use of the NCAP 2011 rating system for lower limb injuries was retained in the rating system for older occupants.

The proposed protocol for older occupants directly addresses the chest protection requirements of older occupants. The example to follow uses the gender-age chest injury risk functions developed by Prasad. [2004, 2010]. Alternative gender-age dependent chest injury risk functions were developed by Laturi. [2005] and could be applied to develop ratings for specific age groups such as 50 year, 65 year, etc.

In summary, the older occupant rating would not change the injury risk curves used by NCAP 1011 for the head and lower limbs. However, the NCAP Nij risk curve would be replaced with the Mertz no muscle tone M_{te} curve (Figure 5). The chest injury risk curve would be replaced by the Prasad injury risk curves for older occupants (Figure 3). The older male curve would be applied to the driver and the older female curve would be applied to the right front passenger.

Table 10 compares the body regions with the highest injury risk when the NCAP 2011 rating scheme is applied and when the older occupant rating scheme is applied. Both the driver and right front passenger are included in Table 10. The body region with the highest injury risk is indicative of the highest priority for injury reduction in order to achieve a higher star rating. The 2011 NCAP data illustrates how the neck risk is the overwhelming leader as the body region with the highest injury risk. In fact for all 2011 NCAP right front passengers, the neck is the body region with the highest injury risk. In contrast, the older occupant rating system shifts the priorities to the chest and lower limbs. This shift is in the general direction suggested by the NASS analysis reported in Table 7.

Table 10.
Body Region at Highest Injury Risk: Alternate Injury Risk Functions for Older Occupants

Body Rehion	Driver		RF Passenger	
	2011 NCAP	Older Male	2011 NCAP	Older Female
Head	0	2	0	8
Neck	60	0	64	0
Chest	3	40	0	27
KTH	1	22	0	29
All	64	64	64	64

The NCAP protocol was followed to develop the elderly rating system. Following NHTSA's star rating protocol, each computed CPI was divided by the reference CPI value giving a relative risk value. The relative risk ratio was used to generate a star rating based on the following boundaries:

0.67 - 5/4 Star Boundary

1.00 - 4/3 Star Boundary

1.33 - 3/2 Star Boundary

2.67 - 2/1 Star Boundary

Table 11.
Alternative Star Rating for Older Occupants

DRIVER STARS	OLD MALE_50M					
NCAP 2011	1	2	3	4	5	Total
1						
2						
3	1	6				7
4		7	5	5	2	19
5				8	15	23
Total	1	13	5	13	17	49
PASS. STARS	OLD FEMALE_5F					
NCAP 2011	1	2	3	4	5	Total
1						
2	5	3	2			10
3		1	3	4		8
4		2	7	10	7	26
5					5	5
Total	5	6	12	14	12	49

Table 11 shows the changes in star ratings when the rating system for older occupants is applied to the 2011 NCAP tests. In this table, the rows show the total vehicles for each star rating based on 2011 NCAP tests. The bottom row shows the total vehicles for each star rating based on the older occupant rating system. The matrix shows how the shifts have occurred. For the driver, there has been a general downward shift in the number of stars. However, two vehicles that were 4 star became 5 star. This change suggests that these vehicles with safety features suitable for older drivers are being penalized by the NCAP rating.

In the case of the passenger, the number of 5 star vehicles increased from 5 to 12. There were almost as many increases in star ratings as decreases. These large changes demonstrate that the 2011 NCAP ratings are very sensitive to the injury risk functions used in the star ratings calculations. In particular, as shown in Tables 8 and 9 the injury risk function for the neck has a profound influence on the star ratings.

The changes in star ratings illustrate how the use of alternative risk functions for NCAP test data is a viable alternative for providing consumer information for older consumers.

LIMITATIIONS

The appropriateness of the NCAP test condition in providing a useful rating system to the older population has not been addressed in this paper. Research from an earlier paper suggested that a lower severity crash test would be more representative of the crash environment that produces most of the serious injuries to older occupants [Digges 2007].

The suitability of the Hybrid III dummy's chest compression measurement for use with the chest risk curves is subject to question, based on a recent study [Haight 2013]. The study examined belt geometry in the 2011 and 2012 NCAP tests and found vehicles with the center of the belt 130 mm above the chest deflection transducer on the Hybrid III driver dummy. A distance of 120 mm was observed for the passenger dummy. The sensitivity of the Hybrid III dummy's chest compression measurements to belt positioning has been highlighted in a number of studies. A 1991 study found that by placing the shoulder belt in contact with the neck of a Hybrid III 50^{th} percentile male dummy, versus 50 mm laterally away from the neck resulted in a 34% decrease the chest deflection [Horsch 1991]. Comparative tests reported by JNCAP found that a high belt position resulted in lower chest deflection measurements than a belt positioned lower and closer to the chest transducer [Yamasaki 2011]. The difference in chest deflection exceeded 18 mm. To correct the rating for high belt locations, the injury risk curves would need to be calibrated for the varying belt geometry or the allowable belt geometry would need to be controlled more closely by the NCAP test specification. It should be noted that this deficiency is relevant the existing NCAP as well as to the elderly rating system proposed here.

The appropriate positioning of the 5th female dummy in the right front passenger location requires additional considerations. In a recently reported series of eight 48 km/hr frontal crash tests the 5th female dummy when seated in mid position produced higher chest deflections readings than observed in the NCAP tests at 56 km/hr and with the dummy full forward [Tylko 2012]. Higher readings at the mid position were observed for six of the eight vehicle models tested.

The proposed rating system does not adjust the head and neck injury risks with age. Table 8 shows that head injury rates increase are reasonably constant between the age groupings of 44-64 and 65-97. Both groups have higher rates in the order of 2 to 3 times higher than the 15-43 group. Head injury risk functions for the older groups are not currently available from publications. Consequently, the NCAP 2011 head injury functions were applied to the rating for older occupants. Future ratings for older occupants should apply age related head injury functions, when available.

Like the injury to other body regions, the neck injury rates increase with age. This increase is particularly evident for older women, as shown in Table 8. It would be desirable to apply an age and gender related neck injury function to the rating system for older occupants. Future ratings should apply more age and gender related injury functions when they become available.

CONCLUSIONS

The application of older occupant risk functions to consumer information vehicle tests is feasible and results in significant changes in the star ratings of vehicles tested by NCAP. Such a system would produce added incentives for safety designs that prioritize the reduction of the most frequent injuries experienced by older occupants involved in frontal crashes.

ACKNOWLEDGEMENT

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VEHICLE SAFETY WITHOUT REGULATION - *A NON-REGULATORY APPROACH TO IMPROVING VEHICLE SAFETY IN NEW ZEALAND*

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ABSTRACT

Consumer information has become the primary means of improving the safety of New Zealand's light vehicle fleet in recent years. With the rapid pace of vehicle technology improvements, and the difficulties associated with introducing new legislation in this area, there are potentially greater benefits to be had from implementing a sound non-regulatory approach than are possible from regulation alone.

The primary objectives of New Zealand's non-regulatory approach are to improve the safety of vehicles entering the fleet by increasing consumer demand for vehicles with high safety ratings, and also to influence the composition of the existing fleet through reduced demand for less-safe used vehicles.

In order to effectively bring this about, it is recognised that there is a need to disseminate credible and relevant safety information through a wide range of different channels. At the heart of the New Zealand approach is a website (www.rightcar.govt.nz) and an associated individual-vehicle-level database of safety ratings and specification data. This provides opportunities to extend the reach of safety information to a level where it is effectively unmissable by the vehicle buyer.

This paper presents a case study of the processes and systems that have enabled the NZ Transport Agency to put in place a consumer-driven programme for positively influencing the composition of the vehicle fleet. It describes how safety data is gathered from a diverse range of sources, how that data is collated and presented to vehicle buyers, and also the consumer education and information activities that support this programme.

INTRODUCTION

The question of how to improve the safety of the New Zealand vehicle fleet is one with no simple solution. Making gains in this area involves using a diverse mixture of tools over a long period of time, ranging from strict regulation in some areas to subtle promotional activities in others.

In the foreseeable future, the most significant gains will be made without regulation. This means getting vehicle buyers in all sectors of the market to understand the value of safe vehicles, to recognise safe vehicles, and to demand safe vehicles (i.e. a shift towards a culture that understands and values safety). The NZTA has a key role to play in influencing all three of these areas, and maximising this influence requires a carefully considered approach that includes a good deal of innovation.

An innovative approach is especially important in light of the need to get the most out of limited financial resources, and there are certainly opportunities for making a substantial impact at relatively low cost. These include:

- Capitalising on the unique capabilities of the Rightcar database to provide a suite of data "products" that can be used by the industry while at the same time greatly enhancing the reach and visibility of vehicle safety information.
- Engaging with current and future industry partners to get vehicle safety ratings in front of vehicle buyers at all stages of the buying process. The aim is for safety ratings to be present wherever a prospective buyer researches or views a vehicle, whether it is online or on a dealer's yard.
- Enhancing and better targeting promotional activities to raise awareness of vehicle safety, also making use of industry and regional partners to extend the reach of key messages.

This area is one where a non-regulatory approach can be fully embraced and exploited to its full potential. There are relatively few limitations or constraints, and there is a genuine opportunity to take a fresh and different approach with low risk and at relatively modest cost.

Vehicle Safety Ratings

The cornerstone around which virtually all non-regulatory vehicle safety activities are built are independent vehicle safety ratings. These provide consumers with a simple, easily understood guide to the safety of vehicles they may be considering.

The primary vehicle safety rating system in place in Australasia is the Australasian New Car Assessment Programme (ANCAP) which is an independent organisation funded by national and state governments, motoring clubs and insurance companies in Australia and New Zealand. ANCAP carries out crash testing on a number of vehicle models sold in the two countries, and also republishes the results of tests carried out by its sister organisation, EuroNCAP. ANCAP has been around since the mid 1990s, with New Zealand becoming a full member in 2002.

Complimentary to ANCAP is the Used Car Safety Rating programme (UCSR), which provides safety ratings for used vehicles based on a statistical analysis of real-world crashes. Used Car Safety Ratings are produced by the Monash University Accident Research Centre (MUARC) for the Vehicle Safety Research Group, which is comprised of many of the same members that fund ANCAP.

The NZ Vehicle Fleet

New Zealand has an unusual and highly diverse vehicle fleet, with vehicles from a range of source markets such as Australia, Europe, Japan, and the USA. A large proportion of the fleet is made up of Japanese Domestic market vehicles that are imported used.

At present, approximately 80% of new cars sold each month have a 5 star ANCAP rating, and around 80-85% are equipped with Side Curtain Airbags and/or Electronic Stability Control. For Light Commercials, the figures are much lower, with only around 30% having a 5 star rating, and between 30-35% with ESC and Side Curtain Airbags.

The overall proportion of 5 star vehicles in the fleet is obviously considerably lower, at around 7.5%. Approximately 14% have 4 star ratings, 3.4% have 3 star ratings and around 0.6% have a 1 or 2 star rating. These figures only include vehicles that have ANCAP ratings so they exclude vehicles manufactured prior to 2000, and unrated vehicles manufactured after that date. ANCAP ratings are available for about 25% of the overall light vehicle fleet.

The safety of the vehicles in the fleet can be measured in a general sense by considering average crashworthiness ratings for vehicles of a particular year of manufacture[i]. A crashworthiness rating is a statistical measure of the likelihood of the occupant of the vehicle being killed or seriously injured in a crash, with a lower number indicating a safer vehicle. As the *figure 1* below shows, crashworthiness is considerably better for newer cars, with the occupant of a 2007/2008 vehicle around half as likely to be killed or seriously injured than the occupant of a car from the early-mid 1990s.

Overlaid on this chart is a graph showing the fleet age profile (i.e. the number of vehicles by year of manufacture)

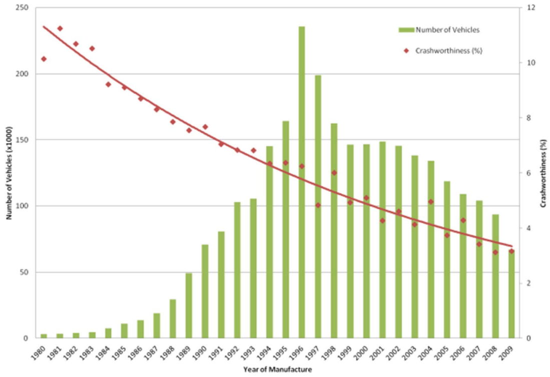

Figure 1: NZ Fleet Profile and Crashworthiness.

This graph shows that there is a disproportionate number of 1996/1997 model year vehicles in the fleet, which poses a particular challenge to increasing the overall level of vehicle safety.

Altering the composition of this portion of the fleet through the provision of vehicle safety information alone is likely to be a relatively slow process and may not yield significant benefits in the short term. It relies on buyers of older, less expensive cars putting a value on safety to the extent that less-safe vehicles have a lower financial value, and are therefore likely to be scrapped earlier.

Despite the lack of immediate benefits, activities in this area are important for bringing about a cultural change in the longer term and this sector of the market should not be ignored. It is important to dispel the myth that vehicle safety is only applicable to new or expensive cars and convey the message that there are safe and less safe choices at almost any price point.

A way of improving the overall level of safety without altering the composition of the vehicle fleet is to encourage those that have a higher risk of crashing to drive vehicles with higher safety ratings. An example of this is young and inexperienced drivers who are considerably more likely to crash than older drivers. Young drivers typically drive old vehicles that provide little protection in the event of a crash.

THE RIGHTCAR DATABASE

Purpose

In order to support a government requirement for mandatory Fuel Economy labelling, a website for displaying fuel economy information and printing physical labels was established.

It was soon realised that the database underpinning this website would be capable of also delivering safety information. The database was accordingly upgraded and an associated front-end website, www.rightcar.govt.nz, was developed and launched in 2007.

Structure

Essentially, the database is a copy of a portion of the Motor Vehicle Register (MVR) to which additional linked data fields are added. The MVR itself is not used as it lacks the required flexibility and ease of access, and there are certain legislative constraints that limit its suitability for use in a web-based environment.

The database is in SQL Server format and consists of a number of data tables including vehicle model attributes, fuel consumption data, safety ratings and safety specifications. It is structured as per *figure 2* below:

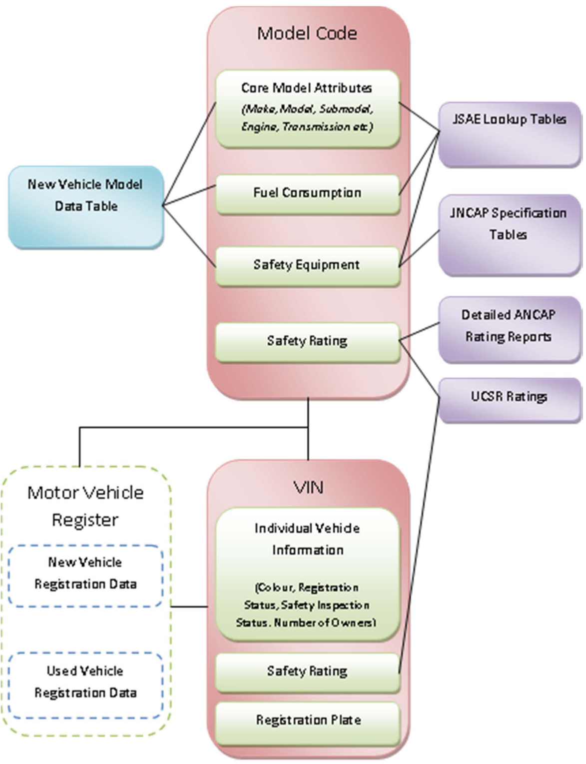

Figure 2: Structure of Rightcar Database.

Vehicle data is stored at two levels: Static data at model code level, and dynamic data (and some static data) at VIN level. Most vehicle data is linked to model codes, which are in turn linked to VIN through data from the Motor Vehicle Register. Many vehicles do not have model codes and are indentified through individual VIN only.

The result is a database that allows a full set of vehicle attributes, including safety information and fuel consumption, to be returned from a search for an individual vehicle (by registration plate or VIN) or from a more general search using make, model, model code or virtually any other attribute.

This database forms the "back-end" of several websites that provide a user-friendly way of accessing vehicle data. The structure of the database allows data to be presented in many different ways via a range of channels.

Data Sources

The Rightcar database draws vehicles data from a multitude of sources and uses a mixture of manual and automated matching to establish links between vehicle models (or individual vehicles) and their attributes.

The flow of data can be described by the (simplified) *figure 3* below:

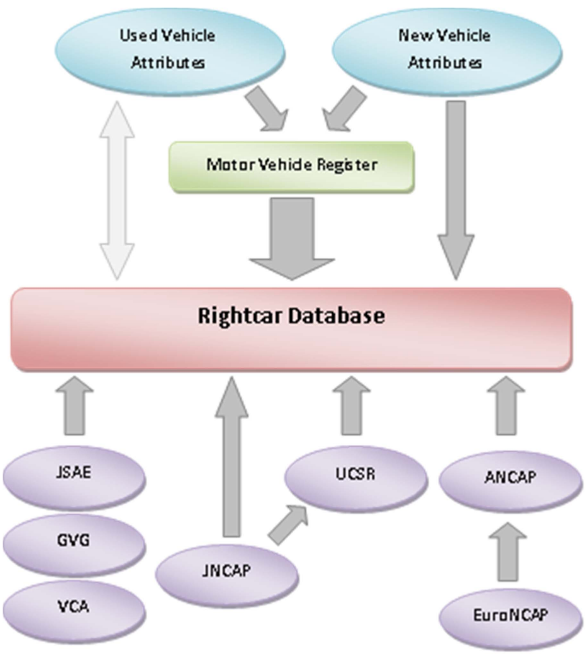

Figure 3: Rightcar Data Sources.

The two primary sources of safety ratings are ANCAP and Used Car Safety Ratings. ANCAP test reports are manually entered into the database and are then automatically or manually linked to the appropriate model codes from the MVR. Similarly, Used Car Safety Ratings are uploaded to the database and are automatically matched to vehicles by make, model and year range. There is capability to allow automated matching to be manually checked and corrected if needed.

As a subset of the Used Car Safety Ratings, Monash University produces a small set of UCSR ratings that have been derived from JNCAP test data.[ii] These incorporated into the Rightcar database and linked to the appropriate used Japanese imported vehicles. Doing this greatly enhances the coverage of the Japanese Domestic Market vehicles that are in the fleet and that are imported in considerable numbers.

Vehicle specification data for models is generally obtained directly from the vehicle manufacturer's agents at the time new model attribute data is loaded into the MVR. Only core model data is legally required to be entered in the MVR, and additional safety specification data is neither required nor able to be accepted by the MVR system. In order to obtain accurate specification data, a streamlined system was set up to allow a full dataset to be loaded directly into the Rightcar database.

By combining the input systems for mandatory data required by the MVR (i.e. core model attributes) with that for non mandatory data (such as safety specification data), we get a high degree of willing compliance with our request for the latter. The level of compliance is further aided by an agreement for the NZTA to provide collated statistical information back to the vehicle manufacturer's industry body, the Motor Industry Association (MIA).

Safety specification data for used Japanese vehicles is obtained from the vehicle specification tables that are published by JNCAP in their annual reports. Fuel consumption and other core attribute data is obtained from data tables that are produced annually by the Japan Society of Automotive Engineers (JSAE). These tables also contain some useful fitment data (such as airbag type) that can also be incorporated into the Rightcar dataset.

Fuel economy data is sourced from a number of different places, most notably the JSAE tables, the UK VCA CarFuelData website and the Australian Green Vehicle Guide (GVG).

Much of the matching of this data to actual vehicles is automated, primarily through the matching of model codes (either those entered by the NZ new vehicle distributors or the Japanese domestic model codes), or by make/model/year where this is appropriate (Used Car Safety Ratings are an example of this).

The core model attributes and dynamic data from the MVR are fed into the Rightcar database via a daily data extract from the MVR mainframe. This means that the data in the Rightcar database is not "real-time," but is at most 24 hours old. This is considered adequate by users.

COMMUNICATING SAFETY INFORMATION

Rightcar Desktop Website

The primary outlet for communicating vehicle safety information is the NZTA's Rightcar website, which is the main public interface to the Rightcar database. The website allows searches by vehicle make and model or by registration plate, and presents the user with a vehicle detail page that provides a summary of all of the static information that is available for that vehicle. This includes:

- Core Vehicle Attributes
- Safety Rating
- Safety Equipment
- Fuel Consumption (with annual fuel costs)
- Exhaust Emissions
- CO2 output.

The primary focus of the site is to convey safety ratings in a way that is accessible to the general public, and it also contains additional information to support the safe vehicle messages that are put forward in advertising. The intended end-point of each search path is the "vehicle detail page," shown below as *figure 4*

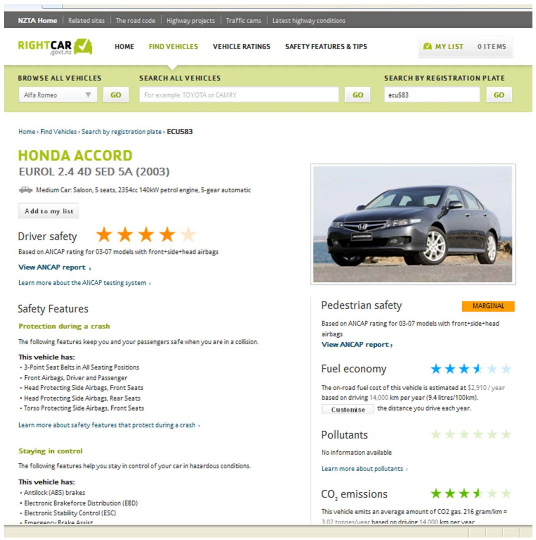

Figure 4: Rightcar Vehicle Detail Page.

Rightcar Mobile Website

In addition to the primary desktop site, a mobile version has also been developed that allows users to input a registration plate into a smartphone and access the safety information that is held for that vehicle. This is intended to be used by vehicle buyers when physically viewing a vehicle, so it is structured in a way that emphasises the safety rating.

The mobile site, like all websites, can also be accessed via a QR code. The advantage of this approach is that a QR code relating to a particular vehicle (identified by registration plate) can be created and placed on the vehicle in a sales yard. This provides an easily accessible link between the vehicle the buyer has in front of them and the safety rating of that vehicle. A screen capture of the mobile site is shown below as *figure 5*.

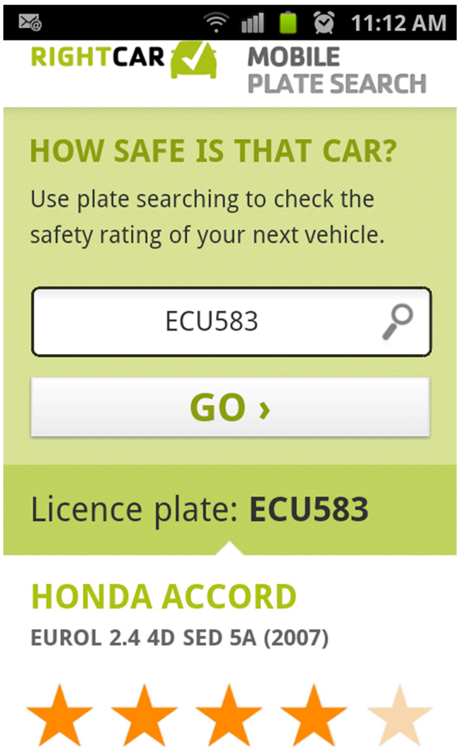

Figure 5: Rightcar mobile site screen capture.

Partner Websites

The drawback with the Rightcar desktop and mobile sites is that it requires the vehicle buyer to make a conscious decision to visit the site. This in turn requires them to be aware of the site, where to access it, and they must have an interest in the content of the site.

In order to bring about a change to buying habits, significantly greater exposure to safety information is needed. The ideal situation is for safety information to be displayed in the places that vehicle buyers normally view when they are searching for vehicles to buy or background information on those vehicles.

To achieve such exposure, it is necessary to enter into partnerships with the organisations that buyers currently use as part of their vehicle purchase process. However, budgetary restraints preclude any significant financial expenditure on this, such as paid placement of safety ratings.

The Rightcar database provides a simple and inexpensive solution to this. A number of the organisations consumers use when buying and selling cars are also users and resellers of bulk vehicle data. These organisations draw both static and dynamic information from the NZTA’s Motor Vehicle Register, package it, and provide it to the public in a number of different ways. The system architecture the MVR itself is based on means that extracting this kind of data on a per-vehicle basis is costly, and users are accordingly charged a fee for every vehicle record that they request. For some bulk users, this is a very considerable cost.

The Rightcar database is, unlike the MVR, based on architecture that is optimised for handling large numbers of requests at extremely low cost. As the database mirrors the data on the MVR that users access the most, it is a relatively simple matter to provide a webservice to bulk users so that they can access the same data they were previously obtaining from the MVR. Furthermore, the low cost of providing access to the data in this way allows the NZTA to provide it free of charge at considerable savings to the industry. This also provides an opportunity for the NZTA to influence how the information is used.

With a view to increasing exposure of safety and fuel economy information, the NZTA has put in place, as a condition of access to the free webservice, a requirement that safety and fuel economy ratings be displayed alongside core vehicle data. This means that wherever vehicle attributes from the Rightcar database are displayed on a third-party website, the safety rating must also be prominently displayed.

The majority of existing users of bulk data have been more than willing to accept this in exchange for access to this valuable data source, and are in the process of incorporating this information into their websites.

Users include:

www.trademe.co.nz – New Zealand’s largest online auction site, which contains listings for the majority of used vehicles on sale in New Zealand (both private and dealers)

www.carjam.co.nz - A vehicle information source and producer/seller of pre-sale vehicle information reports.

The NZ Automobile Association (NZAA) – New Zealand's largest independent motoring organisation. The NZAA website has vehicle sale listings, pre-sale reports and pre-purchase inspections

www.autotrader.co.nz - A large vehicle sales site with both private and dealer listings

www.motorweb.co.nz – A major supplier of vehicle information reports to the public, and a producer of window cards to dealers.

An example of how this type of data will appear to the user is the below mock-up from the Trademe online auction website (*figure 6*)

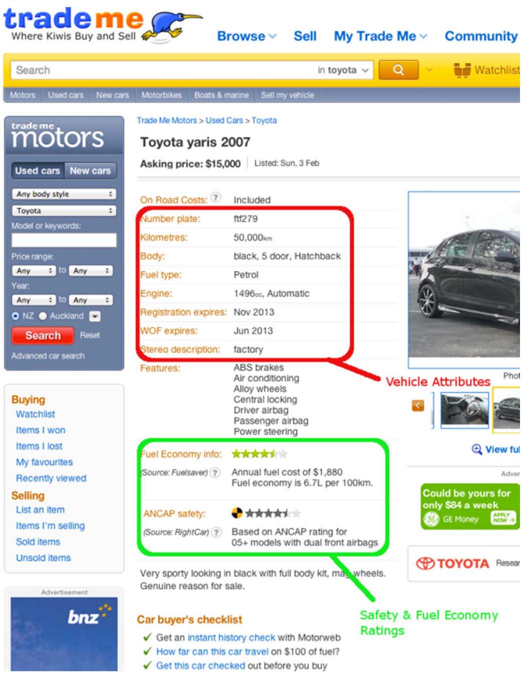

Figure 6: Mockup of Trademe Vehicle Listing.

The sites listed above cover a very significant proportion of the market. For example, the "Trademe Motors" site alone has in the order of 680,000 unique visitors per month, with the NZ Automobile Association website having around 240,000 unique visitors per month.[iii] For reference, the population of New Zealand is around 4.4 million people.

This initiative is perhaps the most important and significant use of the Rightcar database, and it is likely to raise the profile and awareness of safety ratings considerably. This in turn is likely to help achieve the NZTA's objective of influencing the demand for safe vehicles in all sectors of the market.

Physical

New Zealand has mandatory fuel economy labelling regulations that require that all vehicles offered for sale by dealers must display a physical fuel economy label at point of sale. Labels are printed by individual dealers using a system that draws data from the Rightcar database. Although there is no comparable regulation relating to the display of safety ratings, there is no reason why this mechanism could not be used to produce a safety rating label at the same time the fuel economy label is produced. Such a system is capable of enabling a voluntary "Stars on Cars" scheme to be introduced at very low cost.

There is also considerable scope for partnerships with companies that produce vehicle information cards for car dealers using the same mechanism described above for partner websites.

Advertising Strategies

The vehicle safety advertising campaign aims to encourage New Zealanders to buy the safest vehicle they can afford. While the campaign promotes safe vehicles in general, it currently has a specific focus on highlighting the benefits of side curtain airbags and electronic stability control (ESC). It aims to increase awareness of these and other safety features in vehicles, so that people consider them a priority in their next vehicle purchase.

All aspects of the campaign drive people through the www.rightcar.govt.nz for further information on the safety features of vehicles. Our strategy is not simply about driving people through to the Rightcar website, it's also about driving engagement with the various aspects of the website and getting people to spend time on the site.

We've achieved this through different mechanisms: firstly by using large performance networks such as Stuff and Google Display Network. These portals reach a high percentage of NZ's internet audience so this ensures we have a large amount of reach due to the broad target audience.

Secondly we behaviourally target and environmentally target consumers to ensure the advertising appears in relevant content amongst highly qualified eyeballs. This activity drives highly engaged traffic through to the rightcar site.

And finally we utilise Facebook to ensure we can cost efficiently target certain demographics and optimise toward the strong performing areas. Facebook also has a very high time on site so this tends to provide highly engaged traffic.

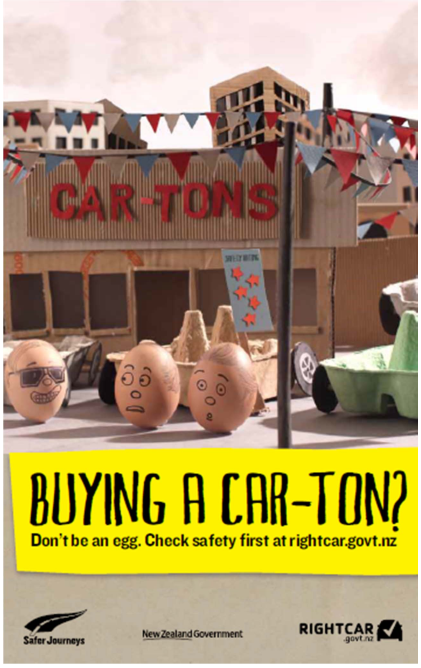

Figure 7: Example of Rightcar Advertising.

OUTCOMES

Due to the fact that parts of this project are still in the early implementation phase, there is little that can be done to gauge the effects it is having on the market. Of the information that is available, new vehicle sales data and website traffic are perhaps the most useful metrics to consider.

Changes in Fitment Rates

It is difficult to properly monitor the effect that promotion of safety ratings has on vehicle purchase behaviour, as upwards trends in safety ratings and safety specifications occur naturally in response to worldwide trends in vehicle design and marketing. However, it is instructive to examine trends in a few key areas and consider the overall outcome on the vehicle market.

The below graphs (*figures 8 & 9*) plot the percentage of cars and Light Commercial Vehicles (LCV) that have a 5 star ANCAP rating, are fitted with Side Curtain Airbags and/or that are equipped with Electronic Stability Control, and were registered in the period from August 2009 to February 2013.

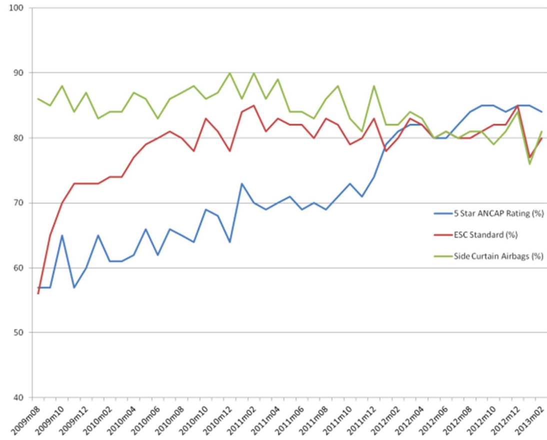

Figure 8: Safety Equipment Fitment Rates, Cars.

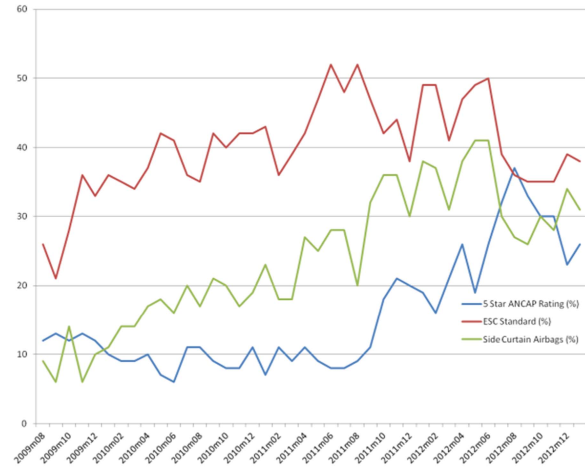

Figure 9: Safety Equipment Fitment Rates, LCV.

These graphs show an early upward trend in 5 star ratings and ESC fitment, and a steady (but high) Side Curtain Airbag fitment rate. It should be noted that there will be some margin for error in equipment specifications due to reporting rates, and there is also considerable month-month variation due to the relatively low numbers of vehicles sold.

The proportion of 5 star vehicle and ESC/Side Curtain airbag fitment rates are significantly lower for light commercials than for passenger cars, but there is an overall upward trend for these vehicles.

Website Traffic

Traffic to the Rightcar site provides some indication of the level of demand for safety information, and the effects of advertising on creating interest in the topic of vehicle safety. A summary of overall traffic is shown below (*figure 10*)

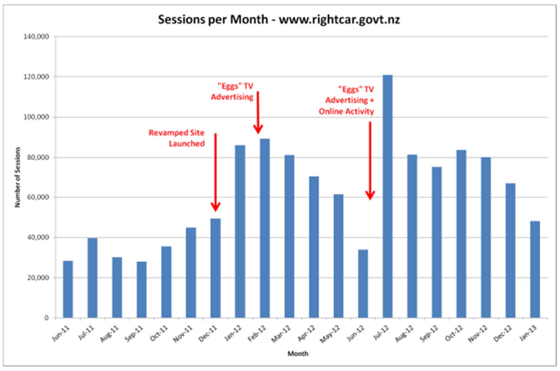

Figure 10: Rightcar Sessions.

The above graph shows considerable variation in the number of monthly sessions recorded for www.rightcar.govt.nz, with some apparent correlation between hits and significant advertising campaigns (such as TV advertising). On average, there are around 75,000 sessions per month on the website.

In the 4 months from 1 October 2012 to 31 January 2013, there were

- 1,821,648 visits to a "vehicle detail" page
- 93,222 searches for ANCAP rating matches (where the user searches for vehicles that match a particular ANCAP report).
- 75,922 visits to the user's comparison list (this allows users to compare core features of several selected vehicles)
- 25,434 visits to the Used Car Safety Ratings page
- 22,678 visits to the general ANCAP rating make/model page.

This shows that there is considerable consumer interest in obtaining in-depth vehicle information and that the users are utilising the site to compare vehicles with one another. There also appears to be some interest in accessing ANCAP and Used Car Safety Ratings without searching for particular makes/models.

REVIEW OF PROJECT

Strengths

Despite its apparent complexity, the underlying systems and processes that enable the RightCar database to exist are fairly simple. Using flexible, web-based database architecture allows new data to be incorporated and matched relatively easily, which means that many diverse data sources can be used. This is very important in an open vehicle market like New Zealand.

However, the key enabler of this project is access to the New Zealand Motor Vehicle Register. This allows the service to be extended beyond a generic source of vehicle model information to become a source of vehicle-specific data. This is of significantly greater value to vehicle buyers and opens up a number of opportunities for disseminating information in a highly targeted manner.

Furthermore incorporating MVR data into the database has resulted in a product that is of considerable value to third parties. Instead of commercialising this, the value of the database can be used as leverage to dramatically increase exposure and awareness of safety ratings and vehicle safety in general. The advantage of this approach is that it requires very little financial outlay: systems changes to enable the webservice have cost less than USD$10,000. Costs associated with incorporating safety ratings into partner websites are met by the partners themselves.

Another important factor has been the relationship between the NZTA and the new vehicle distributors. This has made it possible to obtain reliable vehicle specification information directly for new vehicle models at very low cost.

The overall cost of developing the database and associated websites has also been relatively modest – in the order of US$400,000 over 5 years.

Website traffic indicates an increasing awareness of the Rightcar website and of vehicle safety ratings, and crucially it shows that there is interest in, and demand for, this information. This demonstrates that is value in further expanding the reach of safety ratings.

Difficulties

The main difficulties experienced in the development of this database are:

- Difficulties extracting data from the MVR – until recently, extracting vehicle data from the MVR for use in the Rightcar database was time consuming and complex, which limited data feeds to 2-weekly. A recent system update has alleviated this problem and enabled daily data extractions.
- Managing the manual and automated matching of vehicle attributes to model code/VIN – There are potential sources of error in both methods, and the volume of data can make it difficult to detect such errors.
- Controlling data quality – the database is reliant on quality source data, and there are

sometimes inaccuracies in information it receives.
- Providing meaningful data for a significant proportion of the vehicle fleet – the diverse range of vehicles in New Zealand requires the use of many different data sources, which adds complexity.

