A PROPOSAL FOR REAR SEAT HEAD RESTRAINT GEOMETRIC RATINGS

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ABSTRACT

Consumer safety ratings organisations have published static ratings of the head restraint geometry, with the aim of raising public awareness of correct head restraint positioning, and encouraging vehicle manufacturers to improve geometry. The geometry of front seat head restraints has improved each year, but the rear seats have not been investigated. Research into protection against whiplash injuries has shown that reducing the head restraint backset and improving height is effective in reducing real world injury risk. In comparison to the front seats whiplash injuries occur less frequently in the rear seats, but rear seat occupancy can be as high as 12%. The research objective in this paper is therefore to examine the head restraint geometry of the rear seats in comparison to the front seats, by presenting a feasibility study for geometric rating of the rear seats and an initial set of ratings for over 100 car models.

The RCAR-IIWPG procedure for static geometric rating of head restraints was adapted for use in the rear seats, allowing for the associated space and practical considerations. An H-Point Machine (HPM) with Head Restraint Measuring Device (HRMD) fitted was used to measure the horizontal backset from the head to the head restraint, and the height from the top of the head to the top of the head restraint. The measurements were rated according to zones of Good, Acceptable, Marginal, and Poor.

115 rear seats were rated from a variety of mainstream cars, with the top sellers selected for each vehicle manufacturer. Both the outboard and centre seats were rated where applicable. Only 9% of outboard rear seats rated as Good, but 2% of centre seats. 42% of the outboard seats rated as Poor, but for centre seats this was increased to 69%.

In comparison to the front seats the rear seat ratings were much poorer. The front seats have 91% rated Good, and 0% rated Poor. However nearly half the rear seats are rated Poor, and only 9% are rated Good. Whiplash prevention technologies have focussed on the front seats, but consideration must now be given to the rear seats.

The paper offers a new insight into the protection offered by rear seat head restraints against whiplash injuries. The ratings can be used by consumer safety organisations to increase public awareness and to encourage development of rear seats that can offer protection against whiplash injuries.

INTRODUCTION

A number of consumer safety ratings organisations have published static ratings of the head restraint geometry since 2003, with the aim of raising public awareness of correct head restraint positioning, and encouraging vehicle manufacturers to improve geometry. These geometric ratings assess the proximity of head restraint to the head of a 50th percentile male occupant, using a H-Point Machine (HPM) and Head Restraint Measuring Device (HRMD) [1]. These ratings were published by the International Insurance for Whiplash Prevention Group (IIWPG), and later this rating protocol was adopted by the Research Council for Automobile Repairs (RCAR), and incorporated into the adult occupant score of Euro NCAP. The geometry of head restraints has improved each year. Research into protection against whiplash injuries has shown that improving the head restraint height and reducing backset is effective in reducing real world injury risk [2,3,4,5].

Jakobsson et al. [6] examined rear seat occupancy in the development of the WHIPS system. This study examined insurance claims data on initial symptoms (excluding long-term disability information) and showed that the driver is at significantly greater risk than passengers, of which the front passenger is at greater (although not significantly) risk than passengers in the rear. The female passengers in the rear seats are reported to be over 25%, and for males the risk is over 15%. This study also showed that females are consistently at greater risk than males. Similarly, a study by Berglund et al. [7] examined insurance claims using a patient questionnaire a few days after the collision and found that risk was lower in the rear than in the front seats of cars. Krafft et al. [8] examined real world injury claims comparing the risk for front and rear seats, but using long term disability information a year after the collision. The study showed the risk for males as rear seat passengers was lower than for front passengers and drivers. For females the risk was lower for rear seat occupants than for drivers, although the risk was higher for rear seat passengers than for front seat passengers.

The Final Regulatory Impact Analysis from the National Highway Traffic Safety Administration for FMVSS 202 showed that 8% of whiplash injuries occur for occupants in the rear seats. A real world survey of rear seat occupancy by Thatcham has shown that 12% of rear seats are occupied. This survey recorded 1000 cars on an urban A road, and examined the age and gender of occupants seated in the rear. 33% of the rear seat passengers were teenagers or older, and were not small children that might be offered protection by child restraints. 63% of the rear seat passengers were not adequately protected by a correctly positioned head restraint. Overall the risk of injury is smaller for occupants in the rear seats, but is enough to warrant consideration, especially since around 12% of rear seats are occupied and so few have a correctly adjusted head restraint.

The research objective in this paper is therefore to examine the head restraint geometry of the rear seats in comparison to the front seats, by presenting a feasibility study of a procedure for geometric rating of the rear seats and an initial set of ratings for over 100 car models.

METHOD

The RCAR-IIWPG procedure for static geometric rating of head restraints [1] was adapted for use in the rear seats by making allowances for the associated space and practical considerations. In summary, an HPM is seated in the rear seat. An HRMD was fitted and used to measure the horizontal backset from the head to the head restraint, and the height from the top of the head to the top of the head restraint. An example of the HPM with HRMD installed in an outboard rear seat is given in Figure 1. The measurements are rated according to zones of Good, Acceptable, Marginal, and Poor (Figure 2).

Figure 1. HPM with HRMD installed in rear seat.