An ongoing challenge is influencing purchase decisions at the "lower" end of the market where decisions are strongly influenced by price. The level of interest in Used Car Safety Ratings shown by the Rightcar traffic data shows that there is some interest in safety in this sector of the market, so there is scope to increase promotional activities in this area.

CONCLUSIONS

The approach to vehicle safety promotion taken by New Zealand in recent years has been highly reliant on non-regulatory activities, with a strong emphasis on the promotion of safety ratings and associated information to the vehicle buyers.

In order for such a strategy to be successful, the systems in place for delivering that information must be flexible, reliable, consistent and able to work across a range of different applications. The Rightcar database has, to date, been capable of meeting these requirements.

The development of the database has demonstrated that an easily accessible, registration-linked database of safety information is achievable and does have value in the area of vehicle safety promotion.

How this information is then used is also of considerable importance. The approach the NZTA has taken to communicating safety data is to use a combination of the NZTA-run Rightcar website (with an associated advertising campaign) and external partner websites to communicate safety ratings to prospective buyers in a targeted manner.

In the near future, a project will be started to implement a physical safety rating labelling system that builds on the work done in communicating ratings via online channels. This is likely to bring about further positive changes in consumer behaviour.

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CONSUMER RATING AND ASSESSMENT OF SAFETY HELMETS FOR MOTORCYCLISTS

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ABSTRACT

Consumer focussed product safety evaluation programs can complement safety standards regimes and provide comparative safety performance information that influences purchasing decisions as well as driving improvements in safety performance. A Consumer Rating and Assessment of Safety Helmets (CRASH) program was developed for the Australian motorcycle helmet market. The objective of this paper is to report on the assessment and rating program and results for 2011-12 helmets.

A protocol was developed to assess AS/NZS 1698 certified motorcycle helmets by crash protection and ergonomics. Dynamic crash protection tests included: 2.5 m and 0.8 m impact energy attenuation tests onto a flat anvil; 2.5 m impact energy attenuation test onto a kerb anvil; dynamic strength of the retention system; and dynamic stability. A rating system was developed using, for example, published head acceleration tolerance data with a maximum score given for the 2.5 m tests when the peak headform acceleration was ≤ 150g and none if > 250 g. Other dynamic tests were similarly rated. Usability tests included: in-helmet noise, drag forces and ventilation recorded in a wind tunnel on a KEMAR acoustic mannequin at 100 km/h; visor splash and fog resistance; and ease of use.

In 2011-12 61 helmets were assessed, the lowest aggregate crash protection score was 21% for an open face helmet and the highest was 74% for a full-face helmet. The lowest aggregate usability score was 32% and the highest 75%. There was no correlation between crash and usability scores, although a few helmets scored highly in both areas. There was a correlation between scores for high and low energy tests onto the flat anvil (r=0.799). There was a negative non-significant correlation between helmet mass and average peak acceleration (g) for all three tests, r=-0.546, r=-0.414 and r=-0.204, high energy flat anvil, low energy flat anvil and high energy kerb anvil, respectively. The "A" weighted equivalent sound pressure level (Leq_A) was derived from wind tunnel tests. The minimum was 95 dB and the maximum 110 dB, with an average of 101 dB, demonstrating large differences in noise generation between helmets. For the eight 2011 CRASH helmets that had been assessed in the SHARP program, there was a modest correlation between the aggregate crash protection score and SHARP star rating (r=0.681).

The testing identified differences between helmets largely specific to each test, inferring that each test examined a unique performance aspect. Where possible scores were based on published human tolerance data, including noise, or derived from other standards. In some cases, tolerance data were extrapolated to suit the range of results obtained from the helmet tests, because reference data were not available. An oblique impact test is being considered for inclusion in the CRASH program.

The CRASH program provides motorcycle helmet performance and usability information that can assist motorcyclists in purchasing decisions. Further research and development is required to optimise the testing, scoring and rating system of the program, and the communication of results.

INTRODUCTION

Consumer focussed product safety evaluation programs can complement safety standards regimes and provide comparative safety performance information that influences purchasing decisions as well as driving improvements in safety performance, eg. New Car Assessment Programs. The CRASH program was developed for the Australian motorcycle helmet market.

Motorcycle ownership and usage in Australia has increased greatly in recent years. Between 2006 and 2011 the number of motorcycles registered in

Australia rose from 463,057 to 678,790, an overall increase of 48.5%. During a similar period, 2006 to 2010, the total distance travelled by motorcyclists rose from 1,641 to 2,394 million kilometres, an overall increase of 45.9% [1]. Although deaths as a proportion of registered motorcycles has steadily decreased from 2002 (6.04 per 10,000) to 2011 (2.96 per 10,000), the absolute number of annual Australian motorcyclist fatalities has fluctuated around 215 ± 25 between the years 2002 and 2011, and in 2011 comprised 15.6% of road user fatalities (201/1291) [2]. In addition to fatal injuries, there are hospitalised motorcyclists who may have a range of head injuries from concussion to diffuse axonal injury [3,4]. The 2011 IRTAD report provides a snapshot of the incidence of fatalities by road user groups across 32 countries and shows similar global trends [5]. Therefore, providing motorcyclists with information to assist in the purchase of the safest helmets represents one component of the safe systems approach to reducing motorcycle related trauma.

Research on the helmet performance characteristics that contribute to motorcyclist safety demonstrated the importance of: Crash protection (impact performance, head coverage, chin-bar, dynamic stability) and Ergonomic factors (usability, noise, fog resistance, ventilation, mass, aerodynamics, visibility and weather resistance). For example, Richter et al indicated that misuse of the helmet retention system and failures of the retention system were factors resulting in the loss of a helmet [6]. The authors also compared the head impact speed and impact location to ECE 22-4 in some cases. They observed that 90% of the impacts were below the ECE 22 test line. Such factors could be addressed through usability tests, head coverage, dynamic stability and dynamic retention strength. Although, Liu et al noted that there was "insufficient evidence to demonstrate whether differences in helmet type confer more or less advantage in injury reduction" in their 2004 meta-analysis of motorcycle helmet effectiveness studies; a methodological issue recognised by others [7,8]. Therefore, a program was developed to measure a range of motorcycle helmet safety and ergonomic characteristics on an annual representative selection of motorcycle helmets. Inputs into the development of the program included focus group meetings with motorcyclists, expert opinion and analysis.

For the helmet impact tests, head acceleration limits were derived for concussion, skull fracture and brain injury [9-13]. The boundaries for maximum and no score were based on, respectively, a 20% and 40% risk of fracture and AIS 3/4 head injury. After adjustment for the use of rigid headforms, the approximate 20% and 40% risk thresholds for fracture and AIS 3/4 head injury were 150 g and 250 g. For concussion, the limits were set between 80 g (≈60% risk) and 120 g (≈95% risk).

The objective of this paper is to report on the CRASH motorcycle assessment and rating program and the results for 2011-12 helmets. At the time of writing this paper, an embargo on the publication of individual make/model test results exists for 2012 helmets.

METHODS

Assessment and testing

The test protocols were developed using existing standards (UN/ECE 22, DOT 571.218, SNELL M2010 and AS/NZS 1698) as guidance, or adapted from standard protocols used in related fields (e.g. sound pressure level (SPL) measurement, aerodynamic loads and ventilation). Only one impact per helmet and test site was undertaken. The following tests were undertaken (Tables 1 and 2).

Table 1.
Description of crash protection test methods

Conditions	Measured
<u>Helmet Coverage</u> The amount of inner liner which extends outside the test line at the front, sides and rear is measured	Length (mm)
<u>Chin Coverage</u> Visual inspection	Presence of chin bar
Dynamic Stability AS/NZS 2512:2009 Section 7.2	Angle of rotation of helmet
<u>High Level Energy Attenuation</u> 2.5 m drop onto flat anvil as per AS/NZS 1698. Six impacts.	Peak centre of mass headform acceleration (g) and rebound height (mm)
<u>Low Level Energy Attenuation</u> 0.8 m drop onto flat anvil as per AS/NZS 1698. Six impacts.	as above
<u>Kerb Anvil Energy Attenuation</u> 2.5 m drop onto curb anvil as per AS/NZS 1698. Four impacts.	as above
<u>Dynamic Retention Strength</u> ECE 22.05 Section 7.6	Residual displacement (mm)

Scoring and Rating

After testing all measures were applied to a set of scoring criteria. Individual scores were summed to obtain a total score (Tables 3 and 4). Helmets were assigned stars for both safety and ergonomics according to the following criteria: Score < 30% 1 Star; 30 ≤ Score < 50% 2 stars; 50% ≤ Score < 70% 3 stars; 70% ≤ Score < 85% 4 stars; and, Score ≥ 85% 5 stars.

Table 2.
Description of ergonomic test methods

Conditions	Measured
Operation and fit (i) Standard protocol with ten questions and (ii) in-situ force to commence helmet displacement measured.	(i) Five point Lickert scale (ii) Forwards, Rearwards and Lateral Force (N)
Visor's ability to resist fog up BS EN 166:2002	Time until fogging (seconds)
Ability to seal out weather (splash) Adapted from AS 1337.1:2010 – Eye protectors for industrial applications, Method for the Determination of Splash Resistance	Proportion of unstained surface area.
Wind tunnel tests: SPL and Aerodynamic loads. KEMAR acoustic mannequin mounted in wind tunnel. Wind speed = 100 km/h. Measurements of SPL, ventilation and aerodynamic loads made: face-on with vents open and closed and at 45 degrees with vents open. Furness FC0510 micro manometer measured the pressure difference between a reference and pressure tapping points on (a) the tip of the nose and (b) the crown.	(i) SPL in Leq dB (A) (ii) Aerodynamic loads, Anterior-posterior and vertical forces (N) and bending moment (Nm) (iii) Ventilation pressure (Pa)
Mass Weighed on calibrated scales	Mass (kg)
Field of view UN/ECE 22	Distance (mm)

Helmets

All helmets in the sample were at the time certified to AS/NZS 1698. The helmet sample was derived from advice from wholesalers, retailers and consumers, as well as historical trends and coverage of specific categories of helmets: open face, open face + visor, full face, motocross, flip-up (Figures 1 to 6).

Testing

All tests derived from standards tests methods were performed at laboratories certified to undertake those tests. Aerodynamic and SPL tests were performed in a university operated wind tunnel (Figure 7). The National Acoustics Laboratories performed SPL measurements. The same six individuals performed operation and fit assessments in each year. Each person had an ISO "J" equivalent sized head and all tests were conducted with suitably sized helmets.

Figure 1. Exemplar full-face helmet

Figure 2. Exemplar flip-up helmet

Figure 3. Exemplar motocross helmet

Figure 4. Exemplar open-face helmet

Figure 5. Exemplar open-face + visor helmet

Figure 6. Exemplar dual sport helmet

Table 3.
Scoring and weighting criteria for crash protection criteria. Where otherwise not stated the score was calculated using a linear interpolation between the upper and lower criteria

Crash Protection	Criteria
Helmet Coverage	Max = 5%. Coverage < 225 mm = 0%. Coverage ≥ 307 mm = 5%
Chin Coverage	Chin bar present = 5%. No chin bar = 0%
Dynamic Stability	Max = 10%. Angle of Rotation ≤ 10° = 10% and > 30° =0%.
High Level Energy Attenuation	Max = 30% Score: Headform Acceleration (g) ≤150 = 25% and > 250 = 0%. Standard Deviation: If acc < 200, and SD < 10 g, then SD=0=5% & SD=10=0%
Low Level Energy Attenuation	Max = 15% Score: Headform Acceleration (g) ≤80 = 10% and >120 g = 0% Standard Deviation: a/a
Kerb Anvil Energy Attenuation	Max = 25% Score : Headform Acceleration (g) ≤150 = 20% and > 250 = 0% Standard Deviation: a/a
Impact Energy Rebound	Max = 5% Score: Coefficient of restitution ≤ 0.2 = 5% and > 0.3 = 0%
Dynamic Retention Strength	Max = 5% Score: Dynamic elongation (mm) ≤ 25 mm = 5% and > 40 = 0%

Figure 7. KEMAR acoustic mannequin mounted in wind tunnel.

Analyses

For the purposes of this report data have been de-identified. Descriptive statistics and correlations between performance measures are presented. All analyses were conducted using SPSS™ version 20.

RESULTS

In 2011 31 helmets were included in the program. In 2012 a further 30 helmets were included. A descriptive summary of the impact test results is presented in Table 5. The average peak headform acceleration for the 2.5 m flat anvil drops ranged from 146 g to 265 g; median 186 g. The average peak headform acceleration for the 0.8 m flat anvil drops ranged from 79 g to 132 g; median 99 g. Mean standard deviations for the three impact test types were in the range 6 g to 14 g. This indicates that helmet performance was relatively consistent for each test type. The mass range for the helmets was 0.957 kg to 1.957 kg with a median of 1.61 kg.

A descriptive summary of item and total safety scores for all 61 helmets is presented in Table 6. The median safety score was 59 (three stars) with a range from 21 (one star) to 76 (four stars). Helmets performed best against the following criteria: coverage, and both high impact energy tests and standard deviations. Helmets performed worst against the following criteria: low impact energy, dynamic strength of the retention system and rebound (coefficient of restitution).

Table 4.
Scoring and weighting criteria for ergonomic criteria. Where otherwise not stated the score was calculated using a linear interpolation between the upper and lower criteria.

Ergonomics	Criteria
Operation and fit	Max 20%. Summed and average of responses.
Visor's ability to resist fog up	Pass = 20%. Fail= 0%
Ability to seal out weather (splash)	Max 5%. Proportional to surface area unstained.
Noise inside the helmet	Max 20%. SPL (dB) ≤ 90 = 20% and > 110 = 0%.
Ventilation	Max 15%. Score=0.1 average pressure difference
Aero-dynamic neck loading	Max 10%. Neck force ≤ 5 N = 5% and > 43.5 N = 0%. Neck moment ≤ 0.435 Nm = 5% and > 2.175 Nm = 0%
Mass	Max 5%. Mass ≤ 1kg = 5% and > 2 kg = 0%
Peripheral view	Max 5%. Mid sagittal aperture measured. 5% > 20 mm.

Table 5.
Summary of impact test results (n=61 helmet models)

	Median	Mean	SD	Min	Max
High Impact Energy - Average Peak Acc. (g)	186	188	22	146	265
High Impact Energy - Standard Deviation (g)	10	14	9	1	37
Low Impact Energy - Average Peak Acc. (g)	99	101	11	79	132
Low Impact Energy - Standard Deviation (g)	6	7	4	2	24
High Impact Energy - Kerb - Average Peak Acc. (g)	160	164	16	134	201
High Impact Energy - Kerb - Standard Deviation (g)	5	6	4	0	15
Helmet Mass (kg)	1.6	1.5	0.2	1.0	2.0

Table 7 presents correlations between the crash protection scores. A bivariate correlation was undertaken with two-tailed tests of significance. Although many of the correlations were significant, the pearson correlation statistic (r) values for the pairwise comparisons indicated generally weak to moderate correlations. The strongest correlation ($r=0.799$, $p<0.01$) was between the average peak acceleration scores for the 2.5 m flat anvil and 0.8m flat anvil impacts. There was a negative non-significant correlation between helmet mass and average peak acceleration (g) for all three tests, $r=-0.546$, $r=-0.414$ and $r=-0.204$, high energy flat anvil, low energy flat anvil and high-energy kerb anvil, respectively.

Table 6.
Summary of crash protection scores, total score and star rating (n=61)

	Median	Mean	SD	Min	Max
Coverage	9.3	7.7	3.2	0.0	10.0
Dynamic Stability	5.7	5.8	2.7	0.0	10.0
High Impact Energy - Average Peak Acc. Score	16.0	15.5	5.2	0.0	25.0
High Impact Energy - Standard Deviation Score	0.0	0.7	1.1	0.0	4.3
Low Impact Energy - Average Peak Acc. Score	5.3	4.9	2.6	0.0	10.0
Low Impact Energy - Standard Deviation Score	0.8	1.3	1.4	0.0	4.2
High Impact Energy - Kerb - Average Peak Acc. Score	17.9	17.1	2.9	9.7	20.0
High Impact Energy - Kerb - Standard Deviation Score	2.5	2.2	1.5	0.0	4.8
Coefficient of Restitution	0.4	0.8	1.0	0.0	3.9
Dynamic Strength	1.2	1.2	1.1	0.0	4.5
Total Score (%)	59.0	56.9	13.0	21.0	76.0
Star Rating	3.0	2.9	0.7	1.0	4.0

Table 7.
Correlations between crash protection scores. Pearson correlation statistic presented in cell.
*** p<0.05; ** p<0.01**

	A	B	C	D	E
(A) High Impact Energy - Average Peak Acc. Score					
(B) High Impact Energy - SD Score	.265*				
(C) Low Impact Energy - Average Peak Acc. Score	.799**	.314*			
(D) Low Impact Energy - SD Score	.614**	.268*	.684**		
(E) High Impact Energy - Kerb - Average Peak Acc. Score	.589**	.350**	.555**	.301*	
(F) High Impact Energy - Kerb - SD Score	0.055	0.004	0.158	0.183	0.246

Table 8 presents a descriptive summary of the individual and total ergonomic scores, plus the star rating. The median safety score was 52 (three stars) with a range from 32 (two star) to 77 (four stars). Helmets performed best against the following criteria: splash resistant (Figure 8), neck loads and ventilation. Helmets performed worst against the following criteria: resistance to fogging and noise.

In absolute terms the in-helmet noise measured in the wind tunnel at 100 km/h was high. The median weighted average of the three conditions was 100 dB, with a range from 95 dB to 110 dB.

Figure 8. Post Splash testing of helmet.

Table 8.
Summary of ergonomic test scores, final score and star rating (n=61)

	Median	Mean	SD	Min	Max
Helmet Fit and Operation Score	12.5	12.4	1.6	8.8	15.1
Splash Score	5.0	3.9	1.7	0.0	5.0
Fog Score	0.0	5.9	9.2	0.0	20.0
Noise Score	10.0	9.2	3.7	0.0	15.0
Ventilation Score	9.9	10.2	3.4	3.1	15.0
Neck Force Score	3.7	3.6	0.6	1.3	4.6
Neck Moment Score	3.3	3.0	1.5	0.0	5.0
Helmet Mass Score	3.0	3.4	2.0	0.2	9.6
Peripheral View Score	3.4	3.2	1.8	0.0	5.0
Ergonomic Total Score	52.0	54.6	11.0	32.0	77.0
Ergonomic Star Rating	3.0	2.7	0.7	2.0	4.0
Summary SPL (dB)	100.0	100.8	3.7	95.0	110.0

Correlations between the individual ergonomic scores were generally weak to moderate (Table 9). The correlation between the total safety scores and total ergonomic scores was weak and not significant (r=0.252).

DISCUSSION

The results of an extensive battery of performance tests on 61 motorcycle helmets are presented. All helmets were certified to AS/NZS 1698: 2006, which includes a resistance to penetration test. It was challenging to obtain reliable information on compliance of each helmet to other standards, although SNELL certification is routinely attached where appropriate in the Australian market. For the eight 2011 CRASH helmets that had been assessed in the United Kingdom's SHARP program, there was a modest correlation between the aggregate crash protection score and SHARP star rating (r=0.681). Therefore, the CRASH program and SHARP differ in some regards.

Table 9.
Correlations between ergonomic test scores. Pearson correlation statistic presented in cell. * p<0.05; ** p<0.01

	A	B	C	D	E
(A) Helmet Fit and Operat-ion Score					
(B) Fog Score	-0.07				
(C) Splash Score	.456**	-0.25			
(D) Noise Score	.270*	-0.02	0.17		
(E) Ventilat-ion Score	0.11	0.09	0.10	-0.01	
(F) Neck Force Score	0.18	0.17	0.13	.317*	0.19

The weak to medium level of correlation between individual scores provide some support for the value in undertaking the wide range of tests. This suggests that each test is a measure of a unique characteristic. In addition each test was included because it was considered to be an important factor in crash protection performance and ergonomics. Both areas are considered to contribute to overall levels of safety. In the longer term, feedback from motorcyclists will assist in understanding how useful each test it in terms of influencing purchasing decisions. Brand related responses to the CRASH program through performance improvements might also be a barometer of the weighting helmet manufacturers place on the program and specific elements.

The high correlation between headform accelerations for the high impact energy and low impact energy flat anvil impacts indicates the potential for manufacturers to produce helmets that perform equally well across a range of impact severities. This information is valuable for consumers as it indicates that a 'safe' helmet need not necessarily be tuned to a specific type of use – commuter or touring, freeway commuting or inner city commuting. This is also valuable contribution to discussions regarding helmet standards, where there has often been comment on the need for more compliant foams to accommodate low severity impacts. No strong correlations were observed between ergonomic and crash protection scores. This suggests that there are opportunities for manufacturers to improve the helmets in areas that benefit the public and improve the CRASH performance. Although not proven by these tests, they indicate that a manufacturer could helmet ergonomics that might improve the experience of wearing a helmet without those changes necessarily reducing safety. Both safety and ergonomics could be improved.

Discussions are ongoing regarding the inclusion of an oblique impact test into the CRASH program [14,15]. Two helmets from the 2011 CRASH program were included in a series of oblique impact tests (horizontal speed 35 km/h drop height 1.5 m) [14]. The CRASH program identified the ratio of the average maximum headform acceleration in the high-energy flat anvil acceleration for the two helmets to be 1.40. Ratios for peak headform linear and angular accelerations in the oblique tests were in the range 1.4 to 1.50. At face value this provides a strong indication of consistency between the forms of assessment and might suggest that oblique impacts may not add more detail. Further research is required.

The tests conditions for the wind-tunnel tests were discussed extensively. The final test conditions were determined after consideration for budget, time, and how well the conditions represent riding conditions. The head and neck posture in these tests is upright. It is acknowledged that each motorcyclist will adopt different postures depending upon the type of motorcycle, the environment, their ability, and personal preferences. It is intended that the aerodynamic scores will provide some general guidance.

Ventilation measurements were also challenging. Other measures, e.g. heat dissipation, were considered, but were not compatible with the single test set-up for measuring SPL, aerodynamics and ventilation. Further work is required to compare the results of the testing to date with other measures of ventilation. However, the results do indicate the comparative level of airflow through the helmet.

The helmet tests highlighted the issue of in-helmet noise. The observation that the median SPL was 101 dB for an equivalent road speed of 100 km/h identifies the need to advise motorcyclists about methods to mitigate the short and long term effects of this exposure through the use of ear plugs, for example, or to advocate for 'quieter' helmets [16]. In addition to long term hearing loss, exposure to high noise levels may lead to temporary hearing impairment with safety implications for motorcyclists.

More generally, public feedback is required to ensure that the CRASH program is delivering helmet information to the public that is meaningful, both in terms of content and delivery.

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A study of dummy kinematic and restraint system for IIHS Small overlap

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ABSTRACT

The IIHS (Insurance Institute for Highway Safety) introduced the small overlap frontal crash test in 2012. The small overlap frontal crash performance is evaluated in terms of injury assessment, structural assessment, and restraint and dummy kinematics. The test involves limited horizontal structural engagement at the corner. The small overlap condition is designed such that longitudinal structural members of vehicle have less interaction than during the IIHS' moderate overlap frontal test. Dummy kinematics can be affected if the structure does not absorb the crash impact energy or the driver airbag is not in position to provide restraint to the head. In the IIHS Status Report newsletter (Issue 47, No. 6 August 14, 2012) the IIHS' small overlap test results showed that most of the injury assessments were similar to that of the IIHS' moderate offset crash tests. However, vehicle structure and dummy kinematics were more severe in the small overlap as compared to the IIHS' moderate offset crash test. This study provides restraint system development guidance for dummy head protection in the IIHS' small overlap crash condition.

INTRODUCTION

Today many countries have motor vehicle regulations and Consumer Metric tests with the objective of reducing traffic fatalities. In the US, the NHTSA (National Highway Traffic Safety Administration) established the FMVSS (Federal Motor Vehicle Safety Standard) 208 for Occupant crash protection. This safety standard is frequently amended and supplemented. In terms of consumer information, NHTSA's NCAP (New Car Assessment Program) and the IIHS' crash tests evaluate vehicle crash performance to reduce injuries and fatalities. When an automotive manufacturer launches a new vehicle, safety crash tests are conducted to evaluate crashworthiness and occupant protection. Consumers may consider the vehicle's available crashworthiness information in their vehicle purchase decisions. It is therefore advantageous for automotive manufacturers to have good vehicle crashworthiness and restraint system performance. Manufacturers install and develop airbags, safety belt and other restraint systems, as well as the vehicle structure to provide occupant protection

In a study published by Rudd [2009], the combination of seat belt use and frontal air bags reduces front seat occupants' fatality risk by an average of 61 percent compared to an unbelted occupant in a vehicle without frontal airbags.
NHTSA's FMVSS208 requirements include rigid 0^o to 30° angle barrier impacts with unbelted test dummies at speeds ranging from 32km/h and 40km/h. FMVSS208 also includes belted test dummies in a rigid barrier test at speeds ranging from 0 to 56kph. IIHS conducts 40% offset deformable barrier crash tests with a belted driver at 64 km/h. Through these efforts, consumers have had available to them safer vehicles from which to choose.

In the tests which are conducted for FMVSS208 and NCAP, and the IIHS 40% offset deformable barrier test, the vehicle's longitudinal energy-absorbing structure is able to absorb the crash energy. Also, the direction of the impact force is around twelve o'clock which results in mostly forward occupant trajectories and therefore good engagement with the driver airbag and safety belt. Today, a large majority of new vehicles are receiving the top level of crash performance rating, and the occupants are well protected.

However, in case of the IIHS' small overlap, the extreme offset results in significant lateral rotation of the vehicle relative to the occupant. The longitudinal energy-absorbing structure can be missed entirely and therefore other parts of the vehicle must absorb and deflect the crash energy. Also the direction of impact force in a corner impact is not only from twelve o'clock. The driver dummy could sometimes have less interaction with the frontal airbags as they moved forward and laterally relative to the vehicle interior. A-pillar, dash and toe-pan intrusion can exacerbate the severity for the dummy as compared to the 40% overlap condition.

The paper "Fatalities in Frontal Crashes Despite Seat Belts and Air Bags – Review of All CDS Cases – Model and Calendar Years 2000-2007 –122 Fatalities" DOT HS 811 202, explained the factors influencing the outcome of fatal crashes using data from the NASS CDS (Crashworthiness Data System of the National Automotive Sampling System). The paper describes a primary factor as a necessary condition at or just after the crash which contributes to the fatal outcome, and a secondary factor as increased risk and consequences, sometimes a result of a primary factor.

Figure1 and Figure 2 show each factor weight for the population of fatal crashes studied.

From Figure 1, 78% of the crashes had "crash configuration" or "crash partner" as the primary factor. It shows that the crash configuration is a key factor for the fatal outcome. Extreme offset and corner impacts with other vehicles are examples of crash configurations classified as a primary factor.

From Figure 2, 22% of the crashes had "restraint performance" as the secondary factor.

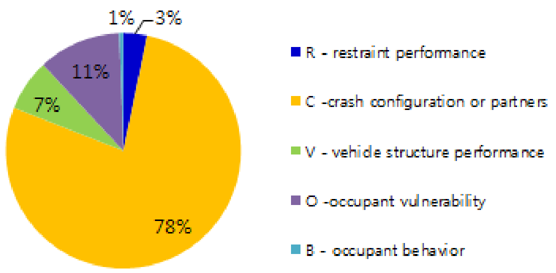


Figure1. Primary factor

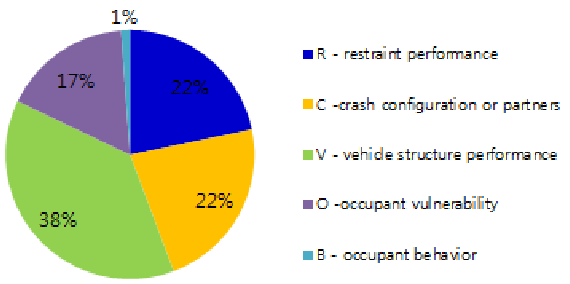


Figure2. Secondary factor

Figure 3 shows the importance of occupant and airbag interaction. Poor occupant-airbag interaction is a factor in 32% of the fatal crashes.

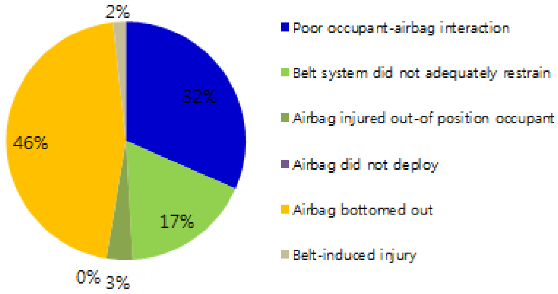


Figure3. Restraint performance factor

IIHS recently released small overlap crash test (25% overlap of a car's width on the driver side striking a rigid barrier at 64 km/h) protocol. The protocol includes assessment of the dummy restraint and kinematics (Table1.)

Table1.
Restraint and dummy kinematics demerit

Frontal head protection	
Stable frontal airbag interaction, or Partial frontal airbag interaction, or Minimal frontal airbag interaction	0 demerits 1 demerit 2 demerits
Excessive lateral steering wheel movement (>10 cm)	1 demerit
Two or more hard head contacts with structure	1 demerit
Late deployment or non deployment of frontal airbag	Automatic poor
Lateral head protection	
Side head protection airbag deployment with sufficient forward coverage, or Side head protection airbag deployment with limited forward coverage, or No side head protection airbag deployment	0 demerits 1 demerit 2 demerits
Excessive head lateral movement	1 demerit
Frontal chest protection	
Excessive vertical steering wheel movement (>10 cm)	1 demerit
Excessive lateral steering wheel movement (>15 cm)	1 demerit
Occupant containment and miscellaneous	
Excessive occupant forward excursion	1 demerit
Occupant burn risk	1 demerit
Seat instability	1 demerit
Seat attachment failure	Automatic poor
Vehicle door opening	Automatic poor
Overall restraint and dummy kinematics rating	
Good	0-1 demerits
Acceptable	2-3 demerits
Marginal	4-5 demerits
Poor	6+ demerits

The purpose of this study is to provide restraints system development guidance for improved driver dummy head protection in the IIHS' small overlap test.

METHOD

IIHS' Status Report newsletter (Vol. 47, No. 10 December 20, 2012) published the test results of small overlap crash tests conducted using 18 midsize vehicles. Some vehicles received a "Good" rating for restraints and dummy kinematics. The vehicles which the IIHS rated "Good" for restraints and dummy kinematics were studied to find ways to improve head-to-airbag interaction. The body

intrusions for A-Pillar and IP structure, and column movement were rated acceptable.
The driver airbags in the 18 small overlap test vehicles varied widely in appearance. Two examples are shown in “Figure 4”.

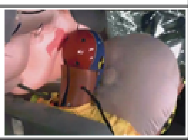
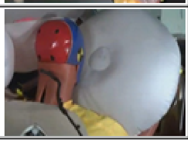
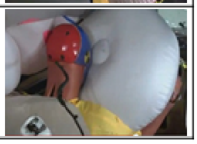
Structure	Restraints & kinematics	Fully deployed	Loading
Acceptable	Good		
Acceptable	Good		

Figure4. Driver airbag type each automaker

An occupant CAE model was constructed to represent a typical small car. The interaction of the dummy’s head with the driver airbag was studied in order to understand the effect of changing the airbag depth and width in the IIHS small overlap condition. The dummy lateral head excursion was studied in sled tests. The IIHS small overlap condition results in increased lateral displacement of the vehicle as compared to the IIHS’ moderate offset crash. In the sled tests, identical driver airbags were used, and the sled buck angle was adjusted in order to compare dummy kinematics in two different impact angles. The ability to affect the driver dummy head through the driver airbag was evaluated.

ANALYSIS

- **Occupant CAE result**

In the occupant CAE evaluations, we investigated methods to increase driver head to airbag interaction. The driver dummy in the small overlap condition moves forward and laterally, with respect to the vehicle, more than during the moderate offset crash tests. The driver airbag is important to protect the driver in frontal impact crashes. But a small offset crash in the field with a significant oblique component or no engagement of the longitudinal member may result in lateral dummy displacement and less engagement with the driver airbag. Based on the driver airbag shape variation observed in the 18 IIHS tests, it was decided to investigate the effect of airbag volume.

Table2 shows the airbag design concepts evaluated with the CAE model. The base (Case #1) and an airbag with 6% increased cushion volume (Case #2) were evaluated. The same airbag inflator was used, and the vent hole size was the same in the two airbag CAE models. There are many techniques to affect the airbag volume. For this study, the 6% airbag cushion volume increase was obtained through a 12% increase in the depth and a 4% increase in the diameter of the airbag, in an inflated condition.

Table2.
Airbag design concepts

	CASE#1 (Base cushion volume)	CASE#2 (6% increased cushion volume)
Depth	Base	Base + 12%
Width	Base	Base + 4%

To evaluate the effect of airbag volume, the displacement of dummy head in both the forward X-direction and the lateral Y-direction was monitored. Figure 5 shows the schematic of the dummy’s head motion in the occupant CAE. Point A is the initial point at the head CG (center of gravity) at 0ms. Line BC indicates forward movement of the dummy’s head CG. Line AB represents lateral movement of the dummy’s head CG.

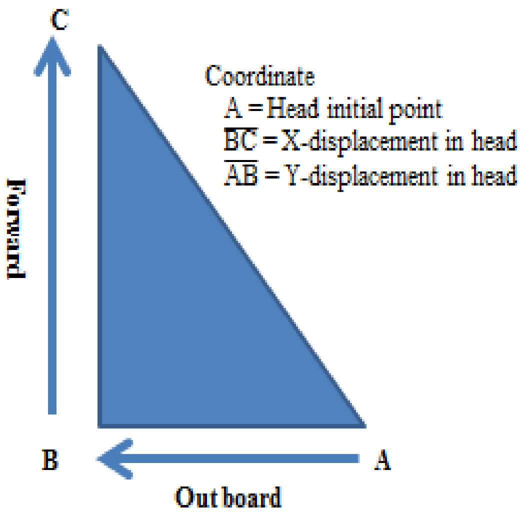


Figure5. Measurement in CAE of dummy head displacement

Figure 6 shows the dummy kinematics in the IIHS small overlap condition as a result of the two airbag volumes. Blue color, Case #1, is the small width and depth, and red color, Case #2, is the large width and depth. The larger volume airbag in Case #2 resulted in reduced occupant forward excursion in the IIHS small overlap condition.

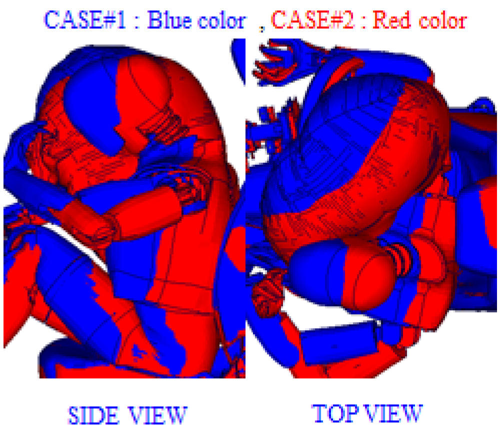


Figure6. Effect of driver airbag volume

Figure 7 shows the head CG forward displacement and lateral (outboard) displacement. Forward displacement was reduced by 23% with the larger volume airbag. Lateral displacement increased by 15%.

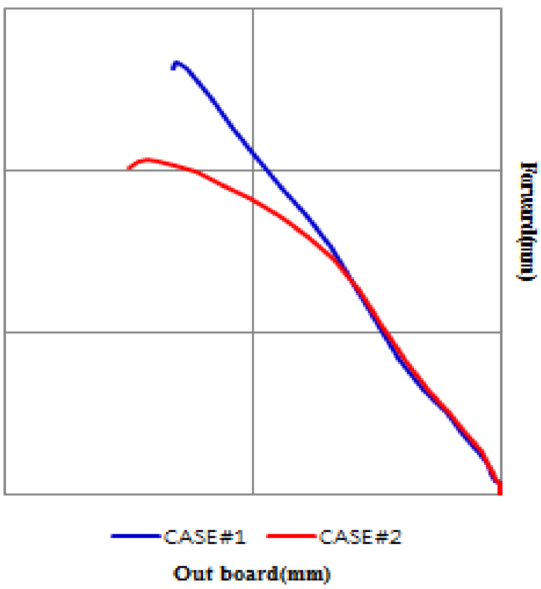


Figure7. Head forward and lateral displacement

Figure 8 shows that the larger volume airbag has more interaction with the dummy's head.

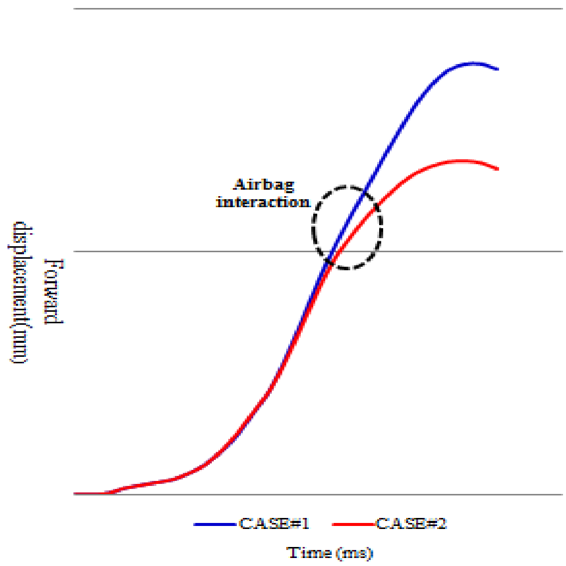


Figure8. Head forward displacement versus time

Figure 9 shows lateral displacement of the dummy's head CG. Lateral displacement of the head increased with the larger volume airbag in this IIHS small overlap condition. Additional countermeasures to reduce lateral displacement may be desired.

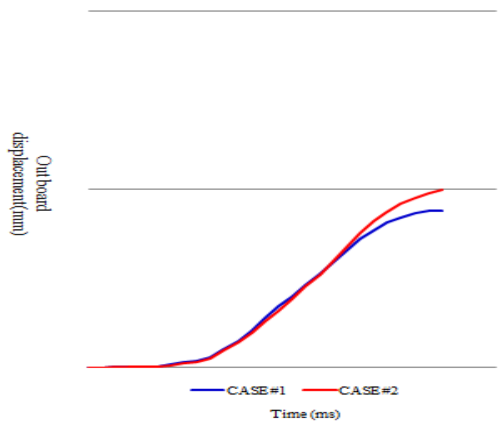


Figure9. Head lateral displacement versus time

These CAE simulations show that in the IIHS small overlap condition, the increased driver airbag cushion volume could affect the dummy's head forward displacement. This is due to more interaction between the dummy and the airbag, even though the larger volume airbag has lower internal pressure.

- **Sled test result**

From the occupant simulation study result, we observed that occupant forward kinematics may be improved by increased airbag volume.

The paper "Injury analysis of real-world small overlap and oblique frontal crash" (Number 09-0555 ESV) studied occupant fatal injury severity in co-liner and oblique condition. It shows an oblique condition is more severe than co-liner condition at the occupant's head region.

We studied the influence of vehicle rotation angle (Yawing) during small overlap crash condition with sled tests. The yawing can be expressed by rotating sled buck angle. We conducted a sled test to check the forward & lateral occupant kinematic influence with same restraints system (airbag and safety belts) according to the different sled buck angle.

Table3 shows the angle variation in the buck. Sled tests were conducted using the same longitudinal deceleration pulse, but with the buck rotated on the sled fixture.

Table3.
Angle variation in buck

No.	Angle variation in buck
CASE#3	Base angle
CASE#4	Base angle + 6degree

Figure 10 shows the instrumentation used to measure occupant excursion in the sled tests. IIHS' latest protocol and excursion template were used.

Figure10. Occupant excursion measurement

As shown in Table4, dummy forward excursion decreased by 4%. But lateral occupant excursion was increased by 28%. Increasing buck angle influenced the lateral movement more than forward movement.

Table4.
Dummy excursion

	Angle variation	Dummy excursion	
		Forward	Lateral
CASE#3	Base angle	Baseline	Baseline
CASE#4	Base angle + 6degree	-4%	+28%

Figure 11 shows occupant front view in sled test. Left side is the CASE#3 (base angle) and right side is the CASE#4 (base angle + 6 degree) motion for occupant. The dummy head in the CASE#4 moved in the lateral direction closer to the A-pillar.

Figure11. Front view

It was observed that the side curtain airbag prevented dummy head from hitting the A-pillar.
Although the small overlap is a frontal crash event, the lateral component is important to comprehend in order to improve occupant kinematics and protection.

CONCLUSIONS

This study, though limited in scope, showed that dummy forward excursion in the IIHS Small Overlap condition can be improved with a 6% larger volume driver airbag. The dummy's head was also observed to interact with side curtain airbag, indicating potential for further excursion improvements in this area.

The effect of increased airbag volume would need to be evaluated in the US NCAP frontal impact, IIHS moderate overlap impact and the belted and unbelted FMVSS208 conditions, including the driver low risk deployment conditions. The driver airbag needed to balance the small overlap crash test in addition to existing crash tests might be sophisticated and complicated.

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NEW NCAP TEST AND ASSESSMENT PROTOCOLS FOR SPEED ASSISTANCE SYSTEMS, A FIRST IN MANY WAYS

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Paper Number: 13-0277

ABSTRACT

Exceeding the speed limit is a factor in the causation and severity of many road accidents. Speed limits are intended to assure safe operation of the road network by keeping traffic speeds to no more than the maximum that is appropriate for a given traffic environment. The speed of traffic also influences the flow of densely trafficked roads.
Voluntary speed assistance systems (SAS) are a means to support adherence to speed limits, by warning and/or effectively limiting the speed of the vehicle. The only technical requirements giving guidance for elements of such devices are laid down in UN/ECE Regulation 89, which is not mandatory in Europe. Those specifications are rather outdated and do not specifically apply to passenger cars.
Since 2009, Euro NCAP has rewarded manually set speed limitation devices (SLD) which meet the basic requirements of UN/ECE R89 but have additional functionality with regards to warning and set-at-speed.
In the meantime more advanced speed assistance systems have been introduced onto the market which are able to inform the driver of the current speed limit based on digital maps and/or camera based traffic sign recognition. Intelligent speed assistance (ISA) systems are expected to improve and will be more readily acceptable to the public. Hence, Euro NCAP has extended the SLD protocol to include the evaluation of the latest generation of intelligent speed assistance systems.
The work of Euro NCAP is soundly based on a synthesis of previous research findings regarding speed assistance systems, including Carsten et al., Oei and Polak, Biding and Lind and others. Functional requirements for the Speed Limit Information Function (SLIF), Manual Speed and Intelligent Speed Assistance systems (MSA and ISA) have been derived using input from various stakeholders. Recent experiences with Euro NCAP's SLD assessment have been included. Besides functional requirements, a set of agreed driving manoeuvres has been defined, in particular to verify the driver-set limitation function. The draft procedures have been evaluated in a workshop with several commercially available and prototype systems.
Test and assessment protocols have been developed that contain specifications for different types of Speed Assistance Systems (SAS), SLIF up to full ISA systems where the SLIF is coupled with the warning and speed limitation function.
Points are available for all elements of SAS with additional points awarded to systems where the speed information is directly linked to the warning and speed limitation function.
The requirements specified in the developed protocols are not design restrictive, to allow the vehicle manufacturer to develop the systems to their best knowledge and experience. It is foreseen that, after a couple of years, Euro NCAP will tighten the requirements based on best practice. As more and more countries are introducing more strict speed managements systems the consumer demand for reliable and efficient SAS is expected to increase.

BACKGROUND

With the introduction of the new rating scheme in 2009, Euro NCAP opened a whole new area of assessment; Safety Assist systems. At the start of the new rating scheme, this "Box" consisted of Seatbelt Reminder systems (SBR), Electronic Stability Control (ESC) and Speed Limitation Device (SLD).
To take into account the fast introduction of forward looking cameras with traffic sign-recognition in new vehicles, Euro NCAP already included an extension of their SLD protocol in their roadmap in 2009.
For the development of the ISA protocols, a separate Working Group was founded under the chairmanship of the Swedish Transport Administration.

The initiative was taken as a response to the introduction of cars with the ability to present speed limit information to the driver. As this information is no longer displayed by aftermarket products only, but also by the car itself, it is of interest to assess. Additionally, the initiative was motivated by the possible benefits of health loss reduction due to speed adaptation shown by earlier studies and discussed below.

The members of this WG consisted of Euro NCAP members and laboratories, vehicle manufacturers representing ACEA, JAMA and KAMA, and the two main digital map suppliers.
New to any Euro NCAP WG was the participation of Australasian NCAP (ANCAP), which supported the meetings based on Australian experience with a variety of ISA systems. The ANCAP Road Map promotes the uptake of promising safety assist technologies, including ISA. Furthermore several ANCAP stakeholders are participants in the Australasian Intelligent Speed Assist Initiative (AISAI) which stimulates the development and implementation of ISA technology in Australia and New Zealand [3].

SWEDISH STUDY

The relationship between driving speed and crash/injury risk has been extensively studied. While the causal role of speed in road injury crashes can be difficult to quantify, exceeding the speed limit is a frequently cited traffic offence and is responsible for many severe road accidents [4]. Speeding has also been recognized as a major public health issue. The Organization for Economic Co-operation and Development (OECD) and the European Conference for Ministers for Transport (ECMT) has reported it to be the number one road safety problem around the world.

Earlier research on ISA is based primarily on field operational tests in Sweden, UK and the Netherlands. The largest field experiment until now was in Sweden 1999-2002 where approximately 5.000 cars and 10.000 drivers participated. Interviews were used to investigate the driver acceptance of ISA and 700 of the vehicles had data logging. In the Netherlands 20 cars were equipped with forcing ISA and driven by 120 drivers during eight weeks in 1999-2000. The field test in UK consisted of one fleet of 20 vehicles driven for two years with a total of eighty participants [5]. Simulations and modeling has also been made in the Netherlands and smaller projects have been made in Denmark, Finland, France, Spain, Australia and China [6].

Effects on speed adaptation

Results from field trials show a reduction on average travel speed and a smaller speed distribution with ISA. The test in Sweden showed an average speed reduction of 3-4 km/h and generally smoother driving with less variation in speed. However, travel times were unchanged, probably due to fewer stops. In addition ISA showed a calming effect on other road users [7]. In a review made by SWOV it was concluded that ISA contributed to an average speed reduction of 2-7 km/h depending on type of ISA. ISAs with forced feedback were more effective than advisory systems. ISA also reduced the number of speed violations and reduced the speed variation [8]. In the UK trial, ISA diminished excessive speeding, but reduced also the speed variation [5]

Effects on injuries

The most cited study was made in England were 100 percent implementation and no behavioral adaptations were the basic assumptions [9]. Results show that an advisory ISA with fixed speed limits is estimated to have an effect of 14 percent reduction in fatal and serious accidents. The argest effect was estimated with a dynamic mandatory ISA, 59 percent reduction in fatal accidents.

Similar studies in the Netherlands, which has made the assumption of 100 percent coverage with mandatory ISA and fixed speed limits, shows similar results; a reduction of severe accidents of 25-30 percent. This study however shows some indications of a more risky behavior with shorter distance to the vehicle in front [10].

AUSTRALIAN STUDIES

Australia has been conducting research on ISA and speed limiting of vehicles since the 1990s. A summary of research and trials is presented by Paine [11]. In 2010 the New South Wales Centre for Road Safety conducted a comprehensive ISA trial in the Illawarra region of East Australia. Doecke and others [12] analysed the results of the trial and applied the findings to predict the savings that advisory ISA could be expected to produce for state government car fleets. It was estimated that casualty crashes could be reduced by 20%.

Using in-depth crash study data for Australia, Doecke and others [13] estimated the reductions in casulty crashes by eliminating various levels of speeding. They concluded that the greatest benefits arise from targeting low-level speeding. That is, speeds of 1km/h to 5km/h over the speed limit. This is range where conventional speed enforcement is not effective. Voluntary speed compliance, supported by ISA, would be effective for low-level as well as high level speeding. The study built on earlier research which showed that reducing collision speeds by just a few km/h can markedly reduce the risk of serious injury. In Australia many motorists tend to travel slightly over the speed limit and this is reflected in the collision speeds determined from in-depth crash studies. It was shown that encouraging this group to not exceed the speed limit would have reduced the collision speeds sufficiently to change a fatal or serious crash into a less serious one.

ASSESSMENT PROTOCOL

As a starting point to achieve the above, the requirements within the assessment protocol are not design restrictive to allow the vehicle manufacturers to develop the systems to their best knowledge and experience.
The Speed Assist Systems assessment protocol is developed in such a way that it allows different types of Speed Assist Systems to be assessed. It foresees four different elements of systems:

- Speed Limit Information Function (SLIF)
- Manual Speed Assistance systems (MSA)
- Systems consisting of both SLIF and MSA but not coupled
- Intelligent Speed Assistance (ISA), where SLIF and MSA are coupled

Car manufacturers may develop systems delivering all or some of the elements listed above.

SLIF

Only basic requirements have been set for the Speed Limit Information Function. For this function, camera or map based systems are considered as well as the combination of both, which is potentially more accurate. It is should be noted that, for map based systems, the speed limit information could either be provided by vehicle-integrated devices or by mobile devices connected to the vehicle network. To be eligible for points in the scoring for the latter, a list of compatible devices needs to be mentioned in the vehicle handbook.
Most important for SLIFs is to show the maximum allowed legal speed at the location and in the circumstance the car is driving. The system needs to display this within direct field of view of the driver and as long as the speed limit is assumed to be valid.
For map-based systems, a short report is required where the OEM details the accuracy of the maps used, the coverage and reliability of these maps and the ready-to-assist rate. With this information, Euro NCAP will in future protocols set more stringent requirements on the maps used to ensure the best possible information to the consumers.

Manual Speed Assist

The manual speed assist is a function that the user activates to limit the speed of the car to a specified value. This part of the protocol is mainly derived from the previous SLD protocol. The SLD protocol covered passive SLD, which are now called the MSA warning function, and the active SLD, which is now called the MSA speed limitation function. The old protocol also allowed additional points to be scored for good warnings and set-at-speed. These items are now incorporated in the MSA requirements.
The warning function needs ~~a~~ to consist of a visual warning combed with a supplementary warning, e.g. audible, haptic or head-up display. The visual warning needs to be shown for the duration of the time that the vehicle speed indicated by the speedometer exceeds the speed the driver has set (Vadj), for more than 3 km/h.
The supplementary warning may have a shorter duration, not to annoy the driver when he intentionally increased the speed without applying a positive action. The total duration of the additional warning is at least 10 seconds that can consist of a positive signal of 2 seconds every 30 seconds.
The speed limitation function will prevent the driver from exceeding the set speed by reducing the throttle input to the engine. However, in some situations the engine brake is not sufficient and either a warning or actively applying the brakes is required to avoid the vehicle going over the speed set. From the old SLD protocol, only two requirements remain. Within stable speed, this stable speed may not vary more than 3km/h and the stable speed shall not exceed the speed set, to which the driver wants to be limited, by more than 3km/h.

Intelligent Speed Assist

New to the protocol are the requirements regarding ISA. An intelligent system, where SLIF and MSA are combined, is the best system to help the driver to adhere to the speed limit. Any change in speed limit will be indicated to the driver by the SLIF and is adopted by the ISA system. It is acknowledged that the performance of the ISA systems primarily depends on the accuracy of the SLIF. That is why for the moment, a driver confirmation to adjust to the newly proposed speed limit is allowed. In future, when the quality of SLIFs improve, an automatic ISA may be required. The warning and speed limitation function have the ~~exact~~ same requirements as for the MSA system described earlier.

TESTING SPEED ASSIST SYSTEMS

At present it is not feasible to verify the complete coverage of the SLIF as Euro NCAP requires the system to be available in all EU-27 countries as an option. A rudimentary check is performed by the laboratories to verify the functionality of the SLIF rather than to verify its accuracy. To do so, the laboratories will drive at least 100km on different types of roads and will determine whether there are any inconsistencies between the speed limit indicated by the SLIF and the actual speed limit as indicated by traffic signs. This information is also

gathered to be able to derive more stringent requirements for future protocols.
The MSA is tested at three different speeds: 50, 80 an 120 km/h. These are representative of the different road types within Europe. The warning is simply assessed by setting the speed and exceeding them. The speed limitation function is verified by setting the speed and accelerating the vehicle without applying a positive action. When the speed limitation function is engaged, the speed is maintained for at least 30 seconds to be able to determine the stabilized speed.
When fitted to the vehicle, the ISA system is simply verified to ensure that the speed limits from the SLIF can be taken over by the MSA.
One difficulty is finding closed roads where the operation of the speed limiting system can be verified without exceeding the posted speed limit on a public road.

SCORING

Points can be scored for the SLIF, the Warning function and the Speed Limitation function separately as shown in Table 1.
A digital map based system is awarded half of the available points, while a camera based system scores only 0.25 out of 1 as it is thought that the digital map based system is able to provide more reliable speed limit information. Only the combination of both can score the full point as this is seen as the optimal system that is able to cover both permanent and temporary speed limits.
When the SLIF and MSA are linked to have ISA functionality, the Warning function score doubles.

Table 1
SAS Scoring overview

	SLIF	MSA	ISA
Communicating speed limit	**1.00**		**1.00**
Camera based	0.25		0.25
Digital Map based	0.50		0.50
Camera and Digital Map combined	1.00		1.00
Warning Function		**1.00**	**2.00**
Speed Limitation		**1.00**	**1.00**

PROTOCOL LIMITATION

The requirements specified in the developed protocols are deliberately not design restrictive, to allow the vehicle manufacturer to develop systems to their best knowledge and experience, especially in the area of HMI.
With regards to the SLIF requirements, Euro NCAP acknowledges that the geographical coverage and map quality varies significantly within the EU-27 countries. It is expected that, due to initiatives like EuroRAP [14] and FP7-ROSATTE [15], the quality of roads and map data will increase rapidly.
Euro NCAP also acknowledges differences in strategy and variability of speed signs around Europe.
For the moment, it is neither feasible nor affordable for an organization like Euro NCAP to perform extensive testing of SLIFs. Possibilities like vehicle in the loop tests are considered and may be an affordable option in the future to perform more extensive tests.
The current speed-alert margin ("more than 3km/h") is taken from the UN-ECE regulation that relies on mechanical speedometers. For future revisions to the protocol the speeding margins may be reviewed for a better efficiency of SAS systems.

Euro NCAP is aware that consumer acceptance of ISA systems depends on the quality of the systems. Without user acceptance the benefits are small. A close collaboration with industry is foreseen as ISA products and Euro NCAP protocols develop in the future.

CONCLUSIONS

In a limited time, the ISA WG has developed a first set of test and assessment protocols for assessing Speed Assist Systems for implementation in 2013.
As a first in the world, two NCAPs worked together to develop a protocol. It is hoped that this successful co-operation will lead to a more global harmonisation of protocols.
Since the enforcement of the protocol an increased percentage of the vehicles assessed in 2013 have a SAS implemented, when compared to vehicles equipped with a SLD in 2012. The implementation rate is expected to further increase over the years to come.
When a large number of systems have been assessed, Euro NCAP will reinitiate the WG to further develop these protocols to ensure the implementation of the best possible system that support the driver to adhere to the speed limits and safe driving.

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APPENDIX: SPEED ASSIST ASSESSMENT PROTOCOL

Speed assist assessment protocol extract from the Safety Assist Assessment protocol "Euro NCAP Assessment Protocol – SA".

4 ASSESSMENT OF SPEED ASSIST SYSTEMS

4.1 Introduction

Excessive speed is a factor in the causation and severity of many road accidents. Speed restrictions are intended to promote safe operation of the road network by keeping traffic speeds below the maximum that is appropriate for a given traffic environment, thereby protecting vehicle occupants and other road users, both motorised and non-motorised. These maximum speeds are intended to control energy levels in typical crashes and to allow sufficient time for drivers to react to traffic situations. Properly selected speed limits should facilitate efficient traffic flow, reduce violations and promote safe driving conditions. Greater adherence to speed limits would avert many accidents and mitigate the effects of those that occur.

Voluntary speed limitation devices are a means to assist drivers to adhere to speed limits. Euro NCAP hopes to encourage manufacturers to promote such speed-limitation devices, to fit them as standard equipment. This, it is hoped, will lead to greater demand by consumers and an increased introduction of speed limitation systems.

The margins for alarm activation set out in this document are based on prevailing speedometer accuracy, which is specified by regulation and typically overstates the vehicle speed by several km/h.

This version of the protocol contains technical requirements for both Manual Speed Assist (MSA) systems where the driver needs to set the limited speed and Intelligent Speed Assist (ISA) systems where the car 'knows' the current legal speed limit to be used in the warning or speed limitation function. To be able to score full points for the speed limitation function the system (both MSA and ISA) need to fulfil the warning function and speed setting requirements.

4.2 Definitions

Throughout this protocol the following terms are used:

- Vindicated – The velocity the car travels as displayed to the driver by the speedometer as in ECE R39.
- Speed Limit – Maximum allowed legal speed for the vehicle at the location and in the circumstance the vehicle is driving.
- Vadj – Adjustable speed Vadj means the voluntarily set speed for the MSA/ISA, which is based on Vindicated and includes the offset set by the driver.
- MSA – Manual Speed Assistance. MSA means a system which allows the driver to set a vehicle speed Vadj, to which he wishes the speed of his car to be limited and/or above which he wishes to be warned.
- SLIF - Speed Limit Information Function. SLIF means a function with which the vehicle knows and communicates the speed limit.
- ISA – Intelligent Speed Assistance. ISA is a MSA combined with SLIF, where the Vadj is set by the SLIF with or without driver confirmation.

The following terms are used for the assessment of the Speed Limitation function:

- Vstab – Stabilised speed Vstab means the mean actual vehicle speed when operating. Vstab is calculated as the average speed over a minimum time interval of 20 seconds beginning 10 seconds after first reaching Vadj – 3km/h.
- Vmax – Maximum speed Vmax is the maximum speed reached by the vehicle in the first half

period of the response curve.

4.3 **Requirements for SLIF, MSA and ISA**

4.3.1 The Speed Assist Systems is developed in such a way that it allows different types of Speed Assist Systems to be assessed. Four types of possible Speed Assist Systems are foreseen:

- SLIF Speed Limit Information Function
- MSA Manual Speed Assistance
- SLIF + MSA Both SLIF and MSA but not coupled
- ISA Intelligent Speed Assistance, SLIF and MSA coupled

4.3.2 The table below details which sections are applicable for the different types of SA systems:

Type	Sections
SLIF	4.4
MSA	4.5.1, 4.6, 4.7
ISA	4.4, 4.5.1, 4.5.2, 4.6, 4.7

4.4 **Speed Limit information Function**

The Speed Limit Information Function can be a standalone function or an integrated part of ISA. Any SLIF, camera or map based or a combination of both, need to fulfil the requirements of this section. Additionally, manufacturers need supply Euro NCAP with additional background information of the SLIF as identified in the table in Appendix III.

4.4.1 General requirements

4.4.1.1 Visual and standard requirements

4.4.1.1.1 When the SLIF is active, the latest known speed limit information (can be absent when last known speed is not reliable) must be shown or accessible at any time with a simple operation and needs to be shown at the start of the next journey (excluding the initialization period).

4.4.1.1.2 The speed limit must be in the direct field of view of the driver, without the need for the head to be moved from the normal driving position, i.e. instrument cluster, rear view mirror and centre console.

4.4.1.1.3 The speed limit indication shall preferably use a traffic sign in line with the Vienna Convention.

4.4.1.1.4 When Vindicated is exceeding the speed limit, the speed limit information shall be indicated to the driver when the SLIF is active.

4.4.1.1.5 (Temporary) absence of reliable speed limit information shall be clearly indicated to the driver

4.4.2 Camera based systems

4.4.2.1 The speed limit display needs to be indicated for at least 20s after the system has identified speed limit information unless there is a change in speed limit.

4.4.3 Digital Map based systems

4.4.3.1 The speed limit display needs to be indicated while the system has valid speed limit information.

4.4.3.2 The speed limit information could either be provided by vehicle-integrated devices or by mobile devices connected to the vehicle network. A list of compatible devices needs to be mentioned in the vehicle handbook.

4.4.4 Combined Camera and Map based systems

4.4.4.1 The speed limit display needs to be indicated while the system has valid speed limit information.

4.5 **Setting the Speed**

Both MSA and ISA systems must comply with section 4.5.1. ISA systems meeting the requirements of section 4.4 are eligible for a higher score when also meeting the requirements in section 4.5.2.

4.5.1 Manually setting the speed (MSA and MSA function of ISA)

4.5.1.1 Activation / de-activation of the system

- The system must be capable of being activated/de-activated at any time.
- At the start of a new journey, the vehicle should not limit the speed without confirmation from the driver

4.5.1.2 Setting of Vadj

- It shall be possible to set Vadj, by a control device operated directly by the driver, by steps not greater than 10km/h between 30km/h and 130km/h or by steps not greater than 5mph between 20mph and 80mph when imperial units are used.
- It shall be possible to set Vadj independently of the vehicle speed.
- If Vadj is set to a speed lower than the current vehicle speed, the system shall limit the vehicle speed to the new Vadj within 30s and/or shall initiate the supplementary warning (section 4.6.2) no later than 30s after Vadj has been set.

4.5.1.3 The Vadj value shall be permanently indicated to the driver and visible from the driver's seat. This does not preclude temporary interruption of the indication for safety reasons or driver's demand.

4.5.2 Automatic setting the speed (ISA)

An automatic setting is using the speed limit information from the SLIF to advise (requiring driver confirmation) or directly set the Vadj. Systems fulfilling the requirements from section 4.4 and section 4.5.1 are eligible for scoring when meeting the following additional requirements:

4.5.2.1 Activation / de-activation of the system

- The system must be capable of switching between MSA and ISA mode at any time with a simple operation.
- At the start of a new journey, the vehicle shall not limit the speed without confirmation from the driver

4.5.2.2 Setting of Vadj

- The system must adopt, with or without driver confirmation, an adjusted Vadj within 5s after a change in the speed limit.
- If Vadj is set to a speed lower than the current vehicle speed, the system starts to limit the vehicle speed to the new Vadj and/or shall initiate the supplementary warning (section 4.6.2) no later than 30s after Vadj has been set.
- A negative and/or positive offset with respect to the known speed limit is allowed but may not be larger than 10 km/h (5 mph). This offset is included in Vadj.
- The Vadj in the automatic mode of an ISA system may be retained at the end of a journey.

4.5.2.3 Where Vadj is set to the speed limit advised by the SLIF, the indication Vadj may be suppressed.

4.6 Warning Function

All MSA and ISA systems need to meet the warning requirements of section 4.6.1 to indicate the driver that Vadj is exceeded. In addition a supplementary warning is required, e.g. audible, haptic and head-up display meeting the requirements in section 4.6.2.

Vehicles with Speed Limiter function activated do not need a warning function when active braking is applied to limit the vehicle speed.

It shall still be possible to exceed Vadj by applying a positive action, e.g. kickdown. After exceeding Vadj by applying a positive action, the speed limitation function shall be reactivated when Vindicated drops to a speed less than Vadj.

4.6.1 Visual warning requirements

4.6.1.1 The visual signal must be in the direct field of view of the driver, without the need for the head to be moved from the normal driving position, i.e. instrument cluster, rear view mirror and centre console.

4.6.1.2 The driver is informed when Vindicated of the vehicle is exceeding Vadj by more than 3 km/h.

4.6.1.3 The driver continues to be informed for the duration of the time that Vadj is exceeded by more than 3 km/h.

4.6.1.4 The warning signal does not preclude temporary interruption of the indication for safety reasons.

4.6.2 Supplementary warning requirements

4.6.2.1 The warning shall be clear to the driver.

4.6.2.2 No supplementary warning needs to be given when Vadj is exceeded as a result of a positive action.

4.6.2.3 The warning commences when the Vindicated of the vehicle is exceeding Vadj by more than 3km/h.

4.6.2.4 The total duration of the warning shall be at least 10 seconds and must start with a positive signal for at least 2 seconds. If the signal is not continuous for the first 10 seconds, it needs to be repeated every 30 seconds or less, resulting in a minimum total duration of at least 10 seconds.

4.6.2.5 The warning sequence does not need to be reinitiated for each exceedence of Vadj until Vindicated has reduced to more than 5km/h below Vadj.

4.7 Speed Limitation Function

Scoring is only eligible when the warning signal requirements from section 4.6 are met.

4.7.1 Speed Limitation

4.7.1.1 The vehicle speed shall be limited to Vadj, also see sections 4.5.1.2 and 4.5.2.2.

4.7.1.2 It shall still be possible to exceed Vadj by applying a positive action, e.g. kickdown.

4.7.1.2.1 After exceeding Vadj by applying a positive action, the speed limitation function shall be reactivated when the vehicle speed drops to a speed less than Vadj.

4.7.1.2.2 The speed limitation function shall permit a normal use of the accelerator control for gear selection.

4.7.1.3 The speed limitation function shall meet the following requirements (see test protocol):

When stable speed control has been achieved:

- Speed shall not vary by more than ±3 km/h of Vstab.
- Vstab shall not exceed Vadj by more than 3 km/h.

4.8 Scoring and Visualisation

The following points are awarded for systems that meet the requirements:

	SLIF	MSA	ISA
Communicating speed limit (Section 4.4)	**1.5**		**1.5**
Camera based	0.50		0.50
Digital Map based	0.50		0.50
Camera and Digital Map combined	1.50		1.50
Warning Function (Section 4.5 and 4.6)		**1**	**2**
Speed Limitation Function (Section 4.7)		**1**	**1**

The final score for the overall rating will be scaled from maximum of 4.5 points to a maximum of 3 points. These points will contribute to the Safety Assist Score.

Note: systems meeting ECE R89 will no longer be sufficient to be rewarded points under this protocol.

Correlation between pedestrian injury severity in real-life crashes and Euro NCAP pedestrian test results

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Paper Number 13-0308

ABSTRACT

In Germany the number of casualties in passenger car to pedestrian crashes has been reduced by a considerable amount of 40% as regards fatalities and 25% with regard to seriously injured pedestrians since the year 2001. Similar trends can be seen in other European countries. The reasons for that positive development are still under investigation. As infrastructural or behavioral changes do in general take a longer time to be effective in real world, explanations related to improved active and passive safety of passenger vehicles can be more relevant in providing answers for this trend. The effect of passive pedestrian protection – specified by the Euro NCAP pedestrian test result – is of particular interest and has already been analyzed by several authors. However, the number of vehicles with some valid Euro NCAP pedestrian score (post 2002 rating) was quite limited in most of those studies. To overcome this problem of small datasets German National Accident Records have been taken to investigate a similar objective but now based on a much bigger dataset.

The paper uses German National Accident Records from the years 2009 to 2011. In total 65.140 records of pedestrian to passenger car crashes have been available. Considering crash parameters like accident location (rural / urban areas) etc., 27.143 of those crashes have been classified to be relevant for the analysis of passive pedestrian safety. In those 27.143 records 7.576 Euro NCAP rated vehicles (post 2002 rating) have been identified. In addition it was possible to identify vehicles which comply with pedestrian protection legislation (2003/102/EG) where phase 1 came into force in October 2005.

A significant correlation between Euro NCAP pedestrian score and injury outcome in real-life car to pedestrian crashes was found. Comparing a vehicle scoring 5 points and a vehicle scoring 22 points, pedestrians' conditional probability of getting fatally injured is reduced by 35% (from 0.58% to 0.37%) for the later one. At the same time the probability of serious injuries can be reduced by 16% (from 27.4% to 22.9%). No significant injury reducing effect, associated with the introduction of pedestrian protection legislation (phase 1) was detected. Considerable effects have also been identified comparing diesel and gasoline cars. Higher engine displacements are associated with a lower injury risk for pedestrians. The most relevant parameter has been "time of accident", whereas pedestrians face a more than 2 times higher probability to be fatally injured during night and darkness as compared to daytime conditions.

INTRODUCTION

In Germany the number of fatal and severe pedestrian to passenger car crashes decreased by a considerable amount in the first decade of 2000. Comparing police recorded passenger car to pedestrian accident records from the years 2001 to 2003 with data records from 2009 to 2011, the number of fatally injured pedestrians dropped by 40%. The number of seriously injured pedestrians decreased by 25% and the number of slightly injured pedestrians was reduced by 11% (see Figure 1). The reasons for that positive trend are still under investigation. As infrastructural or behavioral changes do in general take a longer time to be effective in real world, explanations related to improved active and passive safety of passenger vehicles can be more relevant in providing explanations to this appreciable trend.

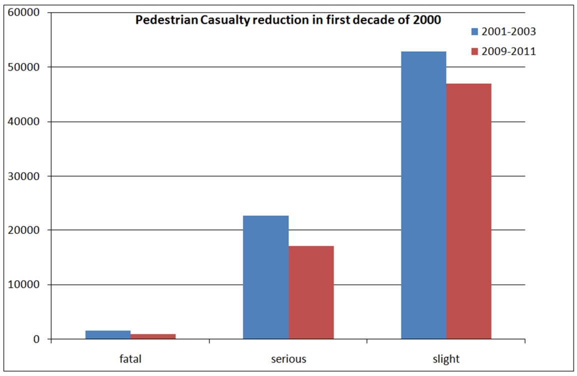

Figure 1. Reduction of pedestrian casualties in first decade of 2000.

The effect of passive safety can be extracted by looking at the proportion of killed or seriously injured (KSI) pedestrians. In the years 2001 to 2003 the share of KSI pedestrians was 31.3% and has been reduced to 27.8% for the data records from the years 2009 to 2011. This means that the probability of pedestrians in getting seriously injured or killed in a crash with a passenger car was reduced by 11% (assuming that the share of underreported cases did not change).

Passive Pedestrian Protection Requirements

In Europe passive pedestrian protection for M1 vehicles is mainly driven by legislation and Euro NCAP. Passive pedestrian protection for M1 vehicles in Europe is compulsory required by the European directive 2003/102/EG, starting with phase 1 for all new models introduced since October 2005.
The European consumer testing program Euro NCAP provides scores on passenger car pedestrian protection since 1997. However, in June 2002 Euro NCAP changed the way pedestrian impact test sites were selected. The limit values and the way points were awarded were also changed [1].
Whereas legislation is compulsory for all M1 vehicles with a gross vehicle weight up to 2.5t the Euro NCAP test program will consider the majority of the most popular cars in Europe.

Field Effects of Passive Pedestrian Protection

The effect of passive pedestrian protection – specified by the Euro NCAP pedestrian test result – has been analyzed by several authors. Based on real world data from Australia, UK, Germany and France no Euro NCAP - effect has been seen by the European Commission funded SARAC 2 project in 2003. However, the data could only consider "pre 2002" tested vehicles and the number of vehicles with some valid Euro NCAP pedestrian score was limited. Strandroth et al. presented a positive correlation at the ESV conference 2011 [2]. Unfortunately, the number of valid datasets used for this analysis was only 488. Euro NCAP scores from pre and post 2002 had to be included which makes the interpretation of the results difficult as the pedestrian rating was changed in June 2002. To overcome these problems German National Accident Records have been taken to investigate a similar objective now based on a much bigger dataset of several thousand records.

Only limited work has been done on studying the effect of legislative pedestrian protection enforcement. In general it must be stated that it is difficult to distinguish effects in the field which are attributed to Euro NCAP and effects attributed to legislation.

DATA SOURCES

The paper uses a set of German Police reported accident records which occurred in between 2009 to 2011.

Data selection process

In order to address the passive safety performance, the following selection criteria have been applied to the dataset of originally 65.140 pedestrian accident records:

- only urban crossing accidents
- only accidents with sustainable pedestrians (aged 6 to 64)
- only accidents with one passenger car (M1) and one pedestrian

Based on that selection, 27.143 (42%) records remained to be available for the analysis. This comes up to 20% of the fatal accident cases, 45% of the serious ones and almost 41% of the slight injury cases.

Many accidents got lost during the age criteria selection process. Figure 2 shows that a rising share of today more than 50% of pedestrian fatalities happen to people being 65 years of age and older. This highlights the importance of the development of active pedestrian protection systems, which shall be able to avoid a collision.

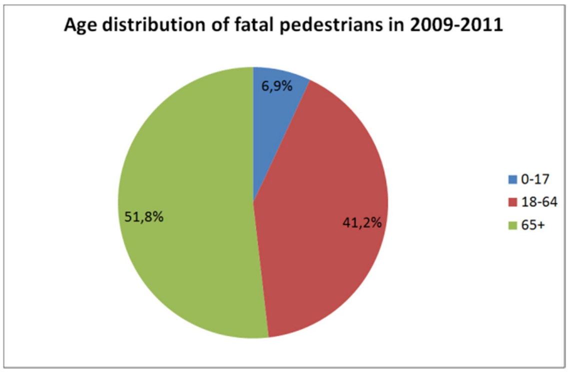

Figure 2. Age distribution of fatal pedestrians in 2009 to 2011.

Furthermore a considerable amount of the accidents dropped out based on the fact that they happen in rural areas. Here it is assumed that the speed is too high for passive protection measures. 50% of the fatal accidents which happened to the age group of 18-64 year old occurred in rural locations.

Identification of NCAP Scores

NCAP scores for 203 vehicles have been taken from the Euro NCAP homepage [3]. The list of cars is attached in the Appendix. To be consistent and as the NCAP pedestrian scoring changed in June 2002, only post 2002 Euro NCAP scores have been used. 7.576 cars have been identified, which is up to 28% of the cars in the dataset. For the identification of the car, the cars trade name, platform, the German Type Approval number and the year of initial registration has been used. The distribution of Euro NCAP scores in the dataset is depicted in Figure 3.

19.567 vehicles in the dataset containing pedestrian casualties from 2009 to 2011 have no valid post 2002 Euro NCAP score. This is explained by the fact that 56% (58%) of the fatal (serious) cases occurred with cars having an initial registration before the year 2003. This is depicted in Figure 4.

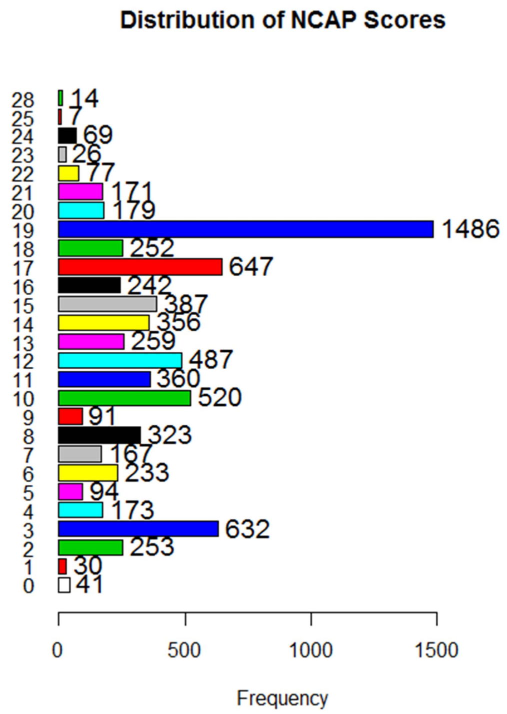

Figure 3. Frequency of NCAP Scores in the accident dataset 2009-2011 (scores ranging from 0 points to 28 points).

This means that 50% of all cars registered in 2003 and thereafter have a valid NCAP score and have been used for the analysis.

Identification of regulatory compliance

Regulatory compliance of vehicles was identified by using the German type approval number. By chance the coding of German type approval numbers for new approvals was changed in October 2005, which is coincident with the enforcement of 2003/102/EG, phase 1. Thus, any car having a type approval number which belongs to the new coding system is supposed to be compliant with the new pedestrian protection legislation.

75% of the cars having a valid Euro NCAP score comply also with legislation, whereas only 25% of non Euro NCAP tested cars – firstly registered after 2002 – do fulfill legislation. Finally only datasets

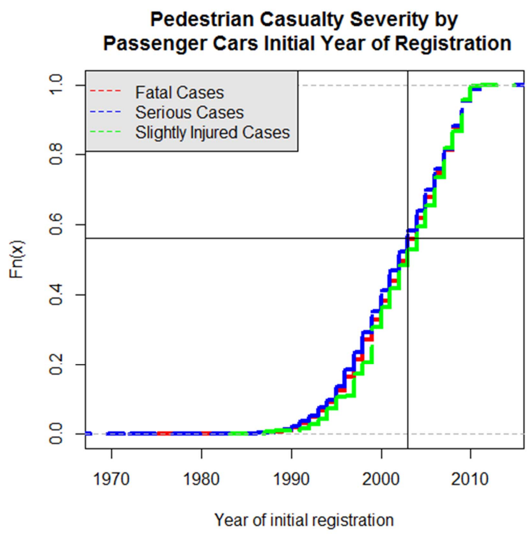

Figure 4. Cummulative share of pedestrian causualty by year of initial registration of the involved passenger car. 44% of the fatal pedestrians had a crash with a passenger car initially registrated after 2002.

with Euro NCAP scored vehicles have been used for the analysis.

METHOD

To establish a correlation between the pedestrians' casualty severity and some possible explanatory variables an ordinal probit model has been used. This was done by using the software package R, version 2.15.2. The function "polr" is provided and documented in the R package "MASS" [4].
We rejected from using a proportional odds model, which – for the sake of simplicity and being less computationally expensive - is often used for modeling ordinal response data. The NCAP test program and scoring is established to prevent quite serious and fatal consequences from road users. Thus, the NCAP score is more relevant for the fatal injury level. This means that the proportional odds assumptions would be violated and thus the proportional odds model shall not be used.

Within the model the pedestrians' casualty severity has been interpreted as the latent response variable, showing three specification on an ordinal scale - "fatally inj." > "seriously inj." > "slightly inj.".

Based on experience we expected the injury outcome in real world to be dependent on the following parameters:

- Light condition
- NCAP score
- Engine size
- Gender
- Regulatory compliance

The parameters have been chosen for the following reasons.
Light condition: Less reaction time and probably higher impact speeds because of less braking.
Engine size: Less deformation space and hard contact of pedestrians during impact
Gender: Higher vulnerability of females

Setting up the ordinal probit model we found significant effects for three of the above mentioned parameters (see Table 1). No effect has been found for Gender and Regulatory Compliance.

To estimate the effect of engine size, an interaction effect of engine type (diesel / gasoline) and engine displacement has been considered.

The final model formula looked as follows:

Pedestrian Inj. Severity ~ Light Condition + NCAP + Engine Type | Engine Displacement (1)

RESULTS

Table 1 shows the results of the ordinal probit regression model.

Explanatory Var.	Estimator	St. Error	t value
Light Condition = *Dark*	3,065E-01	3,336E-02	9,188
Engine Type = *Gasoline*	1,703E-01	4,091E-02	4,162
Engine Displacement/ccm	-4,278E-05	2,280E-05	-1,877
NCAP Score	-8,571E-03	2,467E-03	-3,474
Engine Type = *Gasoline* : Engine Displacement/ccm	-1,510E-04	3,543E-05	-4,263
Intercepts			
Fatal -> Serious	4,020E-01	4,440E-02	9,0506
Serious -> Slight	2,348E+00	6,970E-02	33,6842

Table 1. Results of the Ordinal Probit Regression Model.

Positive estimators indicate an effect increasing the risk, whereas negative estimators can be assessed to be protective factors, reducing the risk of getting fatal and serious injuries. As expected light condition is a very strong and significant effect. Therefore the influence of light condition always needs to be addressed as a significant confounder when dealing with risk models for pedestrian accidents. The engine displacement is given in ccm, thus letting the effect of engine displacement look to be small, however it isn't. All standard errors and t values indicate a significant correlation at a 95% level, at the least.

Correlation of Euro NCAP Score and Injury Outcome in real world

A significant correlation between Euro NCAP pedestrian score and injury outcome in real-life car to pedestrian crashes was found. Each additional point in the NCAP score can have a reduction in probability of fatal injury by as much as 2.5%. The respective reduction of serious injury probability is about 1.0%. Comparing a pedestrian hit by a vehicle scoring 5 points and a vehicle scoring 22 points, pedestrians' probability [daytime accident with a 1600 ccm gasoline car] of getting fatally injured is reduced from 0.58% to 0.37% (-35%) for the later one. The probability of serious injuries is reduced from 27.4% to 22.9% (-16%); see also *Figure 5*.

It can also be seen that the reduction potential is higher for fatal injuries as compared to serious injury outcomes. Whereas the probability reduction can be up to 50% for fatalities "only" 30% reduction can be achieved for serious injuries. It can also be seen that the correlation between NCAP Score and Serious Injury Risk is almost linear, whereas the Fatal Injury Risk Curve is slightly convex.

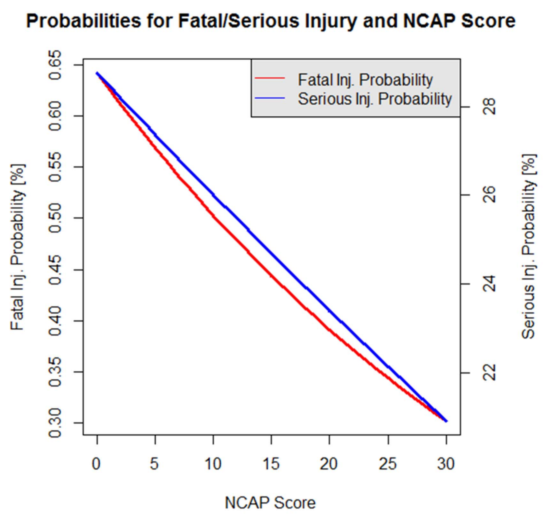

Figure 5. Pedestrians' probability of becoming fatally / seriously injured being impacted with cars of various NCAP score; [referenced to daytime accident with 1.600ccm gasoline car].

Impact of Engine Size

The impact of engine size on the injury outcome is depicted in Figure 6 . The interpretation of the effects is complex.

In the model an interaction term between engine displacement and engine type needed to be introduced. Wherefore either for diesel-type engines and for gasoline-type engines the injury probability decreases with increasing engine displacement. However, the slope of that decrease is different.

The reason for that injury reduction effect is rarely an effect of engine characteristics. Initially it was anticipated that with bigger engines (higher engine displacements) the probability of severe and fatal injuries was going to increase.

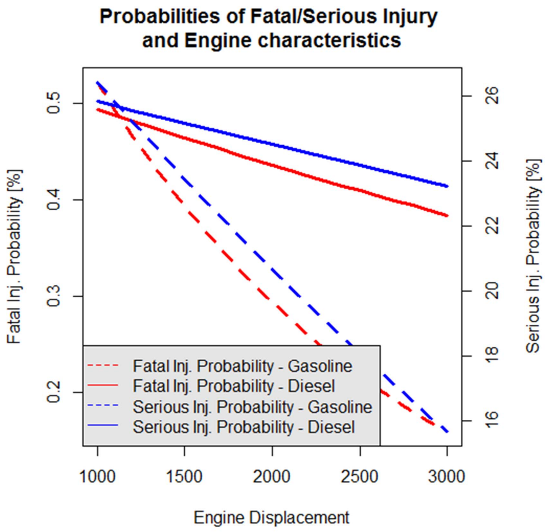

Figure 6. Pedestrians' probability of getting fatally / seriously injured having impacts with cars of various engine characteristics; [referenced to daytime accident with 22 Euro NCAP score car].

It is assumed that the effect of injury probability reduction with increasing engine displacement is associated with some driver behavior characteristics. Drivers of a bigger engine sized cars are expected to drive more carefully and also having more driving experience. In future studies it shall be tried to use vehicle segments as additional variable to isolate this effect. Although it is still expected that the engine size is a relevant factor which shall increase the injury probability, it cannot be proofed with the data available, now.

The importance of driver characteristics can also be seen in Figure 7. Here, the influence of engine displacement is exactly opposite, when looking at just one popular make & model in the German fleet. It can be seen that the highly motorized gasoline variant shows a much higher probability of causing fatal and serious injuries to pedestrians.
It is expected that this effect is however again to a great extend attributed to the driver characteristics. The highly motorized gasoline variant of this car is taken to be the sportive variant, implying a more sportive and sometimes aggressive driving style. In future studies it shall be tried to use specific power as additional variable to isolate this effect.

Such reverse local effects do however not disturb the general trend being depicted in Figure 6.

Hence, looking again at the general effects in Figure 6 it can be observed that diesel-type cars imply in general a higher risk for pedestrians. It is assumed that this is finally related to the different engine size. Taking this information into account it should also be said, that the pedestrian NCAP score for a particular gasoline car needs to be adjusted (reduced) for the diesel version of that car.

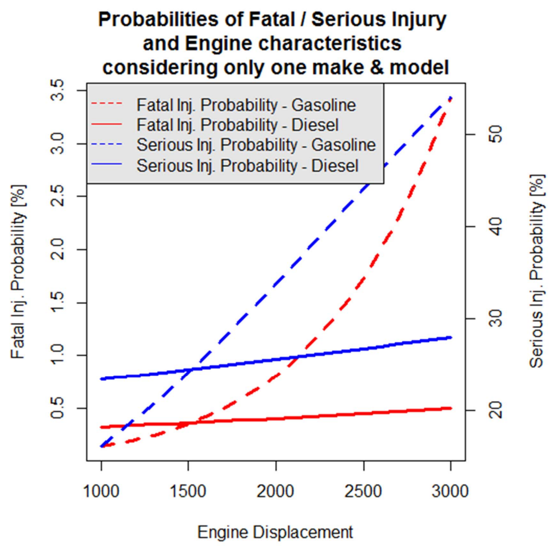

Figure 7. Pedestrians' probability of getting fatally / seriously injured having impacts with cars of various engine characteristics; [referenced to daytime accident with one particular Euro NCAP scored car].

Injury reduction potential of passive safety

Finally we estimated the injury reduction potential of passive pedestrian protection in the fleet. We assumed that each car will have a 22 Point Euro NCAP Score for passive pedestrian protection. Introducing this assumption into the real world dataset we got a reduction of 56 fatalities and 1543 seriously injured in the dataset containing accidents from the years 2009 to 2011. Having had a total number of 953 fatalities and 17.069 seriously injured, that comes up to a reduction of 6% of the fatal cases and 9% of the serious cases.

CONCLUSION

German police recorded traffic accident files have been used to investigate pedestrian to passenger car (M1) impacts. The analysis was in particular interested in the effect of Euro NCAP pedestrian test scores on the injury outcome in real world.

A significant correlation between Euro NCAP scores and real world injury outcome has been found. The conditional probability of fatal and serious injuries to a pedestrian, given the pedestrian is involved in an accident within the target group of accidents, that is:

- urban crossing accidents
- with personal injury
- with pedestrians aged 6 to 64 years,

can effectively be reduced.

As a rule of thumb each point in NCAP score relates to a relative reduction in probability of 2.5% for fatalities, and 1% for serious injuries.
Example: Some score difference of 9 Points between a vehicle A (scored at 13 points) and a vehicle B (scored at 22 points) will give

$0.975^{(\text{score B} - \text{score A})} = 0.975^9 = 0.80$

Thus, the probability of getting fatally injured being hit by vehicle B is just 80% of the respective probability when being hit by vehicle A.
The equivalent computation for the probability of getting seriously injured would be

$0.99^{(\text{score B} - \text{score A})} = 0.99^9 = 0.91$

Thus, the probability of getting seriously injured being hit by vehicle B is 91% of the respective probability when being hit by vehicle A.

Provided every car on German roads would comply to a standard of 22 Euro NCAP point score in pedestrian protection, an injury reduction potential of 6% as regards the number of fatalities and 9% with regard to the number of seriously injured pedestrians in passenger car impacts could be estimated.

As expected, we found a strong correlation between light conditions and injury severity. Probably accidents under adverse light conditions lead to higher injury severities, due to less reaction time and less speed reduction before impacting the pedestrian. Referring to active pedestrian protection systems emerging into the market - frequently mono camera based systems - robustness in adverse light conditions will be needed to make those systems work efficiently.

We found a correlation between engine characteristics - engine type and engine displacement – and injury outcome. Diesel type cars imply a higher thread to pedestrians. The reason could well be the bigger engine size of diesel variants. Thus, it shall be noticed that the NCAP pedestrian rating for a tested gasoline variant is not necessarily valid for the diesel variant of the same car make and model. This should in principal be true vice versa, however testing the diesel variant can be taken as a “worst case” test.

Increasing the engine displacement was linked to a protective – thus injury reducing – effect in real world. This phenomenon can be explained by the characteristics of drivers associated with higher motorized gasoline vehicles, which are expected to drive more carefully and also having more driving experience.

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[3] http://www.euroncap.com
[4] http://cran.r-project.org/web/packages/MASS/MASS.pdf

APPENDIX – LIST OF VEHICLES

CAR	FREQ	SCORE
ALFA_ROMEO_159	10	9
ALFA_ROMEO_GIULIETTA	1	23
ALFA_ROMEO_MITO	6	18
AUDI_A1_2010	5	18
AUDI_A3_2003	188	8
AUDI_A4_2008	74	14
AUDI_A6_2004	91	3
AUDI_Q5_2008	11	12
AUDI_Q7_2006	14	15
AUDI_TT_2003	15	0
BMW_1er_2004	108	2
BMW_1er_2004_Facelift	20	2
BMW_3er_2005	140	4
BMW_3er_2005_Facelift	9	4
BMW_5er_2004	62	2
BMW_5er_2010	13	28
BMW_X3_2008	7	5
BMW_X5_2003	10	2
BMW_Z4_2004	8	14
CHEVROLET_AVEO_2006	10	19
CHEVROLET_CAPTIVA_2007	12	17
CHEVROLET_CRUZE_2009	1	12

CHEVROLET_KALOS_2006	15	11
CHEVROLET_MATIZ_2005	63	13
CHEVROLET_SPARK_2009	9	16
CHRYSLER_VOYAGER_2007	7	0
CITROEN_BERLINGO_2005	38	10
CITROEN_BERLINGO_2008	12	10
CITROEN_C1_2005	63	14
CITROEN_C2_2003	38	12
CITROEN_C3_2009	3	12
CITROEN_C3_PICASSO_2009	4	16
CITROEN_C3_PLURIEL_2003	4	13
CITROEN_C4_2004	17	22
CITROEN_C4_2010	2	15
CITROEN_C4_PICASSO_2006	19	16
CITROEN_C5_2004	14	8
CITROEN_C5_2008	10	11
CITROEN_C6_2005	1	28
CITROEN_DS3_2009	6	13
CITROEN_NEMO_2010	2	20
DACIA_DUSTER_SUV_2011	1	10
DACIA_LOGAN_2005	31	5
DACIA_SANDERO_2008	26	6
DAIHATSU_CUORE_2008	4	12
DAIHATSU_MATERIA_2007	1	16
DAIHATSU_SIRION_2005	19	15
DAIHATSU_TERIOS_2008	1	19
DODGE_CALIBER_2007	2	5
FIAT_500_2007	32	14
FIAT_BRAVO_2007	7	16
FIAT_CROMA_2005	4	6
FIAT_DOBLO_2004	17	1
FIAT_GRANDE_PUNTO_2005	80	19
FIAT_IDEA_2006	9	8
FIAT_PANDA_2004	83	6
FIAT_STILO_2005	41	8
FORD_CMAX_2010	2	18
FORD_FIESTA_2008	94	20
FORD_FOCUS_2004	198	15
FORD_FOCUS_CMAX_2003	60	14
FORD_FUSION_2003	43	11
FORD_KA_2008	32	11
FORD_KUGA_2008	19	20
FORD_MONDEO_2007	55	18
FORD_S-MAX_2006	36	13
HONDA_ACCORD_2003	10	16

HONDA_ACCORD_2008	3	19
HONDA_CIVIC_2006	41	24
HONDA_CRV_2007	12	13
HONDA_CRZ_2010	1	25
HONDA_FRV_2005	2	20
HONDA_JAZZ_2004	62	19
HONDA_JAZZ_2009	22	22
HYUNDAI_GETZ_2004	50	5
HYUNDAI_I10_2008	31	21
HYUNDAI_I20_2009	6	23
HYUNDAI_IX20_2011	1	23
HYUNDAI_IX35_2010	5	20
HYUNDAI_SANTA-FE_2006	7	0
HYUNDAI_SONATA_2006	2	12
HYUNDAI_TRAJET_2003	4	9
HYUNDAI_TUCSON_2006	24	4
JAGUAR_XF_2010	1	16
JEEP_CHEROKEE_2003	1	3
JEEP_GRAND_CHEROKEE_2005	12	0
KIA_CARENS_2007	5	9
KIA_CARNIVAL_SEDONA_2006	4	3
KIA_CEED_2007	27	11
KIA_CERATO_2006	5	8
KIA_PICANTO_2004	42	6
KIA_RIO_2005	12	13
KIA_SORENTO_2003	8	3
KIA_SORENTO_2009	1	16
KIA_SOUL_2009	3	14
KIA_SPORTAGE_2010	3	18
KIA_VENGA_2010	3	23
LANDROVER_DISCOVERY_2006	4	8
LANDROVER_FREELANDER_2007	1	7
LEXUS_IS_2006	2	15
MAZDA_2_2003	34	10
MAZDA_2_2007	31	18
MAZDA_3_2006	44	15
MAZDA_3_2009	10	18
MAZDA_5_2005	37	12
MAZDA_6_2003	65	7
MAZDA_6_2009	14	18
MAZDA_CX-7_2010	3	16
MERCEDES_A-KLASSE_2005	136	17
MERCEDES_B-KLASSE_2006	147	12
MERCEDES_C-KLASSE_2007	112	11
MERCEDES_E-KLASSE_2010	75	21

MERCEDES_GLK_2010	16	17
MERCEDES_M-KLASSE_2008	30	6
MINI_COOPER_2007	49	14
MINI_COUNTRYMAN_2010	15	23
MITSUBISHI_ASX_2011	3	22
MITSUBISHI_COLT_2005	50	7
MITSUBISHI_LANCER_2009	6	12
MITSUBISHI_OUTLANDER_2007	4	17
MITSUBISHI_PAJERO_PININ_2003	5	1
NISSAN_JUKE_2011	1	15
NISSAN_MICRA_2003	83	12
NISSAN_NOTE_2006	27	15
NISSAN_PATHFINDER_2006	2	18
NISSAN_QASHQAI_2007	29	18
NISSAN_X-TRAIL_2007	3	12
OPEL_ASTRA_2004	267	3
OPEL_ASTRA_2009	23	16
OPEL_CORSA_2006	190	19
OPEL_INSIGNIA_2008	21	14
OPEL_MERIVA_2003	164	3
OPEL_MERIVA_2010	11	20
OPEL_SIGNUM_2003	8	1
OPEL_TIGRA_2004	13	10
OPEL_ZAFIRA_2005	143	16
PEUGEOT_1007_2005	6	10
PEUGEOT_207_2006	91	19
PEUGEOT_207CC_2006	6	16
PEUGEOT_3008_2009	2	11
PEUGEOT_307CC_2006	1	10
PEUGEOT_308_2007	16	19
PEUGEOT_407_2004	23	15
PEUGEOT_807_2003	7	6
RENAULT_CLIO_2005	64	9
RENAULT_ESPACE_2003	12	10
RENAULT_GRAND_SCENIC_2009	4	15
RENAULT_KANGOO_2003	51	2
RENAULT_KANGOO_2008	10	14
RENAULT_KOLEOS_2008	2	14
RENAULT_LAGUNA_2003	47	12
RENAULT_LAGUNA_2007	7	10
RENAULT_MEGANE_2008	14	11
RENAULT_MODUS_2004	41	6
RENAULT_SCENIC_2003	55	11
RENAULT_TWINGO_2003	270	10
RENAULT_TWINGO_2007	50	11
RENAULT_VEL_SATIS_2005	2	2
SEAT_ALTEA_2004	25	22
SEAT_EXEO_2010	1	18
SEAT_IBIZA_2008	30	19
SEAT_LEON_2005	22	24
SKODA_FABIA_2007	106	17
SKODA_OCTAVIA_2004	101	17
SKODA_ROOMSTER_2006	34	14
SKODA_SUPERB_2008	10	18
SKODA_YETI_2009	5	17
SMART_FORFOUR_2005	24	7
SMART_FORTWO_2007	115	10
SUZUKI_ALTO_2009	11	13
SUZUKI_GRAN_VITARA_2007	9	19
SUZUKI_SPLASH_2008	11	19
SUZUKI_SWIFT_2005	46	20
SUZUKI_SWIFT_2010	1	22
SUZUKI_SX4_2006	9	22
TOYOTA_AURIS_2006	39	21
TOYOTA_AVENSIS_2003	62	8
TOYOTA_AVENSIS_2009	10	19
TOYOTA_IQ_2009	11	19
TOYOTA_PREVIA_2003	4	5
TOYOTA_PRIUS_2004	12	13
TOYOTA_PRIUS_2009	6	24
TOYOTA_RAV4_2006	26	21
TOYOTA_URBAN_CRUISER_2009	2	19
TOYOTA_VERSO_2010	6	25
TOYOTA_YARIS_2005	79	18
VOLVO_C30_2007	8	9
VOLVO_S40_2004	5	18
VOLVO_V70_2007	11	16
VOLVO_XC60_2008	6	17
VOLVO_XC90_2003	11	10
VW_CADDY_2007	90	13
VW_EOS_2007	13	13
VW_FOX_2005	105	12
VW_GOLF_2004_2008	683	19
VW_PASSAT_2005	222	17
VW_POLO_2009	53	15
VW_SCIROCCO_2009	7	19
VW_SHARAN_2010	4	16
VW_T5_2008	97	3
VW_TIGUAN_2007	39	17
VW_TOUAREG_2004	27	7

VW_TOURAN_2003	270	19

Table 2. List of vehicles used for the analysis; including trade name with valid NCAP pedestrian score and frequency in the dataset.

EVALUATION OF THE AFL ADVANCED EUROPEAN MOBILE DEFORMABLE BARRIER FOR SIDE IMPACT VERSUS THE ECE-R95 IN DYNAMIC LOAD CELL WALL TEST

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Paper Number 13-0326

ABSTRACT

Many countries conducted side impact tests resulting in extensive safety measures for regulation. The IHRA conducted research activity in order to harmonized regulation worldwide, which was a challenging work. This had led to MDB improvements first and then to develop the deformable barrier representative for the EU-vehicle fleet so called Advanced European Mobile Deformable barrier AE-MDB.

This work is a first evaluation of both MDB-R95 and AE-MDB side impact barriers in their standard dynamic Load cell Wall tests knowing that AE-MDB will be introduced to EuroNCAP rating soon.

INTRODUCTION

Side impact protection is a very important part of any total vehicle protection system in order to design, develop and bring in the market the most safety vehicle. The challenge of the side impact protection is about ensuring that intrusions and door velocities are kept as low as possible in order to minimize the effects of the lateral impact onto the occupants. Obviously, car manufacturers and suppliers made great progress in the last 20 years introducing many new technologies like airbags, paddings, structure materials etc.

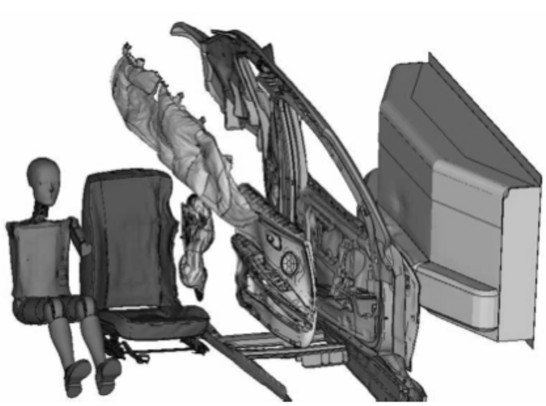

Figure 1: main side impact countermeasures [8]

Side impact issues have been reviewed by the European Enhanced Vehicle Safety Committee Working Group 13 (EEVC WG13 [4]). They conducted a review of injury issues observed in accident analysis, characteristics of different test methods, and cost benefit analyses of different solutions. Current side impact protection in Europe is controlled by a moving deformable barrier (MDB-R95) test in regulation (UNECE R95 and 96/27/EC) and both MDB-R95 and pole impact tests in consumer rating programs (EuroNCAP). The MDB-R95 barrier face is supposed to represent the force/deflection characteristics of a vehicle front. However, when the properties of the barrier were reviewed by the EEVC group, they were not found to be representative of current vehicles and hence a new advanced energy-absorbing barrier so called AE-MDB was developed to address this issue.

MDB-R95 and AE-MDB barrier faces question the relative distribution of forces on the side of the struck vehicle. With the future implementation of AE-MDB barrier as well as the new test procedure first in European NCAP tests, this will ensure the manufacture to continuously support their development and improve their products in side impact configuration.

MDB-R95

The European Enhanced Vehicle Safety Committee Working Group 13 (EEVC WG13 [4]) developed a side impact test procedure, which involved the use of a mobile deformable barrier so called MDB-R95. The deformable element of this barrier was defined in term of the force-deflection characteristics when impacting a six-element load cell wall together with some dimensional requirements. In 1998, this EEVC test procedure was used as the basis for ECE Regulation 95 [3] and the equivalent EU Directive including the MDB-R95 deformable barrier. In 1997, one year prior to this regulation taking effect, EuroNCAP decided to implement the research from the EEVC WG13 into their programs. In 2004, an EEVC WG13 proposal for an updated barrier was implemented into the existing ECE Regulation 95 [3].

In 2003, EuroNCAP decided to implement these modifications from the EEVC WG13 into their rating. This was four years before these modifications were mandatories for new vehicle in Europe.

Figure 2: MDB-R95 AFL Honeycomb Structures

Based on the Aluminum Honeycomb technology, the AFL MDB-R95 side impact barrier (EEVC WG13) is used by car manufacturers and test laboratories worldwide for the assessment of motor vehicle passenger's protection in case of side impact collision. The AFL MDB-R95 side impact barrier is designed and manufactured according to the ISO 9001 (V2008) standard and certified for occupant protections (ECE-R95 am.3 & 96/27/EC for Europe; FMVSS 214 in the US; TRIAS 47-3-2000 in Japan; GB 20971-2006 in China; AIS-099/F in India; ADR 72/00 in Australia; KMVSS 102 in Korea) as well as NCAP tests (Euro-NCAP; USA-NCAP; Japan-NCAP; China-NCAP; Korea-NCAP; Australia-NCAP).

Main specifications

The MDB-R95 side impact barrier consists of six single blocks of aluminum honeycomb, which have been processed in order to give a progressively increasing level of force with increasing deflection. Front and rear aluminum plates are attached to the aluminum honeycomb blocks. The barrier is manufactured to absorb a total quantity of kinetic energy set to 45 kJ +/- 3 kJ. Main geometric characteristic are shown in the figures below [3].

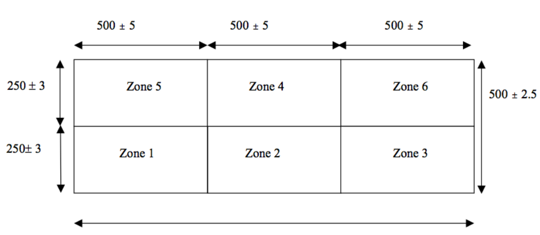

Figure 3: MDB-R95 geometry

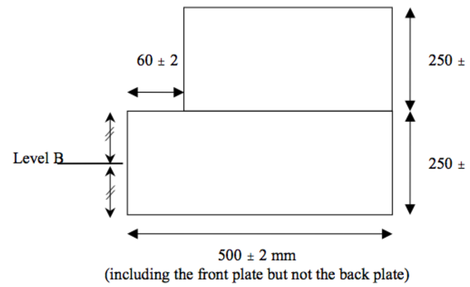

Figure 4: MDB-R95 geometry

A complete testing procedure for certification of aluminum honeycomb is performed in-house according to EEVCC-R95 amendment 3 [3]. The aluminum honeycomb blocks are processed such that the force deflection-curve when statically crushed is within the corridors defined for each of the six blocks.

AE-MDB

The initial IHRA draft protocol was to be representative of worldwide car-to-car side impact accidents. However, due to the differences between North America and European fleet, it has been decided to develop different deformable barriers. EEVC-WG13 was asked by IHRA to develop the deformable barrier representative for the EU-vehicle fleet so called Advanced European Mobile Deformable barrier AE-MDB, which started in 2001.

The European Enhanced Vehicle Safety Committee Working Group 13 (EEVC WG13 [4]) worked closely with the Japanese authorities to develop AE-MDB and then the activities resulted in different AE-MDB versions since more than 10 years. The first version of the AE-MDB has been presented at the ESV-2003 [9] and then the EEVC WG13 activities resulted in a specification version 2 of the AE-MDB, which has been presented at the ESV-2005 [5]. However due to the lack of agreement between EEVC members upon the final specification of the AE-MDB V2 (the resulting vehicle deformation was suggested as not to be in line with real car to car tests), the members continuously modified the AE-MDB barrier as several version 3. Many studies like the one performed by Honda [10] or from the EC funded FP6 project APROSYS 17 [1] have investigated side impact compatibility and updated the AEMDB versions 3. Their approach was first to investigate the effect of modifying the characteristics of a Mobile Deformable Barrier (MDB). These AE-

MDB evolutions have been mainly performed within APROSYS and resulted to the actual AE-MDB version 3.9 [2].

Figure 5: AE-MDB AFL Honeycomb Structures

Designed and manufactured according to the ISO 9001 (V2008), the AFL AE-MDB side impact barriers are used by car manufacturers and test laboratories worldwide for research and development since almost 10 years with several versions. Based on the AE-MDB version 3.9, EuroNCAP decided to implement the AE-MDB side impact barrier into their future rating.

Main specifications

The AE-MDB barrier design was taking into account the main following considerations:

- Reproduce the load path of a perpendicular car-to-car side impact with a stationary target and moving deformable barrier
- Not allow simultaneous loading of the A and C pillars which might prevent realistic loading of the occupants.
- Represent the mean European fleet dimensions for the front cars
- Match the width of standard load cell wall by a center section of 500mm

Main geometric characteristic are shown in the figures 6 and 7 below [2].

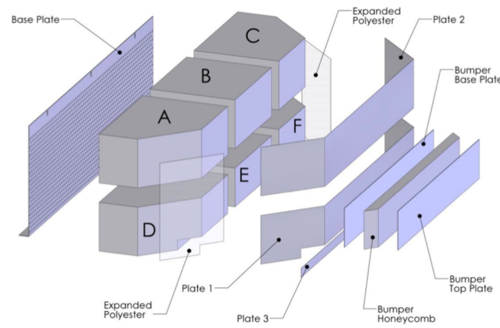

Figure 6: AE-MDB geometry

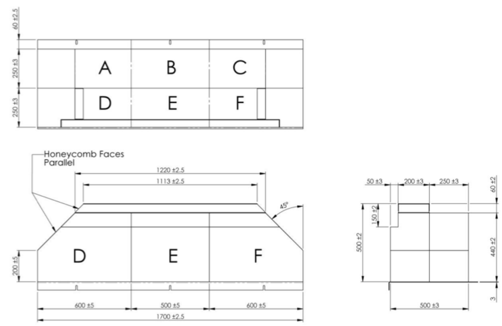

Figure 7: AE-MDB geometry

Based on the Aluminum Honeycomb technology, the AE-MDB V3.9 barrier face take into account the major concerns identified by EEVC WG13 members with the version 2 which did not compare well with that seen in baseline car-to-car tests [6]. Developed within APROSYS, the AE-MDB V3.9 has a bumper beam element in addition of reduced stiffness of the lower blocks by comparison to version 2. The outer blocks D and F version 3.9 have a stiffness set to 55% of the blocks version 2 and the middle block E has a stiffness set to 60% of the block version 2 [2].

As it is for the MDB-R95, the AE-MDB side impact barrier also consists of six single blocks of aluminum honeycomb, which have been processed in order to give a progressively increasing level of force with increasing deflection. An additional single element is attached of 60 mm depth to the front of the lower row of blocks. Front and rear aluminum plates are attached to the aluminum honeycomb blocks. The plates cover the angled surfaces. The AE-MDB barrier is manufactured to absorb a total quantity of kinetic energy set to 61.5 kJ +/- 5 kJ. A complete testing procedure for certification of aluminum honeycomb is performed in-house according to the AE-MDB Build Specification [2]. The aluminum honeycomb blocks are processed such that the force deflection-curve when statically crushed is within the corridors defined for each of the six blocks.

BARRIER TO RIGID LCW PROTOCOL

Procedure description

The test procedure for both barriers faces MDB-R95 and AE-MDB is based on the current test protocol describes in the specifications [2, 3]. The test specifications are the same for both AE-MDB and MDB-R95 impactor:

- The ground clearance, center of gravity, the wheelbase dimensions etc. including both barrier and trolley
- Barrier attachment to the trolley use six M8 bolts
- Ventilation device is mounting to the trolley
- Testing ground with LCW and plywood face as surface protection
- Impact alignment accurate to within 10 +/- 5 mm
- Impact velocity 35 +/- 0.5 km/h
- Loads filtering CFC 60 for all blocks
- Acceleration measured a 3 different location of the trolley and filtering with CFC 180 for integration

In addition of the barrier itself, the only difference is in the trolley mass set to 950 kg for MDB-R95 and 1300 kg for the AE-MDB. This means a dissipated total energy during impact equal to 61.5 kJ for AE-MDB and 45 kJ for MDB-R95. Initially set to 1500kg by IHRA to be worldwide representative, the trolley mass has been finally set to 1300 kg for better European fleet representation by EEVC-WG13.

Test condition

6 AFL barrier faces (3 MDB-R95 and 3 AE-MDB) have been tested at different crash Laboratories. MDB-R95 tests have been performed at UTAC in France and TNO in the Netherlands while AE-MDB tests have been performed at BAST in Germany. All the crash Laboratories are certified Euro-NCAP crash laboratories certified and have the ability to perform certification tests.

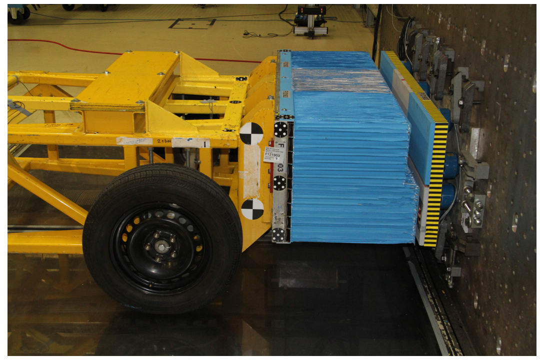

Figure 8: MDB-R95 test

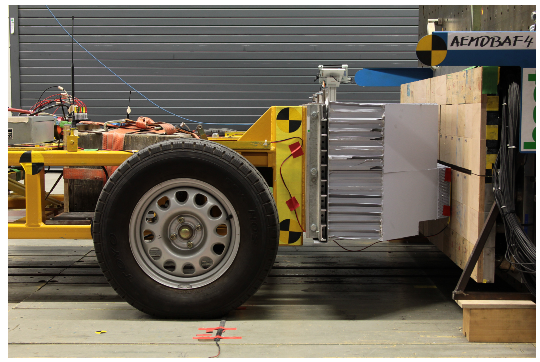

Figure 9: AE-MDB test

The tables 1 and 2 below show the trolley test weight, including deformable barrier and the impact test velocity.

Test Set-up	Mass (kg)	Impact velocity (km/h)
ECE R95 Directive	950 +/- 20	35.0 +/- 0.5
MDB-R95-PR333	957.0	34.8
MDB-R95-PR390	957.0	35.1
MDB-R95-PR102	957.0	35.1

Table 1: MDB-R5 test set-up

Test Set-up	Mass (kg)	Impact velocity (km/h)
AE-MDB Protocol	1300 +/- 20	35.0 +/- 0.5
AE-MDB PR032	1314.0	34.89
AE-MDB PR033	1314.0	34.94
AE-MDB PR034	1314.0	34.84

Table 2: AE-MDB test set-up

The results of the load cell wall tests for both MDB-R95 and AE-MDB barriers in standard dynamic certification tests are presented below with force/deflection per barrier blocks.

Barrier faces deflection

The deflection is calculated by double integration of mean acceleration of three accelerometers placed on the trolley. The maximum dynamic deformation measured during the test, when all of the kinetic energy has been absorbed, shall be 330 mm for MDB-R95 and 364 mm for AE-MDB. The results (see figure 10 and 11) show that all barriers are within the corridors for the complete barrier deformation as well as residual deformation.

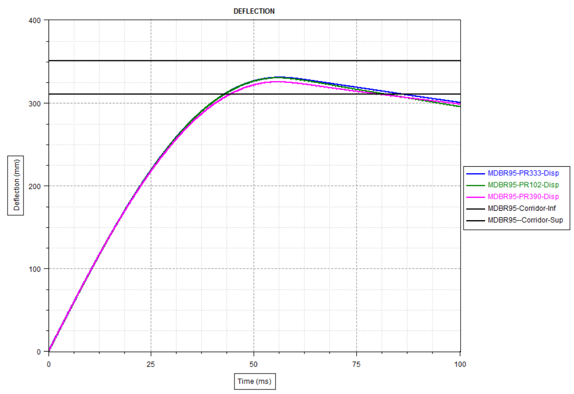

Figure 10: MDB-R95 barrier deflection

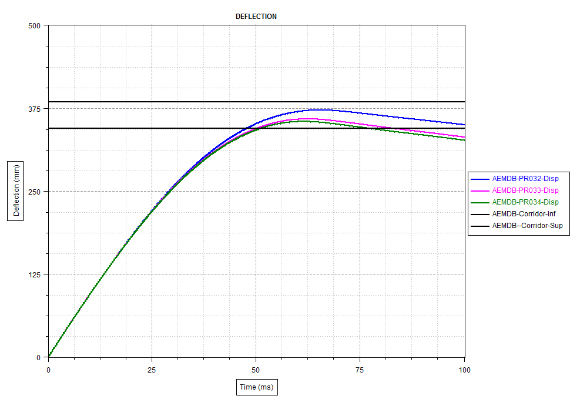

Figure 11: AE-MDB barrier deflection

The mean of maximum deflection is 328.14 mm for MDB-R95 and 361.46 mm for AE-MDB barriers. Global statistics (maximum, minimum, deviation etc.) are shown in appendix 1. The deviation noticed by the crash laboratories for all the 6 barriers are within the required specifications including uniform deformation of the barrier during the tests (see figure below).

Figure 12: MDB-R95 post-test


Figure 13: AE-MDB post-test

The MDB-R95 force/deflection per blocks are shown in the figures 14 to 20.

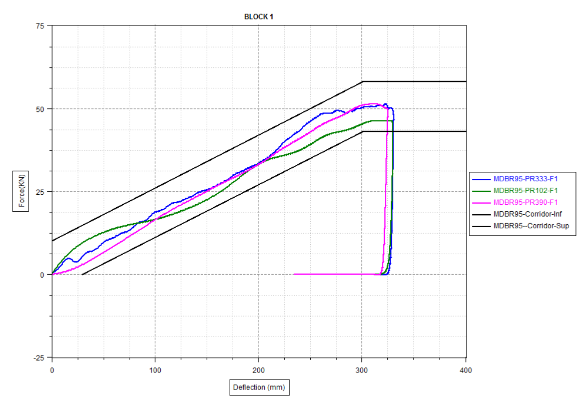

Figure 14: force/deflection MDB-R95 Blocks 1

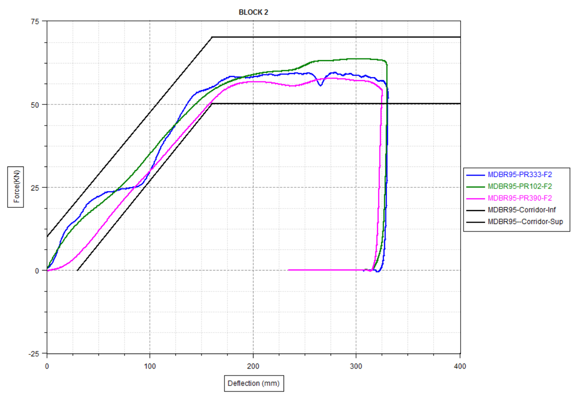

Figure 15: force/deflection MDB-R95 Blocks 2

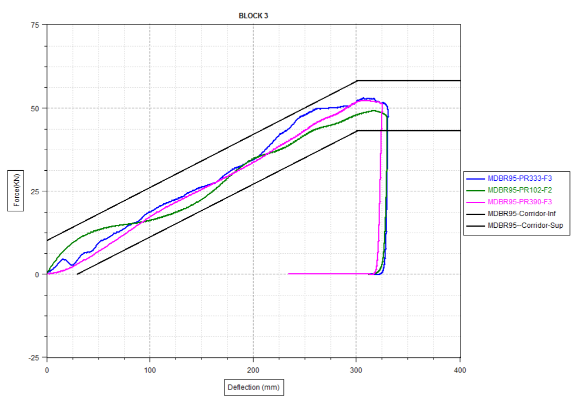

Figure 16: force/deflection MDB-R95 Blocks 3

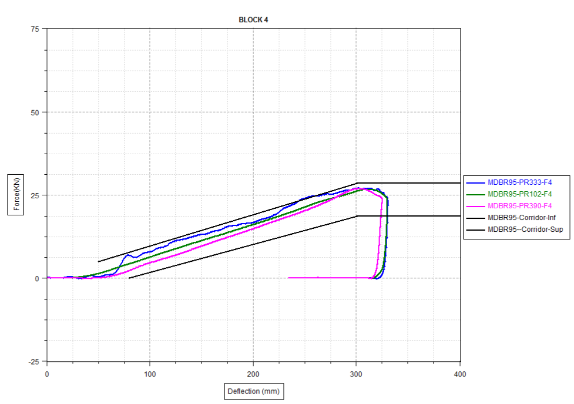

Figure 17: force/deflection MDB-R95 Blocks 4

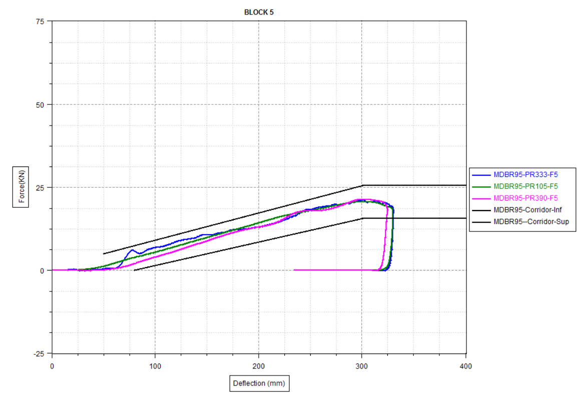

Figure 18: force/deflection MDB-R95 Blocks 5

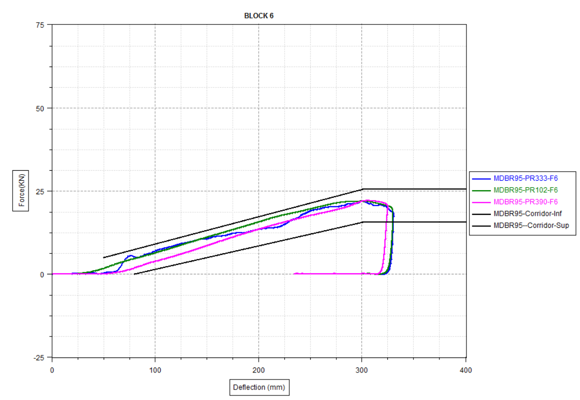

Figure 19: force/deflection MDB-R95 Blocks 6

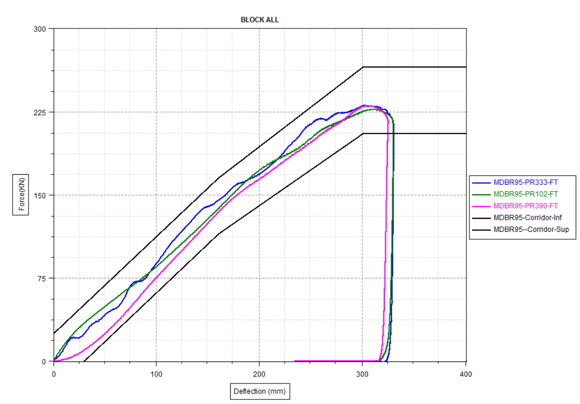

Figure 20: force/deflection MDB-R95 All Blocks

AE-MDB force/deflection per blocks

The AE-MDB force/deflection per blocks is shown in the figures 21 to 27.

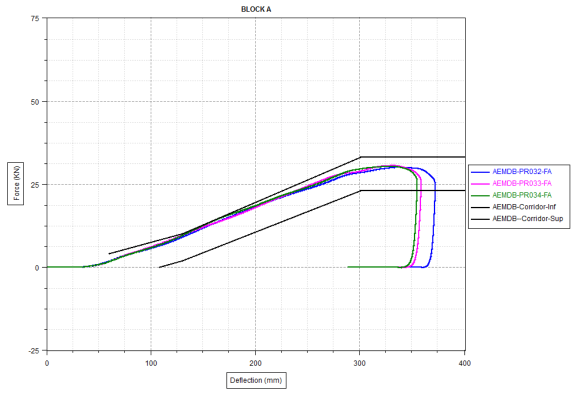

Figure 21: force/deflection AE-MDB Blocks A

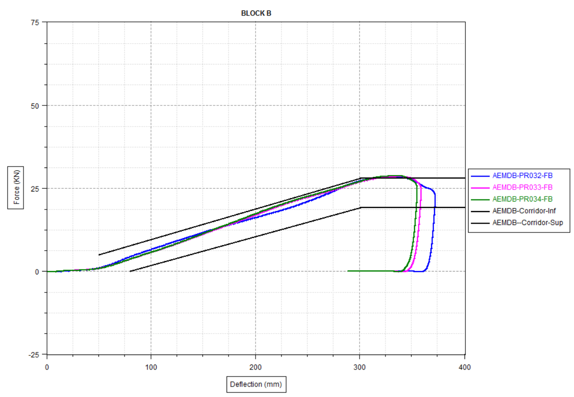

Figure 22: force/deflection AE-MDB Blocks B

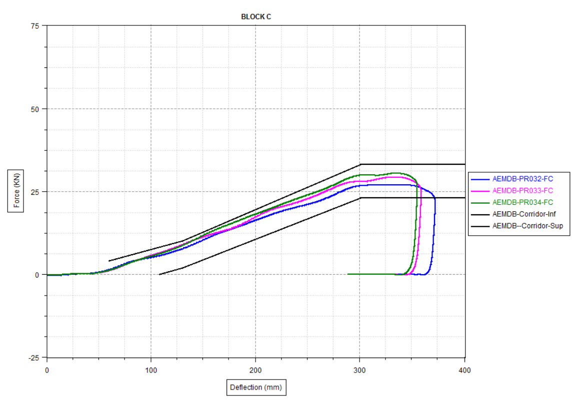

Figure 23: force/deflection AE-MDB Blocks C

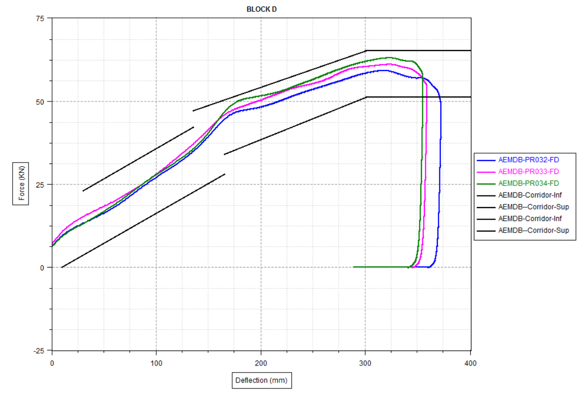

Figure 24: force/deflection AE-MDB Blocks D

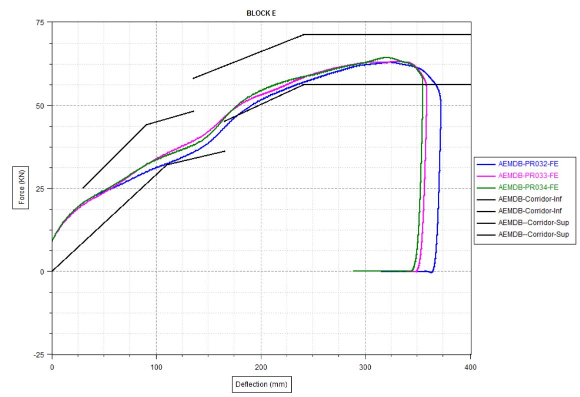

Figure 25: force/deflection AE-MDB Blocks E

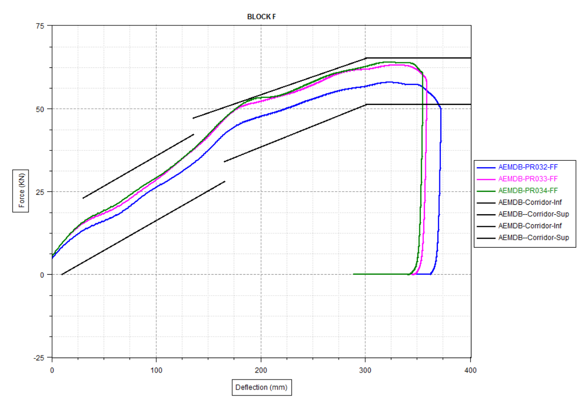

Figure 26: force/deflection AE-MDB Blocks F

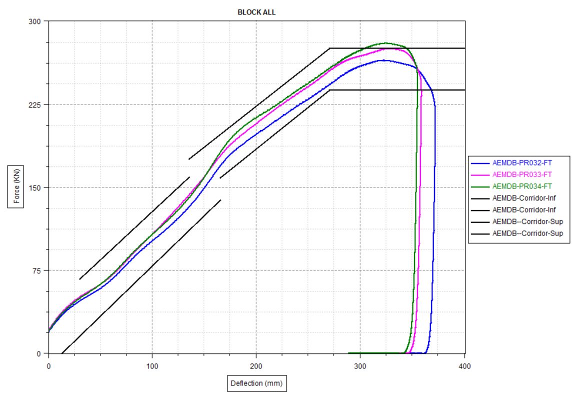

Figure 27: force/deflection AE-MDB All Blocks

EVALUATION METHOD

Methodology

The purpose of the evaluation module is to provide an objective and consistent way of comparing results in order to extract marks from models. To do so, a matrix base approach has been chosen. This approach is detailed below, while all the practical information related to use of this module are in the Hyperstudy User's Guide [7]. In this section we briefly describe the notation method used in Adviser's evaluation module. In our purpose, the scoring is made on the basis of the use of corridors to evaluate results position.

Distance error

The first point concerns the element level evaluation: considering the element corresponding to line i and column j, we first may express a local note Eij that will stand for the difference between experimental and simulation value of element ij. The note is computed as the relative difference between the two values so that we have:

$$E_{ij} = 100 \times \left| \frac{Ref(i,j) - Val(i,j)}{Ref(i,j)} \right|$$

Equation 1: note computed as relative difference between Ref and Val

This is called the "Distance Only Error Score". Please note that Ref or Val values may be themselves complex criteria. This formula implies that elementary scoring will always be between 0 and 100. In addition we have to notice that using a relative difference scheme will lead to a null score if difference between Ref and Val is higher than Ref value magnitude.

Corridor score

In Adviser evaluation module, the score of each element may be modified by analyzing whether the target value (Yij or Val(i, j)) belong to a user specified corridor. This corridor will lead to evaluation of a corridor score. This score, Fcij , will be used to create a global error report over the element. This score Fcij can be either used "alone" or in addition to the distance error Eij. Below is shown the definition of the score function:

$$Fc_{ij} = \begin{cases} \frac{a}{b-e}\left(Y_{ij} - e\right) & \text{if } Y_{ij} \in [e;b] \\ \frac{a-1}{b-M}\left(Y_{ij} - b\right) + a & \text{if } Y_{ij} \in [b;M] \\ \frac{a-1}{c-M}\left(Y_{ij} - c\right) + a & \text{if } Y_{ij} \in [M;c] \\ \frac{a}{c-f}\left(Y_{ij} - f\right) & \text{if } Y_{ij} \in [c;f] \\ 0 & \textit{otherwise} \end{cases}$$

Equation 2: score function definition

In these relations we introduced:

- The bounds of the corridor: b and c
- The value of the function at the bounds of the corridor: a
- We consider the middle of the corridor has the reference point: M=(b+c)/2, so
- e and f are tolerances regarding X position in the corridor and k: e=b-k(c-b),
- f is an integer used to quantify this tolerance: f=c+k(c-b)

For example with k set to 1 and a set to 0.4 we obtain the following shape for the corridor function.

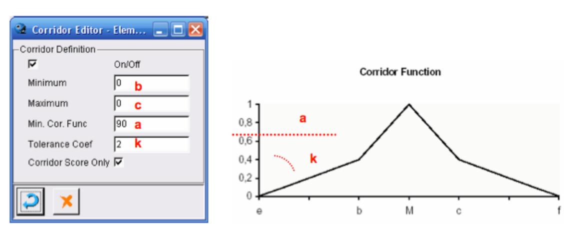

Figure 28: shape of the corridor function

The maximum note is obtained for a value of Yij lying in the middle of the corridor. The parameters a, b, c and k are the data given by the user.

Scoring

We used the scoring method describes above to evaluate both MDB-R95 and AE-MDB results (displacements, blocks forces et.) in front of the LCW tests. Maximum and minimum of the corridors are set as b and c variable. Parameters a and k are set to 0. This means that the score value will reflect how far we are from the middle of the corridor. The rating is set to 100% if we are perfectly in the middle of the defined corridor; set to 0% at the bounds of the corridor. If the results are out of the corridor, the score value will be automatically be set to 0%. The figures below show the evaluation matrix for both MDB-R95 and AE-MDB barriers and the main outputs in dynamic certification.

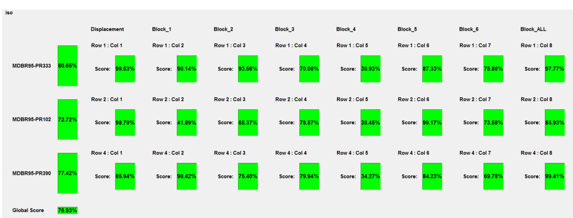

Figure 29: MDB-R95 evaluation matrix #1

Figure 30: AE-MDB evaluation matrix #1

DISCUSSION

None of the 6 barriers tested bottom out for LCW tests with 328mm crush for MDB-R95 and 361 mm crush for AE-MDB. For the barriers, the variance at peak deflection for MDB-R95 and AE-MDB are respectively 9% and 81%. For all the tests performed, we didn't see any imbalance between the outer blocks for MDB-R95 and AE-MDB tests as well. All the barriers were well aligned with the Load Cell Wall according to the crash laboratories measurement. The residual deformation measured after tests are within the specification for all barriers tested.

The 3 MBB-R95 barriers pass the certification for block forces and deflection according to the ECE-R95. Although all blocks are within the corridors and mainly closed to the mean corridors, the middle block of the upper row (blocks 4 for all MDB-R95 barriers tested) have stiffer responses than the median corridor and are closed to the upper corridor see figure XX. In case of barrier MDB-R95-PR102, we also noticed for deflection upper than 200 mm that the force is going down within the corridor. This behavior is less highlighted by he block 3 and not seen from the 2 other MDB-R95 barriers tested. For the upper row, the variance at peak force for blocks 1, 2 and 3 is less than 1%. For the lower row, the variance at peak force for blocks 4, 5 and 6 are respectively 8%, 9% and 4%.

The 3 AE-MDB barriers are compared to the APROSYS corridors [2]. The blocks D, E and F are in the corridors. For the upper row, the variance at peak force for blocks are respectively 3%, 1% and 10%. The blocks A and C are in the corridor with stiffness closed to the mean corridor and variance at peak force of 1% and 3% respectively. The block B for the 3 AE-MDB barrier tested is going above the top corridor from for deflection upper than 310 mm with maximum forces out of the corridor. The block B maximum peak deflection for AE-MDB barriers is 28.67 kN meaning just 0.67 kN outer the top corridor and the variance at peak force for blocks B is less than 1%. The blocks B have a stiffer behavior compared to the mean corridor, which is in line with the corresponding block 4 from MDB-R95.

In LCW tests, the MDB-R95 shows consistent results closed to the mean corridor for all blacks as well as all tests performed at different crash laboratories. The AE-MDB-PR032 has a softer behavior by comparison to the 2 others although the blocks B for all AE-MDB barriers tested are outside the corridor. However, the 3 AE-MDB barriers have consistent results to each other. The figure below shows the evaluation matrix for MDB-R95 and AE-MDB barriers recomputed with the following rating to better highlight the deviation from the middle of the corridor:

- Red if score is under 25% or out of the corridors
- Orange if score is in between 25% and 50%
- Yellow if score is in between 50% and 75%
- Green if score is in between 75% and 100%

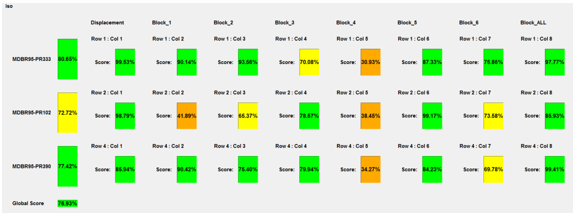

Figure 31: MDB-R95 evaluation matrix #2

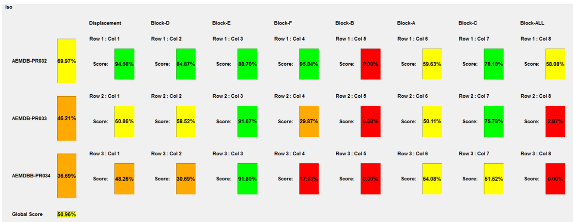

Figure 32: AE-MDB evaluation matrix #2

CONCLUSIONS

The objective of this work was to perform a first status of both MDB-R95 and AE-MDB side impact barriers regarding their respective Load Cell Wall tests configuration.

Due to its new design and materials in addition of the bumper, AE-MDB barrier is much more complicated to manufacture than the well-known MDB-R95. Although MDB-R95 results are all within the corridors which is not the case of the AE-MDB results, the repeatability and consistency of the barriers looks equivalent especially for the upper rows. Some additional tests for both barriers will be added to the work to increase the panel to more than 3 tests per barrier as presented in this paper. This would allow better statistics regarding barrier repeatability, especially for AE-MDB deflection, which seems having higher variance than the MDB-R95. Improvement will be also made for the rating evaluation, which is actually mainly based on the peak force and deflection. In addition, AE-MDB specifications will be updated according to the latest corridors, which will be published soon by EuroNCAP

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ACKNOWLEDGEMENTS

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APPENDIX 1

MDB-R95	Points	Minimum	Mean	Maximum	Range	Ave Deviation	Std Deviation	|SDev/Mean|	Variance
Displacement - mm	3	324.70	328.14	330.18	5.48	2.29	3.00	0.01	8.98
Block_1 - kN	3	46.14	49.53	51.24	5.10	2.26	2.94	0.06	8.63
Block_2 - kN	3	57.54	60.12	63.46	5.92	2.23	3.03	0.05	9.21
Block_3 - kN	3	48.89	51.21	52.74	3.85	1.55	2.04	0.04	4.18
Block_4 - kN	3	26.58	26.77	26.95	0.38	0.13	0.19	0.01	0.04
Block_5 - kN	3	20.54	20.99	21.29	0.75	0.30	0.39	0.02	0.16
Block_6 - kN	3	21.71	21.85	22.01	0.30	0.11	0.15	0.01	0.02
Block_ALL - kN	3	226.48	228.96	230.56	4.08	1.65	2.18	0.01	4.74

AE-MDB	Points	Minimum	Mean	Maximum	Range	Ave Deviation	Std Deviation	|SDev/Mean|	Variance
Displacement - mm	3	354.48	361.46	371.65	17.17	6.79	9.02	0.02	81.44
Block-D - kN	3	59.06	60.94	62.85	3.79	1.28	1.90	0.03	3.60
Block-E - kN	3	62.65	63.21	64.11	1.46	0.60	0.79	0.01	0.62
Block-F - kN	3	57.71	61.47	63.80	6.09	2.51	3.29	0.05	10.82
Block-B - kN	3	28.28	28.45	28.67	0.39	0.15	0.20	0.01	0.04
Block-A - kN	3	30.02	30.27	30.49	0.48	0.17	0.24	0.01	0.06
Block-C - kN	3	26.91	28.85	30.42	3.51	1.29	1.79	0.06	3.19
Block-ALL - kN	3	263.96	272.59	279.36	15.39	5.75	7.86	0.03	61.82

TRENDS WITH ANCAP SAFETY RATINGS AND REAL-WORLD CRASH PERFORMANCE FOR VEHICLE MODELS IN AUSTRALIA

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Paper Number 13-0390

ABSTRACT

Since 1995 the Australasian New Car Assessment Program (ANCAP) has conducted a 64km/h offset crash test. In 1999 the test and rating protocols were aligned with Euro NCAP. This produces a rating out of 5 stars for front occupant (driver and front passenger) protection. In a separate program the crashworthiness of used cars in real-world crashes has been analysed under the Used Car Safety Rating (UCSR) scheme.

The ANCAP and UCSR ratings of more than 30 models on the Australian market can be tracked for more than a decade. This paper sets out the results of an analysis of these data and observations about the safety improvements to these models.

In general an improvement of one ANCAP star rating for a model is associated with a 20 to 25% reduction in risk of serious injury to the driver. It is likely that improvements from 3 stars or less to 4 stars are mostly associated with improved structure and restraints in frontal crashes. Improvements from 4 to 5 stars are mostly likely associated with improved head protection in side crashes.

It is only in the last few years that most popular models in Australia have reached a 5 star rating. Many of these vehicles are not yet covered by Used Car Safety Ratings because of the inherent delay in obtaining real-world crash data. It is therefore planned to repeat this analysis in 2014.

INTRODUCTION

The Australasian New Car Assessment Program has conducted consumer crash tests since the early 1990s. In 1999 ANCAP aligned its test and assessment protocols with Euro NCAP and began republishing applicable Euro NCAP results using a 5-star safety rating.

The Used Car Safety Ratings were developed by Monash University Accident Research Unit (MUARC) in the early 1990s. Police-reported accidents from Australia and New Zealand are analysed to derive estimates of crashworthiness for popular vehicle models. One key output from the analysis is a driver serious injury rate per reported crash for each vehicle model. Statistical techniques are used to account for influencing factors such as age and sex of driver, restraint usage and speed limit of road (Cameron and others 1992).

There is an inherent delay in the time taken to acquire real-world crash data. Furthermore, a sufficient numbers of crashes of a model need to occur in order for sample sizes to be adequate for statistical analysis. For these reasons the USCR do not usually provide reliable estimates of crashworthiness of popular new models until at least four years after the model is launched.

In general, as a vehicle model has been replaced the new model performs better in ANCAP tests than the replaced model (a notable exception was the Holden Barina in 2005). This paper sets out the results of an analysis of the change in ANCAP safety rating and UCSR crashworthiness for more than 30 models of passenger vehicles that have been sold in Australia since the mid-1990s.

RECENT ANCAP TRENDS

In the last few years there has been a dramatic improvement in the ANCAP safety ratings of new models. Figure 1 shows the proportion of rated new models for each star rating by year of rating.

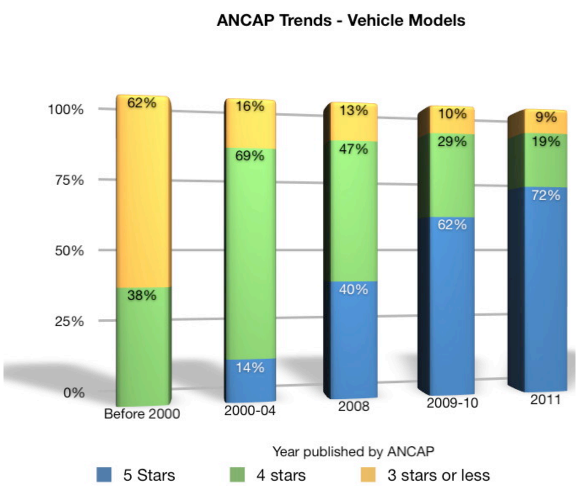

Figure 1. Trends with ANCAP ratings

Before 2000 there were no 5 star ratings and only 38% of models had a 4 star rating. By 2004 14% of models were 5 stars and a further 69% were 4 stars, meaning that the proportion with 3 stars or less had dropped from two-thirds to 16%. These improvements were largely due to improved performance in the offset crash test (Paine and others 2009).

The proportion of 5 star models increased from 14% in 2004 to 40% in 2008 and 72% in 2011. This is likely to be due to further improvements in frontal offset crash performance, but mainly due to the rapid introduction of head-protecting side airbags (e.g. inflatable side curtains), which are necessary for satisfactory performance in the side pole test (which has been an ANCAP 5-star requirement since 2004).

UCSR TRENDS

The 2012 UCSR update confirms a steady improvement in crashworthiness (i.e. reduction in risk of serious injury to the driver) over more than two decades. Compared with a mid 1980s model, a vehicle built between 2007 and 2010 typically has less than half the risk of driver serious injury (Newstead 2012).

It is notable that very few models introduced since 2007 have statistically meaningful crashworthiness ratings. As indicated above, there were simply too few reported crashes of these models for the 2012 UCSR update. This means that the UCSR analysis does not reflect the recent dramatic improvement in ANCAP safety ratings of popular models.

Another limitation for comparison with ANCAP is that, in effect, the Used Car Safety Ratings assume that all variants of a model have the same crashworthiness. However on numerous occasions ANCAP has published different safety ratings for variants of a model, mainly because the base model has fewer airbags.

PREVIOUS STUDIES THAT COMPARE NCAP PERFORMANCE WITH REAL-WORLD CRASHES

Lie and others (2001) compared Euro NCAP ratings with Folksam analysis of real-world crashes: *A correlation was found between Euro NCAP scoring and relative risk of serious and fatal injury as well as for the Folksam rating score (relative risk of fatality or permanent disability). No correlation between Euro NCAP scoring and relative risk of any injury was found.* It was estimated that the risk of a serious or fatal injury reduced by 12% for each Euro NCAP star rating.

Farmer (2004) compared how "good" and "poor" rated vehicles performed in real-world crashes. The study found a clear trend for better-rated vehicles to have a lower driver fatality risk, although the results were not uniform across all vehicle groups. In head-on crashes between similar vehicles the risk of a driver fatality was 74% lower for a good vehicle, compared with a poor vehicle.

Kullgren and others (2010) updated the 2004 study. Importantly good sample sizes were available for 5-star models. These were found to have a 68% lower risk of fatal injuries, compared with 2 star models. Serious/fatal injuries were 23% less and all injuries were 10% less. Figure 2 shows the results, with error bars.

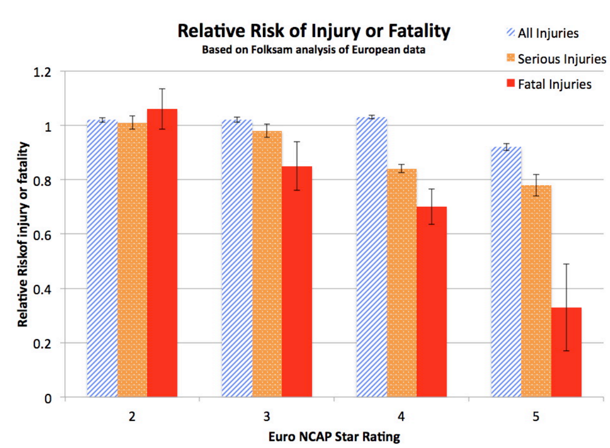

Figure 2. Euro NCAP injury risk analysis

Newstead and Scully (2012) examined whether adjustments to the way in which ANCAP scored the tests could produce better correlation with Used Car Safety Ratings. Statistically significant differences were found in the UCSR crashworthiness when 2-star vehicles were compared with 5-star vehicles. The correlation varied between types of vehicles. Some changes to the relative weights of the components of the ANCAP score were found to produce better correlation.

In 2009 the Insurance Institute for Highway Safety (IIHS) conducted a study of mechanisms of serious injury to occupants of vehicles that were rated "good" in the frontal offset test. (Brumbelow and Zuby 2009). This research resulted in the introduction of the small-overlap frontal offset test by IIHS. Severe chest injuries (AIS3+) were found to be the predominant serious injury in nearly all types of frontal crashes involving these vehicles.

Concern about chest injuries in frontal crashes, particularly with smaller female occupants, led to a recommendation that NHTSA introduces a 40km/h full frontal crash test, with more stringent chest compression limits (Diggs and Dalmotas 2007). To date this recommendation has not been implemented but NHTSA has introduced more crash tests with small adult female dummies.

Serious lower extremity injuries remain a concern with vehicles that have good NCAP ratings (Austin 2012). Morris (2006) reported that leg injuries accounted for 43% of the cost of all non-fatal frontal crashes with serious injuries (AIS 2+) and are "by far the most costly injury according to of UK willingness to pay study". Foot/ankle NCAP ratings (which are based on pedal displacement and footwell integrity) were found to have the closest correlation with real-world serious injuries.

In response to these research findings ANCAP proposes to introduce a minimum injury score for each body region as a condition for star ratings. This is intended to prevent a poor score for one body region being disguised by good scores for other body regions. The following analysis does not take this proposal into account.

METHODOLOGY

ANCAP ratings are available, or can be estimated, for many vehicle models sold in Australian since the mid-1990s. In general ratings are available when models are replaced and in most cases the new model has a better ANCAP star rating than the superseded model. Similarly, UCSR Crashworthiness estimates are available for many models over this period. It was therefore decided to compare the change in UCSR when a model improved its ANCAP star rating. This approach should help to minimise the effects of any uncontrolled confounding factors in UCSR, since the two models (old and new) can be expected to be similar in size and mass and the same type of drivers can be expected to be driving a particular model under similar road conditions (this may be optimistic but vehicle marketing attempts to achieve this outcome).

A list of vehicle models was developed where there was a change in ANCAP star rating between old and new models. Where possible UCSR crashworthiness values were obtained for these models and the change in crashworthiness was calculated. The appendix sets out the data for these models.

In some cases the models were built prior to 1999, when ANCAP commenced star ratings using the Euro NCAP protocols. However ANCAP began 64km/h offset tests in 1995 and data from these tests has been analysed to estimate star ratings for early models, using the points balance criteria of the current ANCAP system (i.e. a minimum score of 4.5 is required for a 3 star rating) and likely deductions that would have applied to these scores due to the application of modifiers such as loss of structural integrity.

RESULTS

Of the 35 models analysed:

- 32 models had data for the change from 3 stars or less to 4 stars (Figure 3)
- The average improvement in crashworthiness for these models was 22%
- All models except the Toyota Corolla improved in crashworthiness. The Corolla crashworthiness reduced by 10%
- The Holden Barina deteriorated from 4 stars in 2004 to 2 stars in 2005. The crashworthiness of the 4 star model was 15% better than the 2 star model.
- 11 models had data for the change from 4 stars to 5 stars (Figure 4)
- The average improvement in crashworthiness for these models was 35%
- 8 models had data for the change from 3 stars or less to 5 stars (Figure 5)
- The average improvement in crashworthiness for these models was 49%
- All of these models had intermediate 4 star models (shown in Figure 4).
- 16 of the models now have 5 star ANCAP ratings but crashworthiness ratings for these newer models were not available in the 2012 UCSR update.

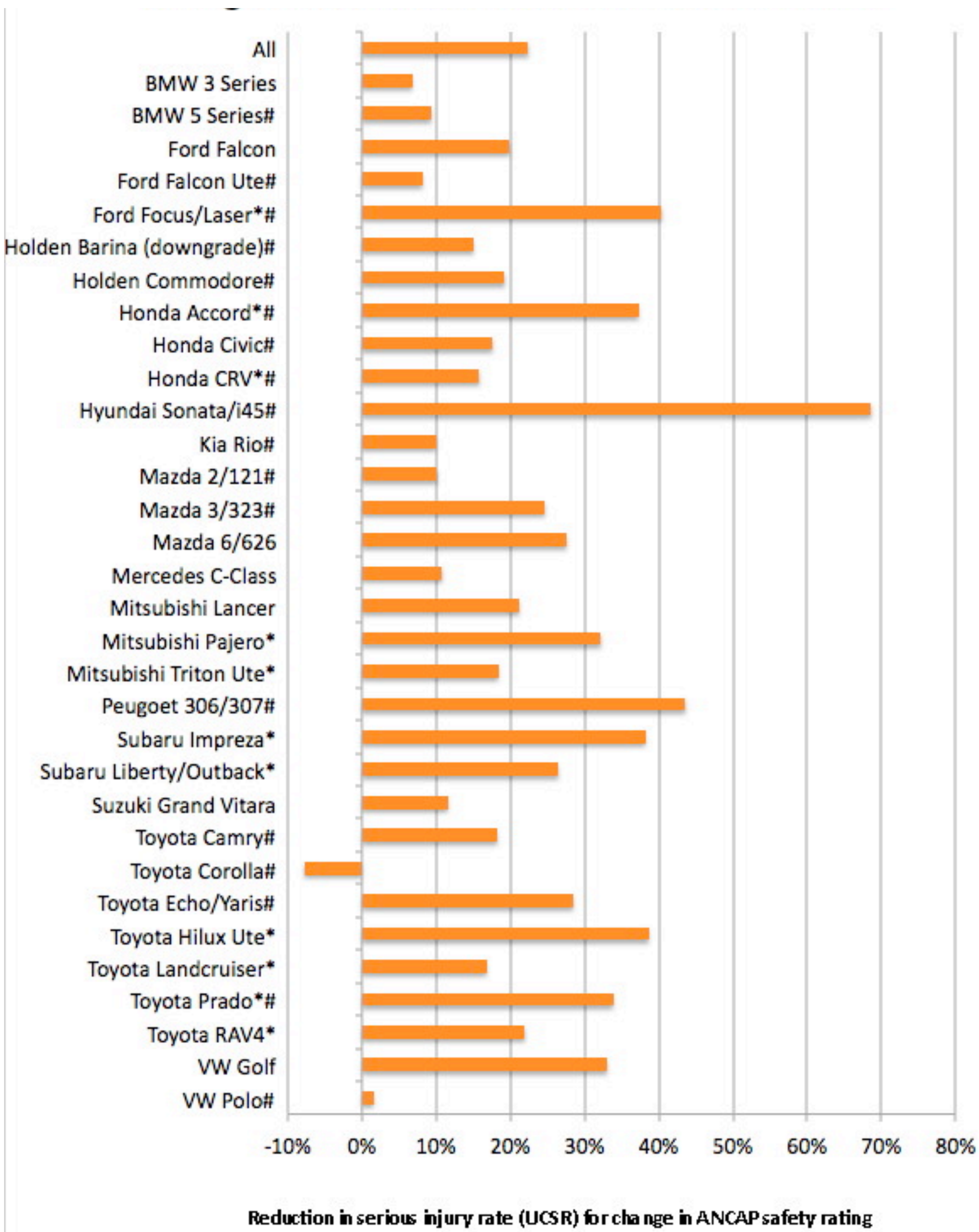

Figure 3. Change in crashworthiness: 3 stars or less to 4 stars

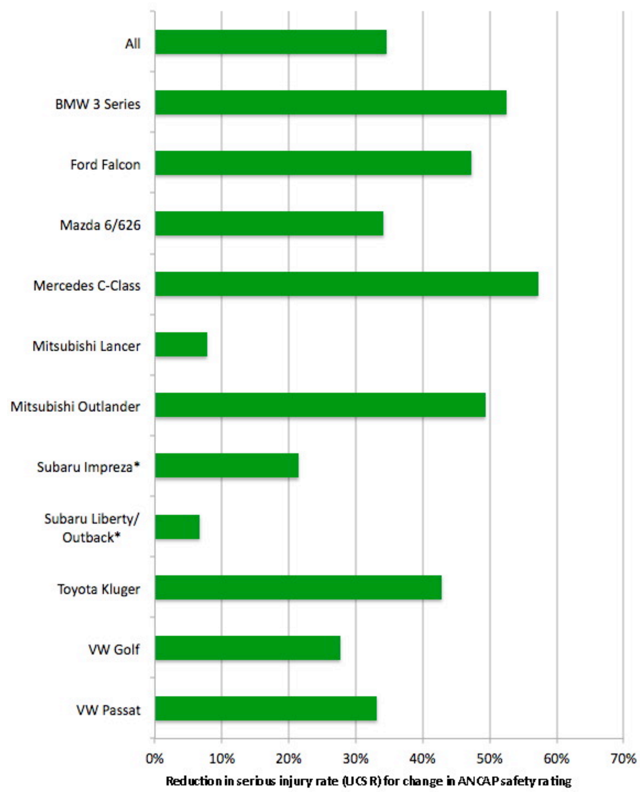

Figure 4. Changes in crashworthiness: 4 to 5 stars

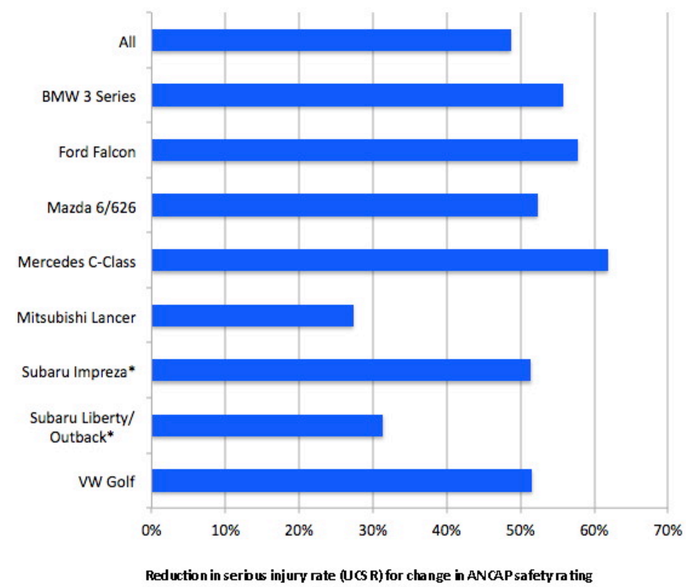

Figure 5. Change in crashworthiness: 3 stars or less to 5 stars

DISCUSSION

Researchers from MUARC have analysed the data collected for UCSR further to determine the potential savings if some groups of drivers drove safer vehicles than the ones in which they were killed or injured. Whelan and others (2009) conclude: "*if all young drivers involved in crashes were driving the safest car available, rather than the cars they usually drove, the road fatality and serious injury rate could be reduced by more than 80 per cent.*" Similar remarkable savings have been estimated for older drivers (Budd and others 2012). The apparent strong link between improved ANCAP star ratings and crashworthiness, as measured by UCSR reinforces the case for promoting safer vehicles. This is supported by European studies of injury risk and Euro NCAP star rating (Kullgren and others 2010)

It has been pointed out that many models have increased in kerb mass over time and that this may partly account for improvement in crashworthiness. For example Newstead and Scully (2012) point out an apparent relationship between crashworthiness and kerb mass.

Physics dictates that, in a two-vehicle collision, the lighter vehicle will experience a larger change in velocity than the heavier vehicle. This places a higher demand on the occupant protection system for the lighter vehicle. If the vehicle does not cope well with the higher forces then the occupants are at increased risk of serious injury, compared with the heavier vehicle. About 84% of crashes in which car drivers are injured are multi-vehicle crashes (Scully and Newstead 2009).

The models covered by this study have therefore been analysed for trends in kerb mass. For vehicles that have improved from 3 stars or less to 4 stars the average increase in kerb mass is 10%. For vehicles that have improved from 4 stars to 5 stars the average increase in kerb mass is 3%.

The observations about trends in occupant protection and structural performance noted by Paine and others (2009) suggest that the reduced risk of injury in newer models is largely due to major improvements in vehicle design and the addition of safety features such as head-protecting side airbags.

These safer vehicles tend to weigh slightly more than the models they replace. This effect needs to be taken into account when looking for a relationship between kerb mass and crashworthiness.

CONCLUSIONS

As measured by the USCR method, there is a strong reduction in the risk of serious injury to the driver each time that a model improves its ANCAP star rating.

On average the crashworthiness improves by 22% when a model improves from 3 stars or less to 4 stars and by 35% when a model improves from 4 stars to 5 stars. The average improvement from 3 stars or less to 5 stars is 49%.

In the past few years many models have improved to a 5 star ANCAP rating. It will be several years before the UCSR program gathers sufficient real-world crash data to determine reliable crashworthiness ratings for these models. Based on the few popular 5-star models that do have crashworthiness ratings, a remarkable reduction in serious injury risk can be expected from these newer models.

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APPENDIX

The following table has the raw data used in the analysis

	YEAR RANGE 1	ANCAP 1	UCSR 1	YEAR RANGE 2	ANCAP 2	UCSR 2	YEAR RANGE 3	ANCAP 3	UCSR 3
BMW 3 Series	92-98	3	3.41	99-06	4	3.18	05-10	5	1.51
BMW 5 Series#	96-03	3	2.25	04-10	4	2.04			
Ford Falcon	98-02	3	3.27	03-07	4	2.62	08-10	5	1.38
Ford Falcon Ute#	00-02	3	2.57	03-08	4	2.36			
Ford Focus/Laser*#	95-97	2	4.9	02-05	4	2.92			
Holden Barina (downgrade)#	05-10	2	4.13	01-06	4	3.51			
Holden Commodore#	97-02	3	3.38	02-07	4	2.73			
Honda Accord*#	94-98	2	3.57	03-07	4	2.24			
Honda Civic#	96-00	2	4.09	01-05	4	3.37			
Honda CRV*#	97-01	2	2.78	02-06	4	2.34			
Hyundai Sonata/i45#	98-01	2	4.21	05-10	4	1.32			
Kia Rio#	00-05	3	4.53	05-10	4	4.08			
Mazda 2/121#	97-02	2	4.73	02-07	4	4.25			
Mazda 3/323#	99-03	3	3.49	03-09	4	2.63			
Mazda 6/626	98-02	3	3.23	02-07	4	2.34	08-10	5	1.54
Mercedes C-Class	95-00	3	2.96	00-07	4	2.64	07-10	5	1.13
Mitsubishi Lancer	96-03	2	4.72	03-07	4	3.72	08-10	5	3.43
Mitsubishi Outlander				03-06	4	3.06	06-10	5	1.55
Mitsubishi Pajero*	92-99	3	3.23	00-06	4	2.19			
Mitsubishi Triton Ute*	96-06	2	2.56	06-10	4	2.09			
Peugoet 306/307#	94-01	3	2.89	01-09	4	1.63			
Subaru Impreza*	93-00	3	4.9	01-07	4	3.03	07-10	5	2.38
Subaru Liberty/Outback*	94-98	3	3.44	99-03	4	2.53	03-99	5	2.36
Suzuki Grand Vitara	99-05	3	3.12	05-08	4	2.76			
Toyota Camry#	98-02	3	3.35	02-06	4	2.74			
Toyota Corolla#	98-01	3	3.21	02-07	4	3.46			
Toyota Echo/Yaris#	99-05	3	4.6	05-10	4	3.29			
Toyota Hilux Ute*	98-02	3	2.95	05-10	4	1.81			
Toyota Kluger				03-07	4	2.94	07-10	5	1.68
Toyota Landcruiser*#	90-97	3	3.16	98--07	4	2.63			
Toyota Prado*#	96-03	2	2.63	03-09	4	1.74			
Toyota RAV4*	94-00	2	3.78	01-06	4	2.95			
VW Golf	93-98	3	3.18	99-04	4	2.13	04-10	5	1.54
VW Passat				98-06	4	2.2	06-10	5	1.47
VW Polo#	96-00	2	3.3	02-10	4	3.25			

* Model built prior to 1999. ANCAP star rating estimated from offset test score

Models that now have a 5-star rating but there is no UCSR score (as at July 2012)

The Subaru Forester was not included in the analysis because between 2002 and 2008 there were two ANCAP ratings - 5 stars for variants with head-protecting side airbags and 4 stars for variants without. The crashworthiness rating was 2.32 for all Foresters built during this period but the proportion of 5 star variants was unknown. A new model Forester, launched in 2008, was 5 stars for all variants. The early crashworthiness rating for this new model was 3.32 (i.e. substantially worse than the previous model) but the sample size was small and so the confidence interval was large. Also this was one of the first popular cars to have electronic stability control as standard and this might have an influence on the severity of crashes (see Scully and Newstead 2009).

Changes to vehicle kerb mass

A brief analysis has been undertaken to determine the change in vehicle kerb mass when vehicle models are updated. The following graph shows the results of this analysis. It is concluded that there is no discernable correlation between increase in kerb mass and crashworthiness for successive models.

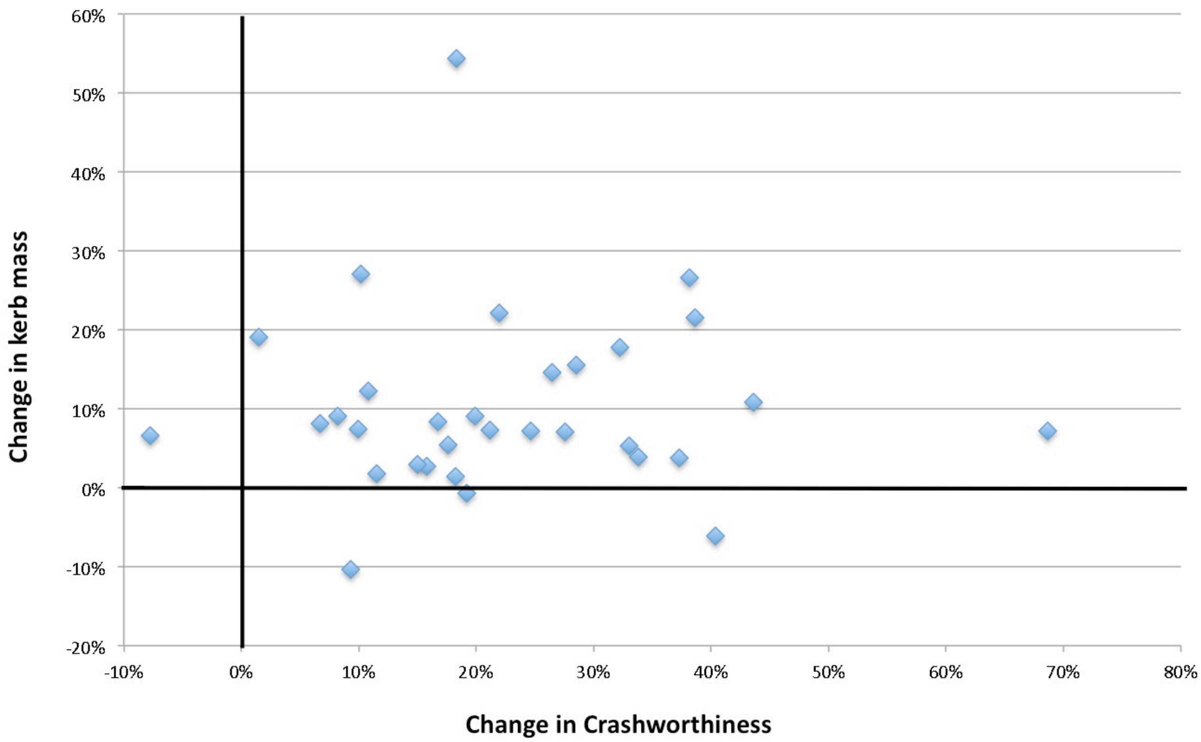

Figure 6. Scatter plot of change in crashworthiness and change in kerb mass for models that have changed from 3 stars or less to 4 stars in ANCAP rating

Development of a test target for AEB systems

Development process of a device to test AEB systems for consumer tests

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Paper Number 13-0406

ABSTRACT

Rear-end collisions are one of the most frequent crashes in Europe. Common causes include momentary inattention, inadequate speed or inadequate distance. Rear-end impacts are among the most common types of road accidents involving injury e.g. Germany with an approx. 15% share in the total number of accidents involving injuries. Accident data shows that the rear end collisions with 65% and more overlap is most common. To test the effectiveness of advanced emergency braking systems and show up their performance to the consumer, a new test setup and assessment has to be developed.

Based on the data of different accident research programs the most common rear end accidents are in a right angular with an overlap of more than 2/3 of the vehicle width. Impact scenarios could fixed to three situations, collision with stand still objects, with stopping objects and with objects of a lower driving speed. Impact speed up to 50kph and more could be seen in the accident data analyses.

Taking into account the findings of the accident research, a test equipment needed to be developed to allow to test all kind of AEB systems in a longitudinal situation, simulating driving, slowing down and stationary condition. On the other hand a system has to be designed to show the consumer the effectiveness of different systems and therefore a target which must be able to strike has to be developed. A balloon car was the best solution for these requirements. In a fist stage the balloon target needed to be developed in a way that nearly all AEB systems could detect it to assess different systems and show the consumer the performance of this new technology. In a second phase the target needed to be improved in a more realistic way according a vehicle rear end, which would make it less easier to detect, but still taking into account the different information of the variable sensors such as radar, lidar, camera or PMD. In addition to the test target also a propulsion system is needed, which should not be recognized by the test vehicle, but allowing testing all the scenarios mentioned before. A ladder frame based system was designed which could be town by a vehicle in front of the target, while the target was place on a movable platform on this ladder frame. Stationary impacts as well as decelerating scenarios up to 6m/s^2 must be realized with this device.

INTRODUCTION

With the development of passive safety features, vehicle safety has increased steadily over the past decades. The introduction of the safety belt and airbag were milestones in passive vehicle safety. In addition to the systems which mitigate the consequences of an accident, active systems for the prevention of accidents and the mitigation of their consequences have become increasingly important.

With the launch of ABS, the first driver assistance system was successfully introduced some 30 years ago. The mandatory introduction of ESC from 2012 is another milestone in driver safety. While ESC is a highly effective technology to prevent cars from skidding or running off the road or to mitigate the consequences of an accident, it is more or less ineffective in accidents which occur in the same and opposite direction of traffic.

Rear-end collisions are the most frequent same and opposite-direction crashes. Common causes include momentary inattention, inadequate speed or inadequate distance. While most rear-end collisions in urban traffic only result in vehicle damage or slight injuries, rear-end collisions outside built-up areas or on motorways usually cause fatal or serious injuries.

Rear-end impacts are among the most common types of road accidents involving injury. Driver assistance systems that detect dangerous situations in the longitudinal vehicle direction are therefore an essential safety plus.

According to the official statics for Germany and some European countries, rear-end impacts are the third most common accident type with an approx. 15% share in the total number of accidents involving injuries. The share varies greatly in some countries. For instance, the US 2006 share of rear-end collisions with stationary or moving vehicles was approx. 28% [1].

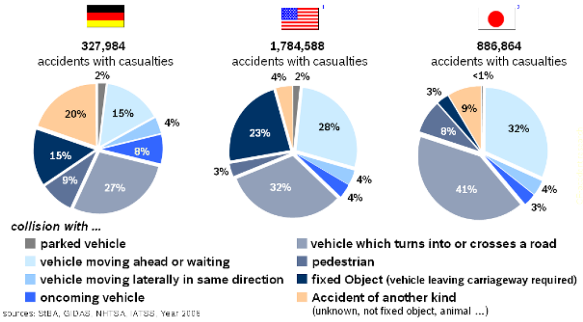


Figure 1: Accidents involving injuries by type of accident constellation [1], [2], [3]

In view of this, systems that alert drivers to dangerous situations and initiate autonomous braking complement ESC as one of the most important active safety features in modern vehicles.

The aim of ADAC is to provide consumers with technical advice and competent information about the systems available on the market. Reliable comparative tests that are based on standardised test criteria may provide motorists with important information and help them make a buying decision. In addition, they raise consumer awareness of the systems and speed up their market penetration.

Also, comparative product testing and the subsequent consumers' buying decisions cause the automotive manufacturers and suppliers to further develop their safety systems.

ADAC, Project Report, advanced emergency braking systems

The test scenarios and criteria selected must be defined such that they represent real-life accidents and allow drawing differentiated conclusions on the state of the art. Test standards that are either too high or too low would cause the test results to be less diversified (e.g. all systems tested are rated either "very good" or "poor").

The assessment must focus on as many aspects of effectiveness as possible and include not only autonomous braking but also collision warning and autonomous brake assist. Additional maloperation tests must be introduced to minimise false alarms and increase the consumers' acceptance of the systems.

According to ADAC accident researchers, longitudinal driver assistance systems can be effective in 13.8% of all accidents.

The literature emphasises the importance of rear-end collisions. They are a common type of accidents in Germany and Europe as well as in the USA and Japan.

The Bosch GIDAS data analysis [4] shows that AEBS can be effective in 12% of German road accidents involving injury (accidents recorded before or in 2005).

Impact velocity

This is also what the analysis of European accident research data concludes. In several sources ([5], [9]), it is concluded that average speed in rear-end collisions (initial speed) ranges between 40 and 60kph, meaning that in 55% of rear-end collisions, maximum speed is 50kph (speed limit in built-up areas).

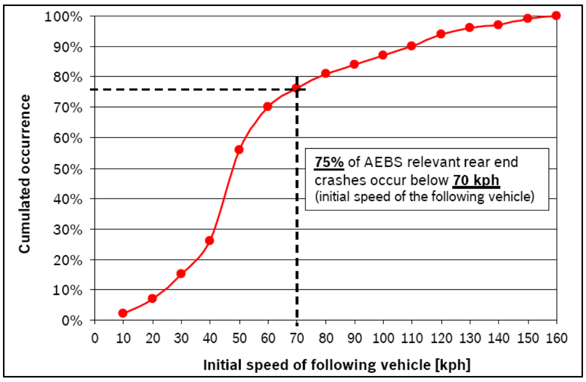
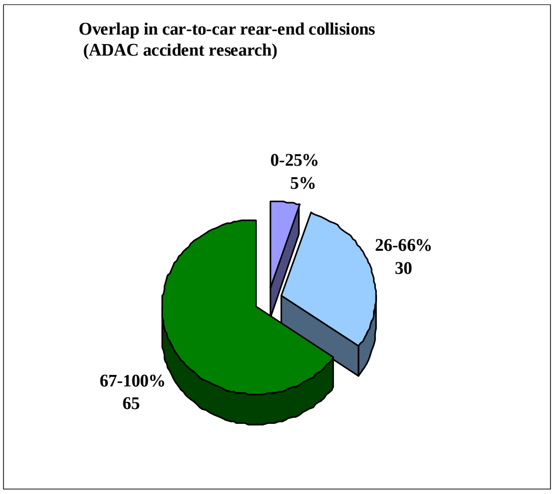


Figure2: Initial speed in rear-end collisions, GIDAS [5]

In this speed range, rear-end collisions only rarely result in serious or fatal injuries. Nevertheless, rear-end collisions are statistically very significant. Up to 70kph, approx. 75% of rear-end collisions are AEBS-relevant. Where the vehicle behind travels at 110kph, this value could increase to approx. 90%.

Test scenarios resulting from Accident research

In addition to speed, overlap and the direction of impact are important factors for the development of test scenarios. ADAC accident researchers found out that in 65% of accidents overlap is over two thirds of the vehicle width. The PENDANT [6] project, where deformation width was quantified indirectly based on the Collision Deformation Classification (CDC), equally showed that in the majority of accidents (54%) overlap is at least two thirds of the vehicle width.



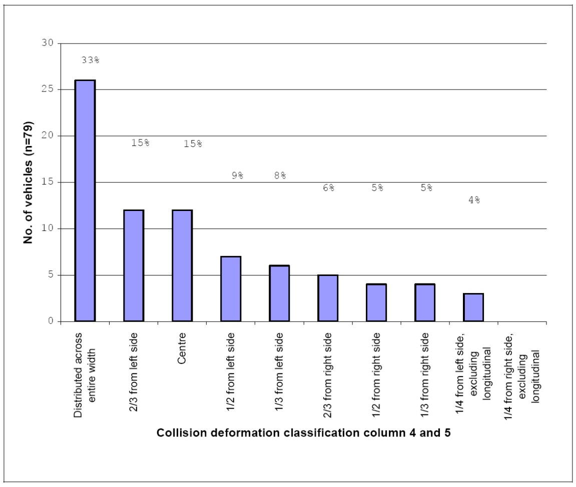


Figure 3 Overlap in rear-end collisions; top: ADAC accident research[7], right: PENDANT [6]

Accident scenarios and circumstances

The analysis of accident types is required to better understand conflict situations that cause rear-end collisions. A GIDAS analysis [5] presents the major accident conflict situations in Germany.

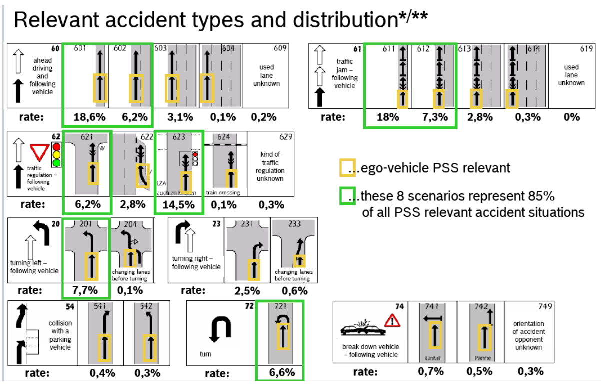


Figure4: Major conflict situations in rear-end collisions, GIDAS, 2001-2006, Dresden and 2001-2005, Hannover [5], accident constellation images based on GDV

DEVELOPMENT OF A TEST TARGET FOR CONSUMER TESTS

Preconditions

The analyses of the accident data, based on several European statistics gave the framework conditions for the setup of a test device for autonomous emergency braking systems.

1. Longitudinal impact

   Approaching a slow-moving vehicle

   Approaching a braking, strongly decelerated or stationary vehicle (traffic jam tail end, waiting traffic)

2. Relevant vehicle speed

   The maximum initial vehicle speed (before the rear-end collision) ranges between 50 and 70kph. Since injury risk is increased in accidents in extra-urban traffic, speeds around 100kph maybe in the focus of testing

3. Overlap upon impact usually is >67% of the vehicle width, 100% in a first approach focused

These test scenarios need to be full filled with a test equipment which should be able to be detected by all of the systems actual available on the market, easy to handle and capturing all tests without any need of huge changes to the system and causing no damages to the tested vehicle.

From the ADAC vehicle database information of the average vehicle size is given by 1600mm to 1850mm in width and 1400mm 1600mm in height, which should be addressed by a simulated target vehicle.

AEB systems are based on radar, lidar camera and other foresight systems to check whether the obstacle in front is a vehicle or a different object, so the target has to full fill all the requirement of the different systems. These requirements capture, radar reflexion, from the metal work of a real car, the dimensions and optical view of a rear end of a vehicle, such as a licence plate, rear lights 3D view and a shadow below the vehicle. Only the target vehicle itself should show these specifications, the towing system should not be detected by the AEB systems to avoid different triggering.

Target

Several suppliers and OEM were using a system with the shape of a vehicle to test AEB systems. With the cooperation partners Continental and Bosch the first step was to use a balloon car, developed for stationary tests, developed by Continental. This balloon car has a front and a rear camber, which are connected by 4 tubes. The front of the balloon should distribute the load; the horizontal 4 tubes, 2 placed on the bottom and 2 on the top of the target should deform and reduce the load during the impact.

Figure 5: inside view of the ballon target

The maximum impact speed is 50km/h on the balloon car without any damages to the balloon, so the impact velocity, formulated in the preconditions could be full filled.
Not all of the requirements are full filled with the use of this stationary target. Whether the vehicle siluette nor the possibility of a dynamic movement is given by the balloon car. The handling, stability and energy absorption seem to be a good reason for the use mentioned above.

Towing device
The chosen target was only designed for stationary impacts, a solution to tow the balloon car to the recommended speed needed to be developed. Scenarios for rear impact in longitudinal traffic show that a vehicle, parallel to the target vehicle and running with the similar speed is unlikely in real world. Another solution is to place the towing system or vehicle in front of the target, which shows the actual situation on the road. This setting would also allow using a towing vehicle and a device, which is covered by the balloon car and can not be detected by the tested vehicle.
With this configuration also a normal passenger car could be used for towing the balloon car and could be steered and decelerated by a person or optional by a steering and braking robot.
Concept 1: frame device as foldable ladder with an overall length of 10m, which is divided into 2 parts, on the rear part the target is mounted and on the other end the frame is attached to the towing vehicle. In case of an impact the system would work like a hinge and be folded together. This system is cheap and easy to realize, but not able to be used at a higher impact speed due to the hinge angle. The system could not be overridden by a vehicle. Small offsets would also load the system in a way that exact longitudinal movement could not be realized.
Concept 2: Telescopic arms on the rear of the towing vehicle, which could guide the target also to a higher speed, but the length could not be realized and also the production and price of telescopic arms of that length as well as the durability would lead to enormous costs.

Concept3: Based also on a ladder frame as concept 1 a solution was developed using the frame as a towing and guiding mechanism for the balloon car. Mounted on a small sled, the balloon car is strike able from the rear and it could be pushed forward the completely length of the ladder frame. With a long frame also higher impact speeds could be realized, even if the AEB system would not work or having only small mitigation. The stability of the system at higher speeds is good and the handling of the test system is easy to use and the production will cause not too many difficulties, without any electric devices used.

Figure 6: balloon car mounted on a ladder frame

The direct comparison between these 3 concepts lead to the decision for the ladder frame, sled based towing device which seemed to have the highest potential to full fill the requirements of the chosen test scenarios and causing the less influence of the target detection. Due to the length of the device, higher impact speed and also malfunctions of AEB systems will not lead to a directly damage of the system.
From the concept phase to the first prototype for testing different other test circumstances have to be sorted out and implemented in the towing device. The ground clearance of the modern sporty cars is lower than 100mm, so the maximum height for the system must be less than this dimension. The width of the rail system must be less than the distance between the tyres, so in case of an impact the tested vehicle will not get in touch with the rail system, even with a small offset during the impact. To avoid contact of the target and the towing vehicle, in case of an impact, the towing device has to stop the hidden target before that point. This is realized with a damping mechanism fixed to the towing hook of the leading vehicle. Wheels, mounted to the ladder frame, avoid contact with the ground and allow a longitudinal movement with nearly now movement to the side. This is important to full fill very tight tolerances for the striking of the target.
The movable sled, guided on the rail system is attached to the frame by wheels to avoid friction and to allow the sled together with the target an easy movement on the ladder frame to reduce the loads on the front of the tested vehicle.
In the test procedures, scenarios were foreseen were the vehicle in front is slowing down or even braking up to a deceleration of $6m/s^2$. This is in contradiction with the recommendation of a target which is easy movable, to avoid damages during an impact, and to keep it in position during this braking deceleration. Experiments with different magnetic elements have been carried out to realise high deceleration and easy movement. An

ideal compromise has not been found yet. The adjustment for the release force could be adjusted with different spacers, which are reducing the magnetic force. To realize the best possible alignment of the towing device with the magnets a bearing was implemented, for the best contact between the surfaces. To use the balloon car as a stationary target a separate sled was designed, to reproduce the same height of the target as on the towing device, but to reduce load in case of an impact the sled was reduced in weight and the sliders on the bottom allow an easy movement on the ground.

Target development

The balloon car, which was chosen as the best compromise of a 3D view and a strike able structure needs several improvements to be realized as the rear end of a vehicle by all of the different types of AEB systems.

For the first test series the concept behind the design of the balloon car was to be detected by the different systems such as camera, radar, lidar or PMD sensor to collect test data for a comparison of different systems under best conditions for detection.

Figure 7 balloon car with cover ADAC V1

The **1st version of the ADAC** target used a cover for the balloon car which shows rear and side windows, rear lights and a licence plate. In figure7 the geometric dimensions of the target and a real car is shown. For radar based systems the balloon car itself was equipped with 2 lower corner reflectors on the lower part and on the left and right outboard side. Relexion material was placed behind the rear window and behind the licence plate.

Figure 8: corner reflectors and reflexion foil on the balloon car

Figure 9: impact of the target in scenario leading vehicle slower

After the first consumer test series the target was updated to a more vehicle based response and an improved optical shape.

In several round robins inside the vFSS group and the HP2 platform of Euro NCAP the response was improved according the recommendation of different OEM with different types of sensors. The focus was to have a target, which is not easy to detect and as close as possible to the response of a real vehicle, for all type of sensors.

During these comparison tests the critics included the 3D view of the target including a more realistic picture of the rear view of a car. The corner reflectors left and right were contra productive, without these, the response was even better. The stability of the test device even at higher speed and wind was rated good.

With the **2nd version of the target** ADAC tried to cover all the critics from round robin tests and the result of consumer test carried out with this system.

The original balloon car showed no critics during the performed tests, it is stable in all weather conditions, even with wind from the side or the pressure on the front at higher speed showed no difficulties. While

impacting the balloon no damages were recognised on the test vehicles up to impact speeds of 50kph. The durability in all test scenarios, standing and moving was good, no damages to the outer shell or loss of pressure could be recognized. So no changes were made to this structure. The biggest changes were done on the cover of the balloon and the radar reflexion. For a better recognition with camera based systems a real picture of a car was taken and printed on the cover. Reflecting materials on the outside and a real licence plate, with the combination of a shadow simulation with anti reflex material should give the cameras a real life picture of the backside of a car.
The criticized corner reflectors on the left and right outside were removed and replaced by a single one in the centre in the region of the licence plate.

Figure 10:Target Version 1 left and Version 2 right

The rear bumper was fixed to the car with a radius of 2,65m and attached to it reflexion foil for radar systems. The attachment of the cover on the sled and the balloon structure was improved to have a tight fit not affected by the wind in the driving conditions.
Equipped with the new improvements for all kind of sensors of AEB systems another round robin and comparison test was carried out on a test track over several days to evaluate the new structure, reflexion materials and position as well as the new siluette and the optics. Also the new attachment was tested.
The outcome of this new round robin test was a better visibility for the camera based systems with the new print on the cover, but still will need some improvement in the lower and the side part of the cover. To have a 3D view and the shadow and tyre area at the bottom of the target needs some improvement for a better recognition. With the balloon car mounted on the sled system, made of alloy the radar response is too high in comparison to a real car. So the backplate and the sled system need to be covered by anti radar reflexive material to reduce the response, while a main response from the rear surface would deliver a better and more realistic signal. For both systems radar and camera the position of the licence plate should be moved between the rear lights to position it in a comparable height with actual vehicles.
The last recommendation came up with the use of the PMD sensor were reflective parts are a need on the rear of a car. So a reflex foil instead of the printed rear/brake lights will be a need, to identify and make a clarification of the object. During this test series several test targets were compared to each other. It was concluded that the ADAC inflatable target was the preferred target for the moment, based on its sensitivity to current generation Radar, LIDAR, camera and PMD sensors and with the recommendations implemented it will show a very good overall performance.

Euro NCAP Vehicle Target (EVT)
All the recommendations of this round robin test end of 2011 were implemented in the next evolution of the target, leading to **version 3.** In May 2012 the final round robin tests use the final version of the target and make to official freeze for the use as Euro NCAP testing device took place. Also that time all different types of vehicles equipped with different kind of sensors, representing the actual state of the art and prototypes were represented in the test.
The final cover should be neutral and not easy to detect in daylight, so silver colour was chosen to make it most complicated for camera based systems, especially in bright daylight to recognize the vehicle target. To realize a 3D view also the left and right side of the cover were printed, looking like rear windows and tyres. The shadow of the vehicle between the tyres was improved by a dull leather part to cover the sled/towing system and the tyres geometries were formed by the cover. The licence plate was set to a higher place, between the rear lights, to meet the requirements of ground clearance Reflexion foil was attached in the area of the rear/brake lights for a better recognition and in a geometric line of the original car.

Figure 11: Original vehicle and target vehicle

The radar reflexion is improved with the coverage of the sled and backplate by anti radar reflexion foam as well as between the cover and the balloon car on the rear end. The bumper element radius is less rounded to 4,5m and covered with reflexion foil. A second stripe of reflexion foil is fixed right behind the rear lights, while a triple mirror, covered by foam to avoid damage, is placed right in the centre of the target just above the bumper element.

Figure 12:ADAC Target Version 3 stripped down

An evaluation of Thacham, Volvo and ADAC showed the improvement of this latest version of the vehicle target. The direct comparison between a real car, in this case a Volkswagen Touran and the comparable ADAC target version 3, is shown in Figure13 .Both objects were approached by a Volvo V60, equipped with camera and radar system. The approaching speed was app. 20kph.

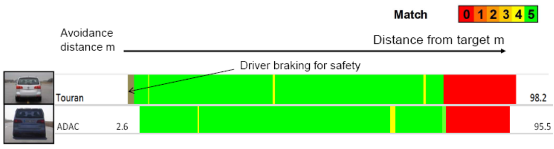


Figure 13 System outputs confidence level of an object based on radar and visual attributes

After this evaluation, the ADAC Vs3 target was specified with all the dimensions, material specification and setup procedure in the Annex A of the Euro NCAP Testing protocol for AEB systems. The name changed to Euro NCAP EVT (EuroNCAP Vehicle Target) and it will be used for stationary and moving impact for assessing AEB systems in interurban and city scenarios which will be the content of the paper 13-0269.[8]

Figure 14:Final Version of the EVT to be used by EuroNCAP from 2014 onwards

ADAC wants to thank the OEMs and suppliers for their support and feedback on the test target and all the members of the P-NCAP WG.

V. Sandner, ADAC

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PROGRESS AND FUTURE OF JNCAP

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Abstract

In 2011, the Japan New Car Assessment Program (JNCAP) started a new test on motor vehicle performance in pedestrian leg protection ahead of the introduction of government legislation. The Agency also started testing the performance of electric vehicles and hybrid electric vehicles in protecting occupants from high voltage electric shocks after collision. Furthermore, the Agency improved its seat belt reminder evaluation from simply publishing whether or not the vehicle has reminders to include a five-point rating of each reminder based on the effect of visual/audio alarms on the use of seat belts.

Thanks to improvements in automotive safety, the number of traffic deaths has been decreasing. In 2008, however, the number of pedestrians killed in traffic accidents exceeded the number of deaths among vehicle occupants for the first time, and has continued to do so. Recognizing that the protection of pedestrians in traffic accidents had become as important as that of vehicle occupants, JNCAP launched in 2011 a new overall safety performance evaluation aimed at protecting not only vehicle occupants but also pedestrians.

On the other hand, merely improving the collision safety performance of motor vehicles is not sufficient to substantially reduce deaths and injuries in traffic accidents. It is vital to promote the spread of motor vehicles with equipment and performance that can avoid accidents in the first place, by conducting evaluations of motor vehicles with preventive safety technologies as part of the new car assessment. In 2012, NASVA drew up a plan setting out milestones for the introduction of evaluations of preventive safety technologies and is now carrying out related research.

1. History of JNCAP

1.1 JNCAP started in 1995 with a full-wrap frontal collision test and a braking performance test. With a side collision test added in 1999 and an offset frontal collision test in 2000, the program published every year the results of an overall evaluation of the collision safety performance of major models on the market, focusing on the protection of occupants, with six stars given to the highest score.

With the addition of a pedestrian head protection performance test in 2003 and a rear collision neck protection performance test, a rear seatbelt usability evaluation test, and a seatbelt reminder evaluation test in 2009, JNCAP has enhanced the assessment of new cars and thus greatly contributed to the spread of safer motor vehicles and helped consumers select safer vehicles more easily. This has also encouraged automakers to develop safer motor vehicles.

In 2011, in view of pedestrians accounting for a majority of traffic deaths in Japan, a pedestrian leg protection test was added. In addition, in view of the rapid spread of electric and hybrid vehicles, an evaluation test of these vehicles' performance in protection from electric shocks after collision was added. Furthermore, the testing method and evaluation method of the existing seatbelt reminder evaluation test were revised.

On the other hand, the program reviewed the existing overall collision safety performance evaluation, which had focused on the protection of occupants. A new overall safety performance evaluation was introduced, aimed at protecting not only occupants but also pedestrians. The results are published every year, with five stars for the highest score.

In 2012, in the testing method of the existing rear collision neck protection performance evaluation, the test speed was revised from 17.6 km/h to 20.0 km/h.

Meanwhile, a plan was drawn up that set out milestones for the introduction of preventive safety technologies, and research on ESC is now being conducted.

1.2 As part of the new car assessment, JNCAP has evaluated child seats since 2001 by conducting a frontal collision test and a usability evaluation test on sled testers, and has published the results as child seat safety evaluations. Thus, the Agency has contributed to the spread of safer child seats by enabling purchasers to select safer child seats more easily while encouraging manufacturers, etc. to develop safer products.

2. Outline of the pedestrian leg protection performance test and evaluation

JNCAP started a pedestrian head protection performance evaluation test in 2003. In view of the increasing number of leg injuries of pedestrians involved in traffic accidents, in 2011 the program started testing and evaluating the performance of motor vehicles in protecting pedestrians' legs using a dummy representing adult male legs (leg impactor) to make the vehicles safer.

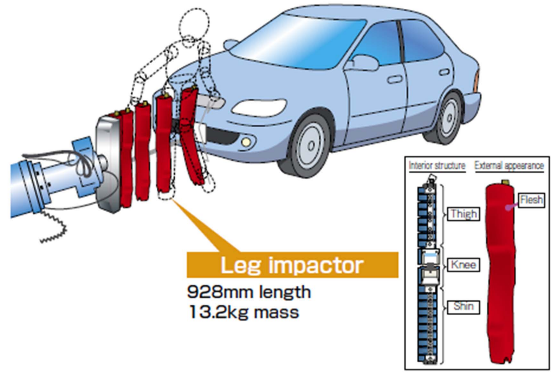
JNCAP is a program sponsored by the Ministry of Land, Infrastructure, Transport, and Tourism, and NASVA. Hence, in line with the national safety standards, the test uses FLEX-PLI as the leg impactor, for which Japan has been a leading developer and which has a higher biofidelity and is better suited for evaluating injuries.

Out of 14 models tested in 2011, 13 scored the highest level of 4, and 6 achieved the full score (4.00).

2.1 Outline of the testing method

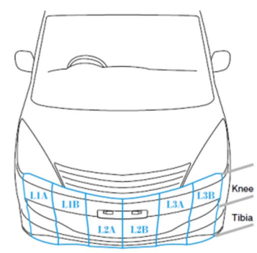
In this test, the leg impactor is launched by the testing machine at a speed of 40 km/h at the bumper of the test car, the lowest part of the bumper being located at 425 mm or less above the ground. When the vehicle collides with a pedestrian, the degree of injuries to the thigh and lower leg areas is measured and evaluated on a four-point scale.

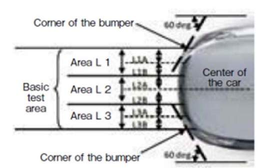
The test area of the bumper evaluated in the leg impactor launch test comprises six segments between both ends of the bumper (excluding the corners), and the points most likely to cause the highest injury values are selected in view of the structure of the vehicle. Thus, the locations at which the leg injury is measured vary depending on the test car. If there are other locations even outside this area that are thought to pose a danger from the effects of structures, a test is conducted for these areas.



2.2 Outline of the evaluation method

In the evaluation results, a higher level number means better protection of pedestrians' legs. With injury values of thigh and lower leg areas obtained from the test as representative values, a score is calculated using a sliding scale. These scores are weighted for each of the thigh and lower leg areas, and the score for each area is calculated and then averaged to give a total score as the evaluation of the vehicle.





Injury index		Injury criteria (upper limit value/ lower limit value)	Points (a)		Weight (b)		Overall points (a) × (b)
Shin	Tibia1	Bending moment (224Nm/380Nm)	0 to 4 points (Only the lowest points for the injury value are used.)	×	0.73	=	2.92 points
	Tibia2						
	Tibia3						
	Tibia4						
Knee	Medial collateral ligament MCL	Elongation (16.4mm/22.0mm)	0 to 4 points (Only the lowest points for the injury value are used.)	×	0.27	=	1.08 points
	Anterior cruciate ligament ACL	Elongation (-/13mm)					
	Posterior cruciate ligament PCL	Elongation (-/13mm)					
							Top score is 4 points

2.3 Interpretation of evaluation results

Based on measurements from the sensors attached to the leg impactor, the tibia bending moment and the elongation of the knee area medial collateral ligament (MCL), anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are calculated into scores using a sliding scale.

The overall average score is evaluated on a four level rating. To accurately differentiate between the results of different vehicles, the evaluation classifies scores of less than two (in a four- point rating) as Level 1, and divides scores above that into three levels of Level 2 to Level 4.

3. Outline of the evaluation test on performance of electric vehicles, etc. in protection from electric shocks after collision

With the rapid spread of electric vehicles and hybrid electric vehicles, consumers have increasing opportunities to purchase these vehicles. When such a vehicle is involved in collisions, occupants should not suffer any electric shocks from high voltage. From 2011, JNCAP evaluates, after conducting tests for full-wrap frontal collisions, offset frontal collisions, and side collisions, the vehicle's performance in protecting occupants from electric shocks in the passenger compartment after collisions.

In 2011, three models were evaluated and all of them satisfied the requirements.

The area of the vehicle evaluated for performance in protection against electric shocks has so far been only "inside the compartment". From 2014, both "inside the compartment" and "outside the compartment" will be evaluated.

3.1 Evaluation items

After each collision test, the vehicle is evaluated for protection against electric shocks, leakage of high-voltage battery electrolyte, and high-voltage battery attachment status according to respective criteria.

Whether each of the high-voltage parts in the power system meets the requirements for protection against electric shocks is checked by one of the following measuring methods:

(1) Direct contact protection and indirect contact protection
(2) Insulation resistance measurement
(3) Residual voltage measurement
(4) Residual energy measurement

3.2 Evaluation criteria

3.2.1 Protection against electric shocks

3.2.1.1 Direct contact protection and indirect contact protection

(1) Protection against the live parts of the power system (not including the hybrid coupling system) must meet Protection Class IPXXB.
(2) Resistance between the electrical chassis and contactable exposed conductive sections (not including the hybrid coupling system) must be less than 0.1 Ω when a current of 0.2 A or more is flowing.

3.2.1.2 Insulation resistance measurement

Insulation resistance measurement must meet the following conditions (not including the hybrid coupling system). This does not apply when the potential of two or more live parts is not protected under Protection Class IPXXB conditions following a collision.

(1) AC circuits and circuits that include AC circuits must have an operating voltage of 500 Ω/V or more (operating voltage of 100 Ω/V or more when Protection Class IPXXB requirements are met or the voltage of AC sections is 30 V or less).
(2) DC circuits must have an operating voltage of 100 Ω/V or more.

3.2.1.3 Residual voltage measurement

Residual voltage at high-voltage parts at 5 to 60 seconds after a collision must be AC 30 V or less or DC 60 V or less.

3.2.1.4 Residual energy measurement

Energy at high-voltage parts in the power system at 5 to 60 seconds after a collision must be 2.0J or less.

3.2.2 High-voltage battery electrolyte leakage

(1) There should be no electrolyte leakage into the passenger compartment.
(2) In the event of leakage to an area outside the passenger compartment, the total leakage quantity at 30 minutes after a collision must be no more than 7% of the total electrolyte quantity. In the event of an open drive system battery, leakage must be no more than 7% of the electrolyte quantity and no more than 5 liters.

3.2.3 High-voltage battery attachment status

(1) A renewable energy storage system (RESS) located in the passenger compartment must be fastened in a prescribed location.
(2) An RESS located outside the passenger compartment must not intrude into the passenger compartment.

4. Outline of the passenger seat belt reminder performance evaluation test

JNCAP started a rear passenger seat belt usability test in 2009. To further reduce the number of traffic deaths and injuries by increasing the usage of seat belts by passengers, the program started conducting a seat belt reminder evaluation test in 2011.

In 2011, 7 out of 14 models tested were equipped with a seat belt reminder for the front passenger seat and one model also provided a reminder for the rear passenger seats.

4.1 Testing method

The operating conditions of the reminder (timing, duration, type, display location, etc. of the alarm) are checked.

Seat belt reminder for rear passengers

【Main requirements】

Type of alarm		Visual alarm or auditory alarm
Start of alarm	Front passenger seat	Within 60 seconds, within 500m, or at a speed of under 25km/h after the car is in motion
	Rear passenger seat	Depending on the specifications of the car manufacturer
Duration of alarm		30 seconds or more
Length of alarm intervals		Must not be longer than 30 seconds
Alarm for change of status		Emitting warnings immediately if the car' s speed is faster than 25km/h and seatbelts are not buckled

4.2 Evaluation method

In 2009 and 2010, the evaluation was limited to checking whether the reminder met the requirements prescribed in the testing procedure, and whether or not the vehicle was equipped with a reminder was published.

From 2011, in addition to checking compliance with the prescribed requirements, an evaluation test is added to rate the reminder's performance for each of the passenger seats by evaluating the effects of visual/audio alarms, and a total evaluation is given on a five-point scale.

4.3 Results of evaluation

An evaluation is given on a 100-point scale for whether or not each of the front and rear passenger seats is provided with a reminder as well as an evaluation of the effect of each reminder. In order to clearly differentiate between the evaluations of the effect of the reminder on different vehicles on the use of seat belts, Level 1 is under 45 points; Level 2 is 45 to 59; Level 3 is 60 to 74; Level 4 is 75 to 89; and Level 5 is 90 or more.

For the new overall evaluation of safety performance, the scores are converted from the 100-point scale to an 8-point scale.

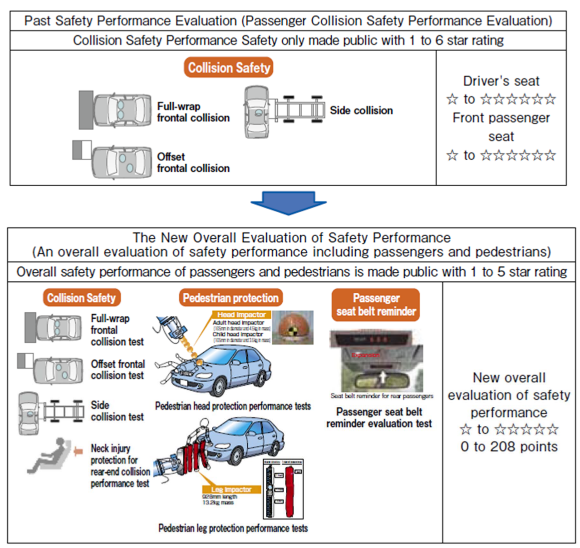
5. New overall safety performance evaluation

As seen in 1 above, JNCAP started in 1995 with a full-wrap frontal collision test and a braking performance test. Later, it expanded the scope by adding a side collision test and an offset frontal collision test, and annually published the results as an overall collision safety performance evaluation, with the highest score gaining six stars.

Enhancements have continued, with a pedestrian head protection performance test and a rear collision neck protection performance test.

In 2011, reflecting the situation of traffic accidents, the program added a pedestrian leg protection performance test. At the same time, the program, which had been limited to evaluating collision safety performance focusing on the protection of occupants, underwent a major review. The new program is a comprehensive evaluation of motor vehicle safety performance aimed at not only the protection of occupants but also that of pedestrians, with the highest score being five stars.

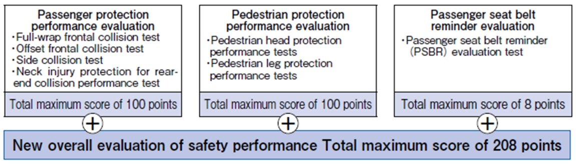
Among the 14 models tested in 2011, 4 models were given three stars, 7 models four stars, and 3 models five stars.



5.1 Overall points

The maximum total of points for the new overall evaluation of safety performance is 208 points, consisting of occupant protection performance evaluation (maximum 100 points), pedestrian protection performance evaluation (maximum 100 points), and seat belt reminder evaluation (maximum

8 points). Since one of the objectives is to reduce the number of traffic deaths and injuries, JNCAP does not prioritize between occupants and pedestrians in reflecting the results of evaluating occupant protection and pedestrian protection to the distribution of scores.



5.2 Results of evaluation

Based on the scores given in 5.1 above, each vehicle is evaluated on a five-point scale (expressed in number of stars).

※ If an evaluation is given that is two levels or more lower than the highest evaluation in any of the safety performance comparison tests (passenger protection performance evaluation tests and pedestrian protection performance evaluation tests), then a five-star rating cannot be obtained.

6. Future tasks

6.1 Introduction of preventive safety technologies

In Japan, JNCAP has conducted safety performance evaluations based on the results of various collision tests to reduce the number of traffic deaths, serious injuries, etc. On the other hand, merely improving the collision safety performance of motor vehicles is not sufficient to substantially reduce injuries in case of traffic accidents. In 1991, Japan launched an Advanced Safety Vehicle (ASV) Project and started studying the commercialization and spread of preventive safety technologies for motor vehicles. With the advancement of electronic control technologies in recent years, various preventive safety technologies have entered practical use, some of which are used in motor vehicles on the market. JNCAP has drawn up a plan setting out milestones for introducing performance evaluations of preventive safety technologies, in order to help protect occupants and pedestrians.

6.2 Regarding electronic stability control (ESC) systems, JNCAP is currently conducting research before determining the testing method and evaluation method. Based on the results, we will start testing in 2013 or thereafter.

6.3 For automatic emergency braking (AEB) systems, we will examine potential problems in introducing an evaluation of AEB in collision with other vehicles based on studies on testing method, etc. in other countries, determine the testing method and evaluation method in 2013 and start testing in 2014.
We will also consider introducing a test on vehicle-to-pedestrian collisions in the future.

6.4 With regard to lane keeping assist (LKA) systems, their effects on reducing accidents are low, but since lane departure warning (LDW) systems, which use the same method of detection, are effective in reducing accidents, we intend to evaluate the two devices together. The target date for starting such evaluation tests is 2016.

6.5 Other devices are not dealt with in the current plan, but we intend to study them if we consider they are effective in reducing accidents and in view of future technological developments and diffusion of these devices.

7. Summary

This document summarized the activities of JNCAP. This year, the program marks the 19th year since its creation. During this time, collision safety performance has significantly improved and contributed to the diffusion of safer motor vehicles.

In the future, JNCAP will continue to enhance its assessments for evaluating not only the collision safety performance of motor vehicles in accidents, but will also introduce the evaluation of preventive safety technologies that are expected to be effective in avoiding accidents themselves. It will thus help consumers select safer vehicles more easily, while encouraging automakers to develop safer motor vehicles.
JNCAP remains committed to fulfilling its mission of promoting the spread of safer motor vehicles.

STUDY OF SECOND ROW OCCUPANT PROTECTION IN FRONTAL VEHICLE CRASHES AND POTENTIAL RESTRAINT SYSTEM COUNTERMEASURES

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Paper Number 13-0430

ABSTRACT

Legal requirements regarding the qualification of the second seat row restraint system with anthropomorphic test devices (ATDs) currently do not exist. Consumer tests with respect to mass production rear occupant protection systems are already being planned or even executed and the results are or will be publicly available. However, there are various factors that make it difficult to apply the strategies applied for first row occupants to second row occupants. Also, there are differences regarding seat deformation and applied decelerations relative to the first row occupants. The purpose of this study is to evaluate the effectiveness of various restraint system components for second seat row occupants.
Sled tests with different occupant sizes have been conducted and analyzed in the second seat row. Based on these tests, a numerical simulation model has been built and correlated for various crash modes. Investigations were conducted that evaluate the relevant restraint parameters and their impact on the occupant protection performance for second seat row occupants. Restraint components have been modified in order to determine their potential to enable a premium rating under the current consumer test protocols for second row occupants.
A reduction of the external loads applied to the ATD due to the use of pyrotechnic seat belt pretensioners and seat belt load limiters has been shown. Low force levels result in increased displacement of the occupant's head and thorax and therefore increases the risk of occupant contact to the vehicle interior components. The potential of controlling the head kinematics with the seat belt alone without the addition of other restraint components is limited. A conventional 3-point seat belt seems to be insufficient to secure premium ratings for future consumer test programs. Additional inflatable devices like an airbelt allow a further reduction of the occupant loads with comparable or even reduced occupant displacement. Adaptive seat belt components with selectable force levels are recommended since this technology allows a reasonable trade-off between reduced occupant loads and controlled occupant displacement for various occupant sizes. Additional influencing factors for the occupant loads have been identified, including: the mechanical and geometrical properties of the seat ramp, and the timing and intensity of the vehicle pitch.

INTRODUCTION

Accident statistics over the last decades have shown a continuous reduction of killed and severely injured passengers [1]. This development was driven forward by new legislative requirements and the introduction and continuous progress on worldwide consumer test programs like the Euro-NCAP. The user's consciousness on safety is continually increasing due to publications and public discussion of road safety issues. Car manufacturers, in cooperation with suppliers, have taken massive action in order to achieve a top rating in consumer tests. The equipment rate of active and passive elements is steadily increasing and allows predicting further positive effect on road safety for the future.
Several recent publications discuss the passenger safety of the second row. Kuppa et al. [2] indicate higher mechanical loads on back seat passengers during a crash and deduce a higher injury risk compared to drivers and passengers in the first row. Restraint components like inflatable cushions (airbags) in order to protect the head and thorax or the lower extremities as well as pyrotechnical pretensioners partly with multi-stage load limiters for belt retractors are standard equipment in the front seat row.
The next generation is already under development. Individualized restraint systems, like those providing adaptive pressure control of the airbag pressure and multi-stage belt force limitation concepts, are pending market introduction. These systems enable tailored restraint performance depending on crash severity and occupant size. In contrast to this, a 3-point belt retractor without pretension and force limitation is still the standard for the back seat passengers.

These recent studies confirmed the effectiveness and the benefit of using a pyrotechnical pretensioner and belt force limiter for back seat passengers in order to reduce the occupant loads in frontal crashes. Forman et al. [3] highlighted significantly decreased chest loads in tests with ATDs if a pyrotechnical pretensioner and an adapted belt force limitation is applied for rear seated occupants. Stegmeier et al. [4] stated belt pretensioner and belt force limiter are recommended all times. However, full adaptive load limiters are required to cover all dummy sizes. Each configuration requires an adjusted load level in order to reduce the injury risk to a minimum.
Consumer protection organizations incorporated adult passengers on the back seat in their frontal test programs. The Hybrid III ATD with the 5th percentile is already an element of a test configuration for China-NCAP [5] and Japan-NCAP [6]. Euro-NCAP [7] announced a follow up in 2015. Figure 1 gives an overview of recent and future crash test configurations for worldwide consumer tests focused on back seat passengers:

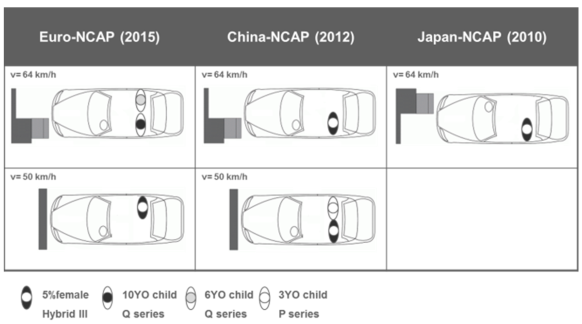

Figure1. Recent and future rear seat consumer test configurations.

The challenging requirements by NCAP programs and their continuous amendment feed the prediction that standard measures like pyrotechnical pretensioners and belt force limitation are not sufficient to achieve a top rating for the second row in the long- term.

ACCIDENT STATISTICS

An evaluation of the GIDAS database effective January 2011 exposed a lower occupation rate of the back seats compared to the driver seat and passenger seat in Germany. Single collisions with frontal impact direction and belted passengers have been considered for the next steps only. Figure 2 shows the distribution of the seat occupation of all passengers involved in those accidents.
The occupation rate for all back seats is close to 10 percent. Compared to the first row passengers, driver and front passenger, this percentage appears low.

Figure 3 highlights the gender specific distribution of back seat passengers. A similar ratio to the German population can be observed if all injured and not injured passengers are considered. With increasing injury severity a trend is observable. The percentage of female passengers is increasing.

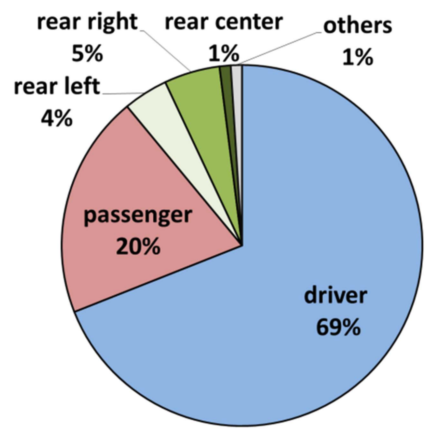

Figure2. Distribution on seating position, N=10.551 (source: GIDAS).

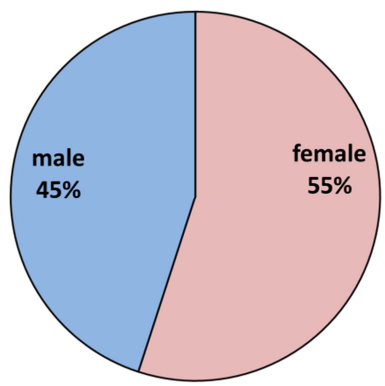

Figure3. All MAIS – gender distribution, N=806 (source: GIDAS).

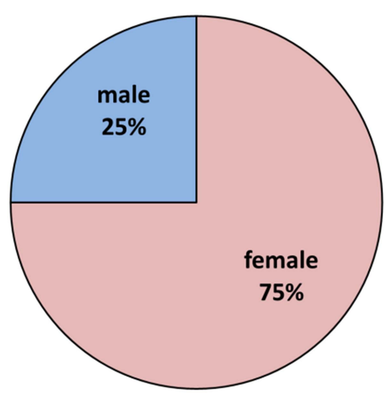

Figure4. MAIS 2+ - gender distribution, N=44 (source: GIDAS).

Figure 4 shows the gender distribution of back seat passengers which are subjected to an injury severity level of MAIS 2+. At this severity the portion of female passengers is close to 75 percent.
More than 50 percent of MAIS 2+ injured back seat passengers in the documented cases are between 150 cm and 170 cm tall. Figure 5 displays the distribution of the occupant height clustered in 3 groups.
Most frequently injured body regions are with 80 percent head and chest and upper extremities on rear occupants with a total injury severity level of MAIS 2+. AIS 2+ Neck injuries are rather rarely observed. The injury-causing component has been identified according to the database. Injuries of the head region are mainly caused by the contact with first row's seat back and the contact with the own extremities. Chest injuries are induced by the interaction with the seat belt webbing. The distribution of injury-causing components appears similar between female back seat passengers and male back seat passengers.

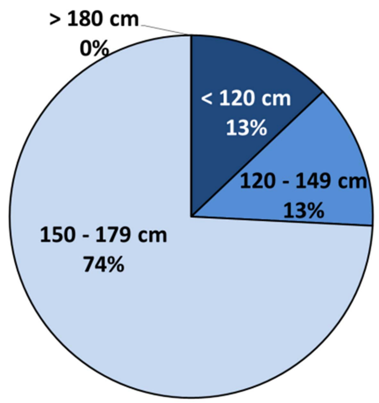

Figure5. Height distribution MAIS 2+ passengers, N=31 (source: GIDAS)

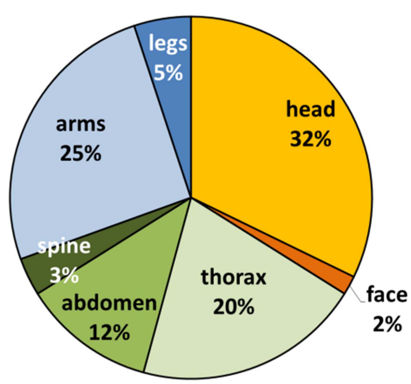

Figure6. AIS 2+ injuries by body region, N=59 (source: GIDAS)

The evaluation of the accident data indicates that small and medium female back seat passengers are one focal group in order to improve the passenger safety for rear seats.

RESULTS AND INTERPRETATION

Method

The experimental testing was done by sled tests. A body in white of an executive compact vehicle has been reinforced and adapted to the sled test facility. An extensive test matrix has been conducted with several frontal impact types equipped with adult and child dummies.
Primary test configuration has been a frontal crash with a crash pulse of 50 km/h against a flat full width barrier. Tests with Hybrid III ATDs with 5th and 50th percentile have been conducted. All passengers were protected by at least a 3 point seat belt. The first row seat was adjusted to a middle position. Test results in this configuration are shown in the following sections.
A market study confirmed a back seat passenger in mass production vehicles is protected by fewer safety components than occupants in the first seat row. Frontal airbags are not a standard yet. The recorded femur forces in this test configuration were low. In almost every test the femur compression did not exceed a level of 0.4 kN.

Seat structure

Most influencing components on the injury level of a rear seated occupant in a standard safety setup are the seat structure and the seat belt unit. The seat ramp is structure-integrated in most passenger cars. An easy replacement of the seat ramp or the seat unit after a test similar to the first seat row is not feasible. The deformation of the seat structure is dependent on crash pulse severity and occupant mass. It has been observed that components like the fuel tank and fuel pumps installed below the seat ramp might impact the occupant loads since they come in contact with the seat ramp after a certain deformation. If a seat ramp deformation is intended in the development methodology, multiple use of a car body is therefore limited. Reinforcements of the seat ramp in order to keep the seat ramp's geometry have a considerable impact on the dummy loads.
Figure 7 displays the impact on the dummy loads depending on the seat ramp stiffness. Exemplary tests with a stiff seat ramp (reinforced, no deformation) and a production seat ramp without any tank support have been compared. The injury values with a reinforced seat ramp decreased. Moreover, the seat structure is an important restraint factor since the deformation behavior influences the interaction between dummy and lap belt portion (sub-marining tendency) with possible abdominal injuries.

The dummy loads are normalized with selected Euro-NCAP's lower performance reference values (5th percentile female: discussed reference values; table 1, appendix). In particular, the head and neck injury values dropped with the use of the reinforced seat ramp. The measured forward excursion of the dummy's chest was slightly lower. Even though no head contact has been observed, the HIC value was considered for the assessment.
The results confirm that it is essential to recreate the real seat structure stiffness in order to produce correlating sled test results for a prediction of a full scale crash.

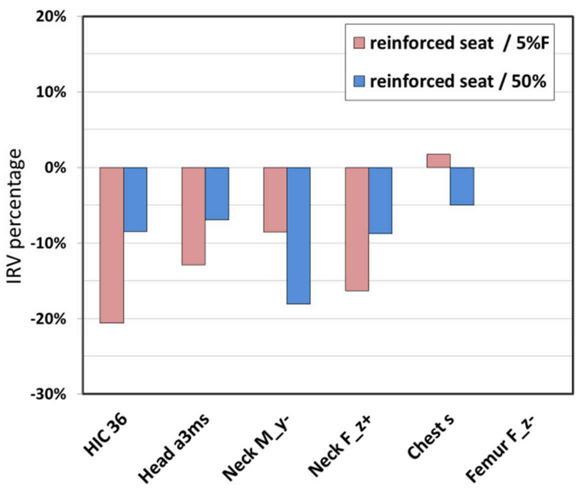

Figure7. Change in injuries level with reinforced seat structure.

Vehicle pitch
The vehicle kinematics is very complex in certain full scale crash configurations. As observed in tests with offset deformable barrier (ODB), several vehicles tend to have clearly visible rotational motion around the Y and Z axes (pitching and yawing). This motion is well visible in the test movies. The pitching behavior can be detected in full width barrier tests too. However, the motion is less noticeable in the crash movie. The measured acceleration occurs with shorter duration and at a different starting point compared to ODB tests. An evaluation of a wide range of crash pulses highlighted a widespread variety of different pitching pulses. A standard pitching crash pulse has not been identified yet.
A CAE model based on an executive compact vehicle has been validated in order to identify the impact from pitching on the occupant kinematics as well as on the injury values. The most important factors of the complex pitching movement should be identified. Several factors listed below have been considered:

- Z acceleration level, Z acceleration duration, starting point of Z acceleration
- Dependence on the X pulse characteristics
- Center of rotation

Based on the CAE results the most influencing factor is the character of the Z pulse applied to the structure of the back seat. An impact on the occupant kinematics and forward excursion was detected. Furthermore, the characteristics of the belt forces and the seat ramp contact are influenced that ultimately led to changed dummy loads.
A pitching pulse was chosen that correlates to real crash data and a sled test matrix have been conducted. Figure 8 shows the deviation of pitching sled tests with reinforced and deformable seat ramp compared to non-pitching tests. Both configurations show the same trend.
The sled tests confirmed the previous CAE study. The peak loads as well as the load curve time history change depending on the shape, the height and the duration of the pitching acceleration.

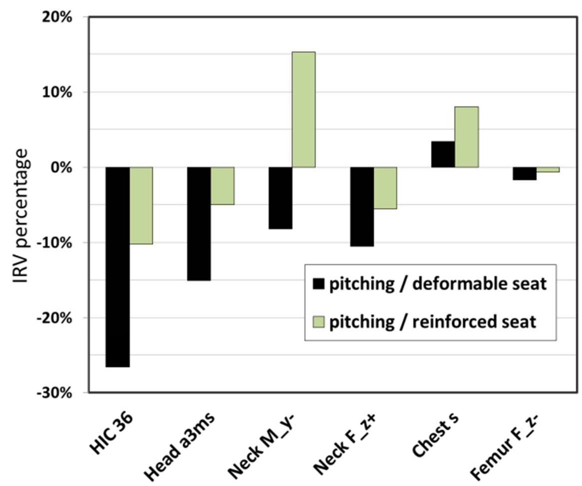

Figure8. Change in injuries level with vehicle pitch (5%ile female).

Restraint components
As a result of the developments in the NCAP programs, some rear safety layouts might be adjusted in order to keep a top level rating. The configuration with the 5th percentile ATD is a central load case. Internal investigations proved that the new NCAP requirements are challenging for chest deflection and neck loads. In particular, pyrotechnical pretensioners and belt force limiters allow addressing the chest deflection while a certain level of the head's forward excursion is not exceeded.

A reduction of the belt force level is possible to a certain extent only. Component requirements like the ECE R16 must be met and a head contact to the front seat or the own extremities should be avoided. Figure 9 shows the comparison of sled tests with different belt layouts. The images display the maximum forward excursion shortly after t= 100 ms.

Figure9. Forward excursion with different safety belt layouts (5%female).

The motion analysis also confirmed that a belt-only restraint is not capable of controlling the head and neck kinematics as done by the airbag in the first seat row. With a low belt force, which appears to be very beneficial for the chest deflection the head comes very close to the knees.

Figure 10 shows the benefit for a small female dummy compared to the standard 3 point seat belt restraint without pretension and without force limitation. Most of the dummy loads in the baseline test clearly exceeded Euro-NCAP's lower performance level. Even though the integration of a pretensioner and a force limiter provide a substantial benefit, a clear margin remains before dropping the injury values below the higher performance level.

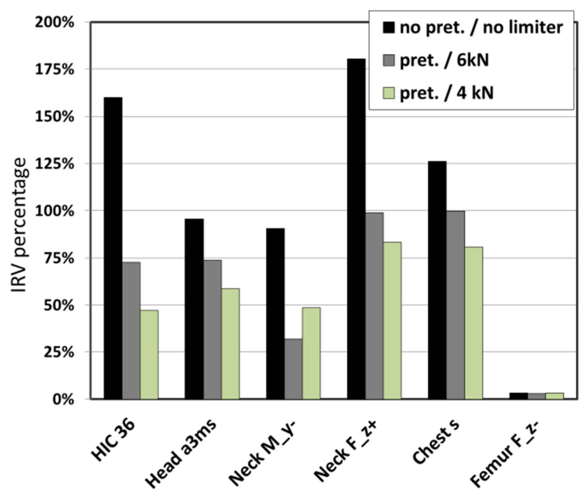

Figure10. Dummy load reduction with retractor pretension and belt force limitation

Figure11. Advanced restraint components in operation / airbelt (5%female)

Advanced components are capable of achieving a further load reduction. Additional sled tests have been conducted. An airbelt was integrated into the sled buck and the retractor force level has been adapted. This setup generates a similar head contact risk compared to the baseline test with belt force limitation and pretension. The airbelt is characterized by an inflatable portion integrated in the chest belt segment. This component is designed to distribute the restraint forces applied to the chest portion. The operation in a test is shown in figure 11.
The test results are shown in figure 12. The results are displayed in comparison to an already optimized rear safety setup with retractor pretension and a linear force limitation of 6 kN. The occupant loads have been reduced further. In particular, chest deflection and the neck tension forces have been lowered up to 40%.

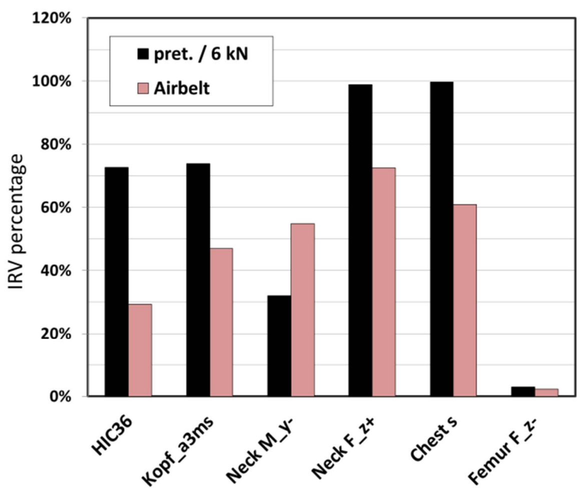

Figure12. Comparison of occupant loads (3 point belt vs. airbelt)

In further tests an inflatable head restraint has been added and optimized. The inflatable head restraint is designed to control the head and neck kinematics. The intention is to couple the head mass with the airbag which generates positive effects for the chest region too. The concept of the head airbag is shown in figure 13.
In order to mitigate chest injuries low, belt forces are required for the cases with small occupants like children and small female adult passengers. As shown before, taller adult passengers in combination with a severe crash pulse, are subjected to a certain risk of head contact with the front seat and with other interior parts or with the own extremities if the force level of a belt-only restraint is adjusted to address the rear seat NCAP configuration only. The inflatable head restraint enables controlling the upper torso motion and the head contact risk respectively while keeping the beneficial belt force level for the chest deflection. The results with head airbag compared to a standard 3 point belt restraint system with pretension and force limitation of about 6 kN are shown in figure 14. The combination of an adjusted belt force limitation in combination with the head airbag provides a balanced load distribution.

Figure13. Advanced restraint components in operation / head airbag (5%female)

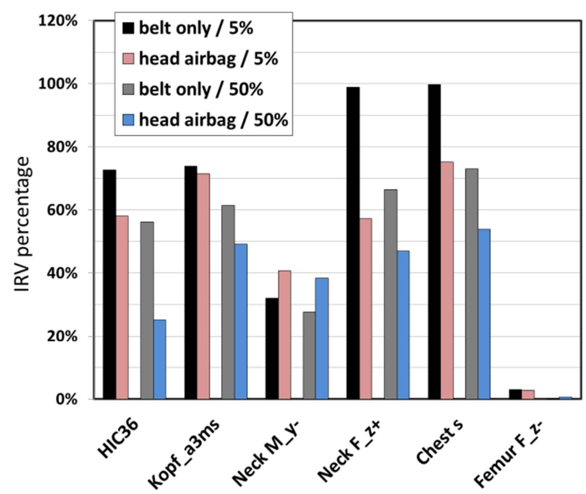

Figure14. Comparison of occupant loads (3 point belt vs. head airbag)

SUMMARY

Recently published investigations on countermeasures for reducing loads on back seat passengers have been confirmed. Pyrotechnical belt pretension and belt force limitation appear very beneficial. These measures are necessary at least for achieving a top rating in NCAP tests. However, seat

belt restraints alone are not capable for controlling the head and neck kinematics. Advanced components offer an additional benefit with a further reduction of the dummy loads. In comparison to the first seat row an integration is recommended in order to establish a similar level of restraint system performance for rear seat passengers.
The methodology for setting up rear seat restraint systems needs to be adapted. Vehicle pitch and the seat ramp behavior are essential factors for some vehicles. Those factors need to be considered since they can clearly affect the overall level of the dummy loads respective to the NCAP rating.

OUTLOOK

Human body model

An Investigation with a human body model has been initiated as a part of this project. The existing rear seat CAE model has been modified. A human body model based on the 50th percentile male has been added. This previously validated Takata in-house full human body model was further developed. The upgraded model (named as TKHM v4.0) was integrated with latest developed refined body region models of the thorax, the shoulder and upper extremities, the abdomen, and the pelvis. These body region models were constructed with more accurate anthropometry data and refined meshes of elements with higher standard of meshing quality.
Different belt force limitation concepts are being compared under configurations with different crash severity. Dummy loads and kinematics are being evaluated. However, the human body model study is not completed at this point.

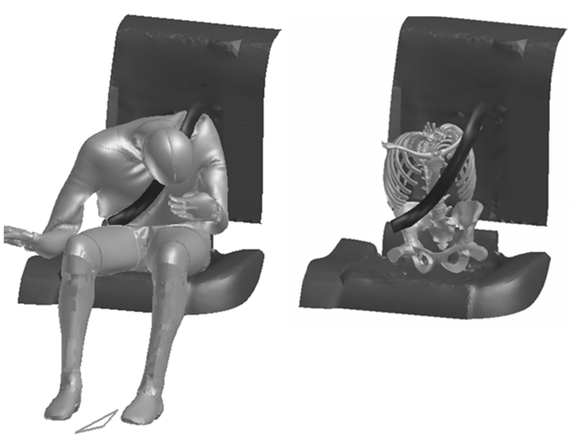

Figure15. Human body model motion with a 3 point belt.

First results indicate a change of the occupant kinematics and the peak loads level compared to 50th percentile hybrid III in particular with high crash pulse severity. Figure 15 shows the forward motion and deformation of the human body model's chest at 100 ms. The model tends to have a higher upper torso rotation around the Z axis when exposed to a full width flat wall crash configuration at 50 km/h with a seat belt with no pretension and no belt force limitation.
This might lead to a more selective assessment of the head contact risk with adapted belt force limitation concepts and advanced components in real accidents.
The started activities are intended to be continued in order to confirm the benefit of the countermeasures discussed before.

APPENDIX

Table1.
Injury reference values

Reference Values	5% female	50% male
HEAD		
HIC_{36}	**1000**	**1000**
res. acceleration (3 ms) [g]	**88**	**88**
NECK		
Tension force [kN[	**2,1**	**3,3**
Extension moment [Nm]	**49**	**57**
CHEST		
Compression [mm]	**41**	**50**
FEMUR		
Compression force [kN]	**6,0**	**9,07**

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A CONSIDERATION ON THE OVERALL RATING FOR THE CRASH TEST PERFORMANCE IN KNCAP

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Paper Number 13-0441

ABSTRACT

The Korean New Car Assessment Program (KNCAP) has been carried out by the Korean Ministry of Land, Transportation and Maritime Affairs (MLTM) since 1999 in order to encourage that the auto makers shall launch the safer cars into the domestic market. Various test methods were amended in the KNCAP since 2003. Now, the test procedures in the KNCAP are consisted of 8 fields. It was difficult for consumers to understand the KNCAP results because of various test methods.
The crash safety in the KNCAP consists of the full frontal impact, the offset frontal impact, the side impact, the pole side impact and the whiplash test. The overall rating on the crash safety in KNCAP is to inform test results easily to consumers. Each crash test result is converted into scores. The overall rating system is classified into 5 grades depending on the distribution of scores. From 2010 to 2012, the KNCAP evaluated the occupant protection performance of 34 vehicles from domestic and foreign auto makers. The overall ratings on the crash safety of 34 vehicles were listed and discussed.

INTRODUCTION

The Korean New Car Assessment Program (KNCAP) has been carried out by the Korean Ministry of Land, Transportation and Maritime Affairs (MLTM) since 1999 in order to encourage that the auto makers shall launch the safer cars into the domestic market.
The full frontal crash test based on the US-NCAP has been adapted to enhance the occupant protection under the frontal crash environment [2]. The full frontal crash test has contributed to the enhancement of the occupant protection performance of domestic vehicles reducing of the head and the chest injuries [3]. However, the full frontal crash test is more or less insufficient for the protection of the lower extremities compared to the offset frontal crash test.
To reduce the social cost by the injuries of the lower extremities, the offset frontal crash test based on the EuroNCAP was added and conducted in the KNCAP in 2009.
The side impact test has been conducted since 2003, and the pole side impact test based on the EuroNCAP was added in 2010. The pole side impact test is additional test by the choice of car maker. The star rating system by the points calculated using the injury criteria of the body parts is used for the crash test.
In 2001, the brake test was added and conducted in KNCAP. And, the rollover test in 2005, the pedestrian test in 2007, and the seat safety test was added and conducted in 2008. So, the KNCAP is consist of eight safety test categories, such as the full frontal impact test, offset frontal impact test, side impact test, pole side impact test, seat safety test, pedestrian test, rollover test, and brake test. It was difficult for consumers to understand the KNCAP results because of various test methods. Therefore, the overall rating method was developed for the consumers [1]. In the first stage, the overall rating on the crash test for full frontal impact, offset frontal impact, side impact, pole side impact and seat safety is carried out. From 2013, the overall rating including pedestrian, rollover and brake test will be carried out.
From 2010 to 2012, the overall rating on the crash test performance of 34 vehicles from domestic and foreign auto makers were evaluated by the procedures of the KNCAP [4-6]. In this paper, the results of 34 vehicles for each KNCAP test and the overall evaluation results on crash safety were listed and discussed.

TEST AND EVALUATION METHOD

Full Wrap Frontal Impact Test

The full wrap frontal impact test is performed at the velocity of 56 kph [1]. The photo and the schematic view of the full frontal impact test are represented in Figure 1. The performance of the vehicle safety is evaluated by the injury rate, possibility of the door opening during the test, the door opening ability after the test and the fuel leakage. The injuries for the occupants are evaluated using the points of a serious injury for the head, the chest and the knee, femur of the driver and the passenger dummies. The modifiers are also applied but the subjective items are excluded. The injury evaluation and rating method for the full frontal impact is shown in Table 1.

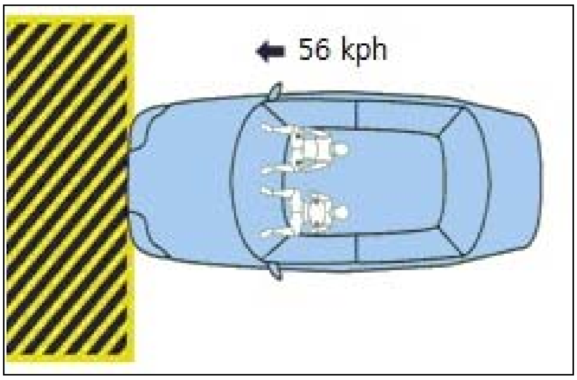

Figure 1. Full frontal impact test.

Offset Frontal Impact Test

The offset frontal impact test is performed at the velocity of 64 kph [1]. The vehicle is subjected to an offset impact into an immovable block fitted with a deformable aluminum honeycomb face. The photo and the schematic view of the offset frontal crash test are represented in Figure 2. The performance of the vehicle safety is evaluated by the injury rate, the car body deformation, the possibility of the door opening during the test, the door opening ability after the test and the fuel leakage. The points are evaluated using the injuries for the head, the neck, the chest, the knee, the femur and the lower leg of the driver and the passenger dummies. The modifiers are also applied but the subjective items are excluded. The injury evaluation and rating method for the offset frontal crash is shown in Table 2. Unlike the EuroNCAP, the injury rating is evaluated respectively at the driver and the passenger position in the KNCAP [1].

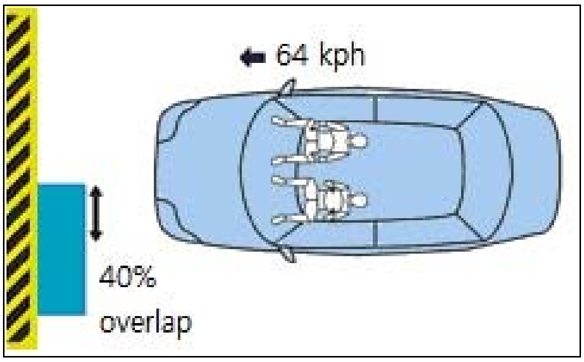

Figure 2. Offset frontal impact test.

Side Impact Test

The side impact test is performed at the velocity of 55 kph [1]. The moving deformable barrier is subjected to the vehicle with a deformable aluminum honeycomb face. The photo and the schematic view of the side impact test are represented in Figure 3. The performance of the vehicle safety is evaluated by the injury rate, possibility of the door opening during the test, the door opening ability after the test and the fuel leakage. The injuries for the occupants are evaluated using the points of a serious injury for the head, the chest, the abdomen and the pelvis of the driver dummies. The modifiers are also applied but the subjective items are excluded. The injury evaluation and rating method for the side impact is shown in Table 3.

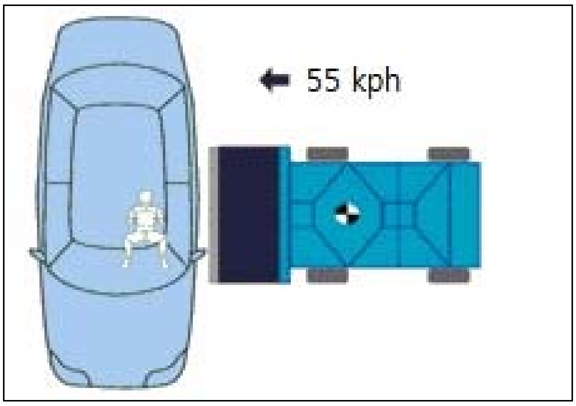

Figure 3. Side impact test.

Pole Side Impact Test

The pole side impact test is performed at the velocity of 29 kph [1]. The moving carrier with test car is subjected to the pole. The photo and the schematic view of the side impact test are represented in Figure 4. The performance of the vehicle safety is evaluated by the injury rate, possibility of the door opening during the test, the door opening ability after the test and the fuel leakage. The injuries for the occupants are evaluated using the points of a serious injury for the head of the driver dummies. The injury evaluation and rating method for the side impact is shown in Table 4.

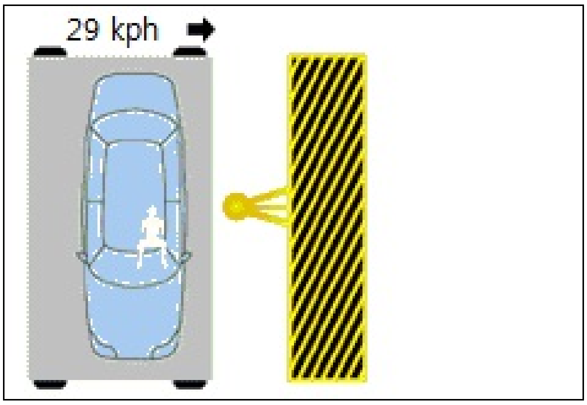

Figure 4. Pole side impact test.

Whiplash Test

The whiplash test is performed at the velocity of 16 kph [1]. The dynamic performance is assessed using a seat mounted on a sled test. The seat and head restraint dynamic performance is evaluated by the injury rate. The injuries for the occupants are evaluated using the combination results of head restraint contact time, T1 x-acceleration, upper neck shear force, upper neck tension, head rebound velocity, NIC and N_{km} of the BioRID and seatback dynamic opening of static test. The injury rating method for the side impact is shown in Table 5.

Figure 5. Whiplash test.

Overall Evaluation on Crash Safety Test

Total assessment for all KNCAP tests has been studied from 2009 to integrate in a single rating system. So, the overall evaluation for crash safety was added and evaluated in the KNCAP from 2010.

The overall evaluation on the crash safety is evaluated with the full frontal impact test, the offset frontal impact test, the side impact test, the pole side impact test and the whiplash test. Significantly, the side pole impact test is additional (optional) test by car maker. The additional side pole impact test is performed with the lowest model with curtain air bag installed.

The grade of overall evaluation is shown in Table 6. The overall evaluation will be graded 5 level rating, and the first grade will be scored from 47 to 54 point.

TEST RESULTS AND DISCUSSIONS

Twelve vehicles from four Korean auto makers such as Hyundai, Kia, GM Korea and Renault Samsung, and three foreign auto makers such as Lexus, BMW and Audi were tested in 2010 [4]. Eleven vehicles from four Korean auto makers such as Hyundai, Kia, GM Korea and Ssangyong, and three foreign auto makers such as Nissan, VW and Audi were tested in 2011 [5]. Eleven vehicles from four Korean auto makers such as Hyundai, Kia, GM Korea and Renault Samsung, and three foreign auto makers such as Toyota, VW and BMW were tested in 2012 [6]. The test results and star ratings for the vehicles are represented in Table 7 to Table 9. As shown in Table 7 to Table 9, 32 vehicles got 1st grade for the overall rating on the crash safety test and 2 vehicles got 2nd grade. As shown in Table 8, Hyundai Veloster finally got the 1st grade through re-test step.

The whiplash and pole side impact test may not be the main factor that affects the overall ratings on the crash safety. Under the current overall evaluation system, the overall ratings may be mainly affected by the results of full frontal, offset frontal and side impact test.

The main factor affecting results of the frontal impact test was chest injuries. In the case of light vehicles, the main factor was head injuries.

The main factor affecting results of the offset frontal impact test was injuries of chest and lower legs. In the case of light vehicles, the results were affected by injuries of all the part of the dummy on the driver's seat.

The main factor affecting results of the side impact test was chest injuries.

As shown in Table 7 to Table 9, it is easy to understand that the auto makers have been tried to launch the safer vehicles into the market. However, it is difficult to expect the discrimination of the overall ratings for the tested cars.

CONCLUSIONS

The overall rating on the crash safety in KNCAP is to inform test results easily to consumers. Each crash test result is converted into scores. The overall rating system is classified into 5 grades depending on the distribution of scores. From 2010 to 2012, the KNCAP evaluated the occupant protection performance of 34 vehicles from domestic and foreign auto makers. 32 vehicles got 1st grade for the overall rating on the crash safety test and 2 vehicles got 2nd grade. It is difficult to expect the discrimination of the overall ratings for the tested vehicles. In the KNCAP, the overall rating will be performed to a high standard from 2013 and planned to raise the level of each grade gradually in the near future.

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Table 1.
The evaluation method for the full frontal crash test.

	Injury		Criteria	Points	% AIS3 > 3
Head	HIC36		650 - 1000	0 - 6	5 – 20 (%)
	Neck	Shear	1.9 – 3.1 (kN)		Significant risk of injury
		Tension	2.7 – 3.3 (kN)		
		Extension	42 – 57 (Nm)		
Chest	Compression		22 – 50 (mm)	0 - 6	5 – 50 (%)
	Viscous Criterion		0.5 – 1.0 (m/s)		5 - 25 (AIS4)
Knee, Femur	Femur Compression		3.80 – 9.07 (kN)	0 - 4	5% – Femur fracture
	Knee Slider Compressive Displacement		6 – 15 (mm)		Cruciate ligament failure
Injury Rating	★★★★★ 13.0 – 16.0 Points				
	★★★★ 10.0 – 12.9 Points				
	★★★ 7.0 – 9.9 Points				
	★★ 4.0 – 6.9 Points				
	★ 0.0 – 3.9 Points				

Table 2.
The evaluation method for the offset frontal impact test.

	Injury		Criteria	Points	% AIS3 > 3
Head	HIC36		650 - 1000	0 - 4	5 – 20 (%)
	Neck	Shear	1.9 – 3.1 (kN)		Significant risk of injury
		Tension	2.7 – 3.3 (kN)		
		Extension	42 – 57 (Nm)		
Chest	Compression		22 – 50 (mm)	0 - 4	5 – 50 (%)
	Viscous Criterion		0.5 – 1.0 (m/s)		5 - 25 (AIS4)
Knee, Femur	Femur Compression		3.80 – 9.07 (kN)	0 - 4	5% – Femur fracture
	Knee Slider Compressive Displacement		6 – 15 (mm)		Cruciate ligament failure
Lower Leg	Tibia Index		0.4 – 1.3	0 - 4	10% risk of fracture
	Tibia Compression		2.0 – 8.0 (kN)		
Injury Rating	★★★★★ 13.0 – 16.0 Points				
	★★★★ 10.0 – 12.9 Points				
	★★★ 7.0 – 9.9 Points				
	★★ 4.0 – 6.9 Points				
	★ 0.0 – 3.9 Points				

Table 3.
The evaluation method for the side impact test.

	Injury	Criteria	Points	% AIS3 > 3
Head	HIC36	650 - 1000	0 - 4	5 – 20 (%)
Chest	Compression	22 – 42 (mm)	0 - 4	5 – 30 (%)
	Viscous Criterion	0.32 – 1.0 (m/s)		5 – 50 (%)
Abdomen	Abdomen Forces	1.0 – 2.5 (kN)	0 - 4	
Pelvis	Lateral Acceleration	3.0 – 6.0 (kN)	0 - 4	
Injury Rating	★★★★★ 13.00 – 16.00 Points ★★★★ 9.00 – 12.99 Points ★★★ 5.00 – 8.99 Points ★★ 2.00 – 4.99 Points ★ 0.00 – 1.99 Points			

Table 4.
The evaluation method for the pole side impact test.

	Injury	Criteria	Points	% AIS3 > 3
Head	HIC36	650 - 1000	0 - 2	5 – 20 (%)

Table 5.
The injury rating method for the whiplash test.

Injury Rating	★★★★★ 4.9 – 6.0 Points ★★★★ 4.0 – 4.8 Points ★★★ 3.1 – 3.9 Points ★★ 2.2 – 3.0 Points ★ 0.0 – 2.0 Points

Table 6.
The overall evaluation method on the crash safety test.

Test	Points	
Full frontal impact test	16.0	
Offset frontal impact test	16.0	
Side impact test	16.0	
Pole side impact test	(2.0)	Additional Test
Whiplash test	6.0	
Total Point	54.0	The maximum is 54.0
Overall evaluation rating	1st Grade (Good) 47.0 – 54.0 Points 2nd Grade (Acceptable) 40.0 – 46.9 Points 3rd Grade (Marginal) 33.0 – 39.9 Points 4th Grade (Poor) 26.0 – 32.9 Points 5th Grade (Bad) 0.0 – 25.9 Points	

Table 7.
Test results and star ratings.

Vehicle	Class		Full Frontal Impact	Offset Frontal Impact	Side Impact	Whiplash	Pole Side Impact	Overall Evaluation Results
GM Matiz	Light	Star	★★★★★	★★★★★	★★★★★	★★★★		1st
		Points	15.1(94%)	14.3(89%)	15.0(94%)	4.8(80%)		49.2(91%)
Renault SM3	Sub -mid	Star	★★★★	★★★★★	★★★★★	★★★★		2nd
		Points	12.5(78%)	14.2(89%)	14.1(88%)	4.4(73%)		45.2(84%)
Hyundai Avante	Sub -mid	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.8(99%)	14.8(93%)	15.8(99%)	5.0(83%)	2.0(100%)	53.4(99%)
Kia K5	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.7(98%)	15.0(94%)	15.4(96%)	5.2(87%)	2.0(100%)	53.3(99%)
Renault SM5	Medium	Star	★★★★★	★★★★★	★★★★★	★★★		1st
		Points	13.4(84%)	14.7(92%)	15.8(99%)	3.8(63%)	2.0(100%)	49.7(92%)
Hyundai Sonata	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	16.0(100%)	15.2(95%)	15.3(96%)	5.1(85%)	2.0(100%)	53.6(99%)
Kia Sportage	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.2(95%)	14.5(91%)	15.6(98%)	5.3(88%)		50.6(94%)
Hyundai Tucson	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	14.8(93%)	15.2(95%)	15.0(94%)	5.3(88%)		50.3(93%)
Kia K7	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.2(95%)	15.5(97%)	16.0(100%)	5.0(83%)	2.0(100%)	53.7(99%)
Lexus ES350	Large	Star	★★★★★	★★★★★	★★★★★	★★		1st
		Points	16.0(100%)	14.6(91%)	16.0(100%)	3.0(50%)		49.6(92%)
Benz E220	Large	Star	★★★★	★★★★★	★★★★★	★★★★		1st
		Points	12.2(76%)	14.3(89%)	16.0(100%)	4.5(75%)	2.0(100%)	49.0(91%)
Audi A6	Large	Star	★★★★	★★★★★	★★★★★	★★★		1st
		Points	12.9(81%)	15.1(94%)	15.4(96%)	3.6(60%)		47.0(87%)

Table 8.
Test results and star ratings.

Vehicle	Class		Full Frontal Impact	Offset Frontal Impact	Side Impact	Whiplash	Pole Side Impact	Overall Evaluation Results
KIA Morning	Light	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	13.2(83%)	14.0(88%)	15.5(97%)	5.2(87%)	2.0(100%)	49.9(92%)
GM Aveo	Compact	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.5(97%)	15.3(96%)	16.0(100%)	5.1(85%)		51.9(96%)
Hyundai Accent	Compact	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.6(98%)	13.4(84%)	16.0(100%)	5.2(87%)	2.0(100%)	52.2(97%)
Hyundai Veloster	Sub-mid	Star	★★★★★	★★★	★★★★★	★★★★★		2nd
		Points	14.5(91%)	7.6(48%)	15.8(99%)	5.8(100%)	2.0(100%)	45.7(85%)
Hyundai Veloster	Sub-mid	Star	★★★★★	★★★★★	★★★★★	★★★		1st
		Points	15.7(98%)	13.6(85%)	15.8(99%)	3.8(63%)	2.0(100%)	52.9(98%)
Nissan Altima	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★		1st
		Points	15.6(98%)	15.1(94%)	14.9(93%)	4.6(77%)	2.0(100%)	52.2(97%)
Audi A4	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	13.7(86%)	15.0(94%)	16.0(100%)	5.6(93%)	2.0(100%)	52.3(97%)
VW Golf	Medium	Star	★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	12.0(75%)	15.4(96%)	14.4(90%)	5.1(85%)	2.0(100%)	48.9(91%)
Ssangyong Korando C	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	13.1(82%)	13.4(84%)	15.4(96%)	5.5(92%)		47.4(88%)
GM Orlando	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	16.0(100%)	15.3(96%)	16.0(100%)	5.8(97%)		53.1(98%)
GM Alpheon	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	16.0(100%)	15.3(96%)	16.0(100%)	5.4(90%)	2.0(100%)	54.0(100%)
Hyundai Grandeur	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	16.0(100%)	15.9(99%)	14.8(93%)	5.7(95%)	2.0(100%)	54.0(100%)

Table 9.
Test results and star ratings.

Vehicle	Class		Full Frontal Impact	Offset Frontal Impact	Side Impact	Whiplash	Pole Side Impact	Overall Evaluation Results
Kia Ray	Light	Star	★★★★★	★★★★	★★★★★	★★★★★		1st
		Points	13.4(84%)	12.6(79%)	16.0(100%)	5.4(90%)	2.0(100%)	49.4(91%)
Kia Pride	Compact	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	16.0(100%)	14.6(91%)	16.0(100%)	5.6(93%)	2.0(100%)	54.0(100%)
Hyundai i30	Sub-mid	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.2(95%)	14.6(91%)	16.0(100%)	5.4(90%)	2.0(100%)	53.2(99%)
GM Malibu	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	16.0(100%)	15.6(98%)	15.8(99%)	5.9(98%)	2.0(100%)	54.0(100%)
Hyundai i40	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.4(96%)	15.4(96%)	16.0(100%)	5.4(90%)	2.0(100%)	54.0(100%)
BMW 320d	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★		1st
		Points	14.5(91%)	15.4(96%)	16.0(100%)	4.6(77%)	2.0(100%)	52.5(97%)
Toyota Camry	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★		1st
		Points	16.0(100%)	15.3(96%)	16.0(100%)	4.7(78%)		54.0(100%)
VW CC	Medium (SUV)	Star	★★★★★	★★★★	★★★★★	★★★★★		1st
		Points	13.9(87%)	12.9(81%)	16.0(100%)	5.2(87%)		50.0(93%)
Kia K9	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	16.0(100%)	15.2(95%)	16.0(100%)	5.6(93%)	2.0(100%)	54.0(100%)
Renault SM7	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	15.2(95%)	14.3(89%)	15.5(97%)	5.8(97%)	2.0(100%)	52.8(98%)
Hyundai SantaFe	Large (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1st
		Points	16.0(100%)	15.9(99%)	16.0(100%)	5.7(95%)	2.0(100%)	54.0(100%)

THE PILOT PHASES OF LATIN NCAP: HOW FAR IS THE MARKET FROM IMPROVEMENT?

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ABSTRACT
Since 2010 Latin NCAP has been testing the most popular models in Latin America.
It was demonstrated that Latin America's best selling models are 20 years behind Europe, US, Japan, Australia in terms of vehicles safety. How far is the market in Latin America from an improvement in the best selling models' safety?.

27 different models were tested since 2010 in Latin NCAP phases 1, 2 and 3. The results obtained during the test as well as the inspections supplied the data for the discussion of results.

The most basic equipped versions, which are the ones selected by Latin NCAP, showed that the absence of airbags exposed the passenger dummies to serious injuries. The structural performance of the passengers' compartment was weak to poor in the best selling models of Latin America. Latin NCAP also tested cars that looked exactly like the European models but their structure showed a poorer performance in the crash test. In the case of the Child Occupant the main reasons for the low star rating were incompatibility of CRS-vehicle seat and seatbelts, poor labelling and poor dynamics in several cases.

The results are limited to the tested models. But considering the annual sales volume of 250.000 units of the best selling model in the region, the coverage of the results in terms of drivers and their families reached is considerably important.

Considering the poor structural performance, and also the old platforms being used to produce popular cars in Latin America, the Industry will have to bring to the market new or improved platforms, with better performance in occupants' protection. This should come as the governments make the local regulations tougher, but Latin NCAP is already helping to bring changes faster

INTRODUCTION
Latin NCAP has been helping to improve the crashworthiness of today's passenger vehicles in Latin America.

For phases 1, 2 and 3 Latin NCAP has been assessing the cars in a 40%ODB crash test at 64km/h.

The status of technical performance regulations in Latin America regarding vehicle safety and occupant protection is little to non existent
At the time that Euro NCAP begun to rate cars' capacity to protect occupants performance technical regulations were already mandatory like ECE94. This situation brings Latin NCAP since its beginning a more challenging task in helping improve car's safety in the region

In Europe like in other countries, the consumer then had a certain level of safety established by the regulations. In Latin America this is mostly not the case. As from 2014 Brazil will include a performance criteria technical regulation that gives the manufacturer the option to test the model according to ODB crash test performance criteria based in WP29's regulation and full frontal performance criteria based in the FMVSS regulations.
Before the regulation was published, there was a law that made airbags and ABS mandatory but no performance criteria was required. This action was followed by almost all Latin American government.

Consumers and authorities expects that same models from other markets, produced locally will eventually offer similar Occupants performance protection. Including in cases where models do look the same and have same equipment specifications.

All this might be considered as a first step, but the technology and know-how to improve vehicle safety is available since years and it is about to take it and bring it to Latin America.

The actual situation is that manufacturers complain that safety does not sell cars in Latin America, however some manufacturers are advertising about their cars safety in magazines and newspapers. Probably the real reason why consumer do not buy safer cars of cars with safety equipment is explained by the high price charged to cars with safety devices, often due to availability only with certain packages, which specially affect the payment capacity originally planned by the consumer that buy the most popular cars.

Latin America does not have CRS technical regulation and lack of mandatory use law with the exception of Brazil.
Most of the CRS available are old and low performing CRS that used to be available in other markets like Europe for example.

Latin NCAP has independent and transparent procedures.

Some of the points mentioned above were reflected in the different situations along Latin NCAPs phases 1, 2 and 3, also called the pilot phases.

This paper will mainly focus on the cars that were selected and sponsored by Latin NCAP, however mention to the manufacturers sponsored car will be pointed along the document.

DATA
The cars that Latin NCAP sponsored and selected are the following:
VW Gol, Chevrolet Corsa, Chevrolet Celta, Fiat Novo Uno, Fiat Palio, Peugeot 207 Compact, Geely CK1, Nissan Tiida, Ford Ka, Ford Fiesta Hatchback, VW Bora, Jac J3, Renault Sandero.
The best selling models have the following sale levels: the VW Gol (hatchback) sells more than 280,000 per year in Latin America, Fiat Uno more than 220,000 units per year (old and new UNO together but Old UNO lost market share to the new one in the last years), Chevrolet Classic sells 142,000 units per year, The Chevrolet Celta sells 120,000 units per year, Renault Sandero more than 85,000 units per year, Fiat Palio (Old model) used to sell when tested more than 150,000 units per year in all its versions, VW Bora more than 60,000 units per year, Ford Ka more than 50,000 units per year at the time of being tested.

Latin NCAP selects the most basic safety equipped version available of a model.

Adult
The following models were tested without airbags: VW Gol, Fiat Palio, Peugeot 207 COMPACT, Fiat Novo UNO, Chevrolet Celta, Chevrolet Corsa, Ford KA, Renault Sandero. Geely CK1 They are available in the most basic version without airbags. They all scored 1 star in adult.
The VW Gol and Fiat Palio structures were rated as stable, the other models' structure were rated as unstable.

The models that presented unstable structures, sell more than 650,000 units per year in Latin America. According to Latin NCAP assessment a structure considered unstable means that it is not capable of withstanding further loadings.

All the models mentioned above that represent the best selling models scored 1 star rating in the adult safety assessment.

Latin NCAP tested a JAC J3, with double frontal airbags equipment that scored 1 star in adult occupant safety.

Child
CRS use is not mandatory in Latin America with the exception of Brazil that also has technical regulation.

In phase 1 the Child safety rating were 1 and 2 stars results.
In phase 2 manufacturers reached 3 stars in child safety for the first time and later in phase 3 4 stars in child safety (Ford Fiesta and Honda City)

Most of CRS offered in Latin America showed incompatibility with the listed cars restraint systems and a poor dynamic performance resulting in poor child occupant safety ratings.

The instructions in most of the CRS sold in Latin America are insufficient.

METHODOLOGY
Latin NCAP ODB 64km/h test and assessment for Adult and Child occupant according to Latin NCAP Protocols

RESULTS

Adult

The results of the cars tested by Latin NCAP as showed below:

The Chevrolet Celta, Chevrolet Corsa, Fiat Novo Uno, Ford KA, Renault Sandero, Peugeot 207 COMPACT, and Geely CK1 structures were rated as unstable (modifier -1 point applied).

Geely CK1

Chevrolet Corsa Classic

Chevrolet Celta

Ford Ka

The Chevrolet Celta, Chevrolet Corsa, Fiat Novo Uno, Ford KA, Peugeot 207 COMPACT, and Geely CK1 (modifier -1 point applied)

Child

Latin NCAP requires the manufacturer to recommend of the CRSs to be used in the test. Incompatibility car-CRS was present in most of the Latin NCAP selected cars.

The lack of instructions in the way that the protocols require brought a loss of points for most of the Latin NCAP selected cars.

Acceptable dynamic performance was observed in some models, however in cases where the structure was rates as unstable was observed better dynamics of the CRS than in models which structure was rated stable.

DISCUSSION

Adult

The results of the models tested that belong to the top 10 selling cars showed that most of them presented an unstable rated structure in the test. In some cases like the Geely, it is reasonable to expect that even with airbags the injuries in the front passenger will still be considerable.

One powerful results that can illustrate the risks of an unstable structure even with airbags is the JAC J3 that scored only 1 star in adult occupant safety even with 2 airbags and pretensioners.

JAC J3

Some government in the region are requiring airbags in the law, and the previous example shows clearly that airbags may not solve the problem and that a performance requirement is needed. Some countries in the region are focusing to introduce performance criteria regulations.

Cars with no airbags showed high risk of life threatening injuries in the passengers. In cases where the same model was tested with and without airbags the benefit of the airbags was clear in the result bringing some models from 1 to 3 stars and another one from 1 to 2 stars. This also shows that there is room for improvement in some cases with not very dramatic changes in the cars to make them perform better in the test.

The dynamic results of the Child occupants was average to good in cars which structures were rated as unstable and poorer performance results in cars which structures were rated as stable, like the Nissan Tiida, Toyota Corolla for example. In some cases we have seen CRS broken due to the accelerations. As the structures become stiffer, then the rear restraint systems as well as CRS must be improved in order to offer good child occupant protection.

Latin NCAP also compared models tested in our program to the same models tested by other NCAPs like Euro NCAP. There is a clear difference in safety equipment of the same models like less airbags, no ABS or no ESC for example. But we have seen cases where the structures of 2 same looking models behave in a very different way. Examples of that are the Nissan March compared to the Nissan Micra and March, or Renault Sandero and Dacia Sandero. In those cases the Latin NCAP structure was rated as unstable and intrusions were higher as well.

Latin NCAP received comments from consumers claiming that the airbag versions of the models tested are much more expensive then the basic (nom airbag version). In some cases the consumer must pay from 18% to 33% on top of the basic price to get just double fontal airbags. In some cases this is explained by the "package" that offers the manufacturer matching airbags with other non safety related items like Bluetooth or alloy wheels. In one sample case of same European model but different structural behaviour, having the Latin NCAP model no airbags, but the European model 6 airbags, ABS and ESC the price difference at the same time between those cars one sold in Europe and the other sold in Latin America was less than 1000 Euros. However these price differences are strongly linked to the local taxes, cars in Latin America are as or more expensive than in Europe and they offer a lower level of occupants protection. Some consumers are wondering why this is happening and how it can be fixed.

Until phase 3 (2012) the models that could offer a 4 star level of safety to their occupants were large and expensive models, but the Toyota Etios showed that a car from the small most competitive market in the region can offer 4 star in adult occupant safety and be sold for a price close to the 10.000 Euros in Brazil and locally produced.

Before the test of 2 models selected in 2012 were conducted, the manufacturers decided to make a change in production for safer equipment. The VW Bora and Ford Fiesta are sold in Latin NCAP market with double standard airbags.

In phase 3, 2 cars reached the 4 star result n Child occupant: Ford Fiesta and Honda City, both using ISOFIX CRS. The protection offered by the CRS was very good as well as the instructions and

vehicle compatibility. This is a remarkable result considering the beginning of the program.
Only one market in Latin America has CRS regulation requirement for type approval: Brazil. The ISOFIX CRS are not contemplated by the regulation therefore they are cannot be approved for importation. Hopefully the Latin NCAP results will help to show the benefit of the ISOFIX in misuse reduction and dynamic performance.

CONCLUSIONS

Bodyshell integrity, airbags and seatbelts are critical for the protection of occupants.

Models for Latin America showed poorer protection than the same model even with same equipment for Europe.

The latest models tested showed already an improvement in the structural stability.

The protection of child occupants is low because of the marginal to poor protection offered by the CRS, the incompatibility car-CRS and high probability of misuse.

As structures become more stable and stiff, the rear seat restraint systems and CRS must be improved to offer better protection.

First cars to score 4 stars in Child occupant safety: Ford Fiesta and Honda City. ISOFIX CRS were used and showed good protection performance and considerable reduction of misuse possibilities.

Latin NCAP recommends all governments to make the requirements of UNECE94 (technical standard) mandatory for all cars. Currently no car without airbags will pass UNECE94.

Latin NCAP strongly recommends all governments to reinforce the conformity of production in the regulatory tests for car's protection performance and make tests in independent or governmental test laboratories

Latin NCAP recommends all governments to make CRS use and technical standard approval for CRS mandatory. Latin NCAP would welcome when all governments will allow ISOFIX use according to the UNECE technical standards.

Latin NCAP promotes the use of CRS in cars and strongly recommends closer cooperation between car manufacturers and CRS manufacturers to improve Child safety in the region.

Latin NCAP welcomes Ford's and VW's rapid efforts to bring safer vehicles on sale in Latin America (Fiesta and Clasico) and strongly encourages other manufacturers to follow suit and increase the availability of airbags on their new cars.

A car locally produced in the smallest most competitive segment could offer 4 stars in adult safety, and same models jumped from 1 to 3 stars in adult safety with just the double airbags.

The previous cases show that it is possible to produce an affordable car in Latin America that offers a 4 star safety level. More stable structures and airbags in vehicles will help to get closer to safer cars in the region. Technology and knowledge is there from the mature economies markets, no need to develop new technologies for Latin America stage
Latin NCAP helps to improve the safety of the cars in the market and consumer awareness not all the cars in the market are being tested.
Considering our actual regulatory situation in comparison to European regulations when Euro NCAP started, Latin America is as close or far from safer cars as the governments, manufacturers and consumers want to be. Governments regulations will help to have better performing cars in occupant protection and will bring safer CRS to the local market but all this must be present together with laws, regulations enforcement and education.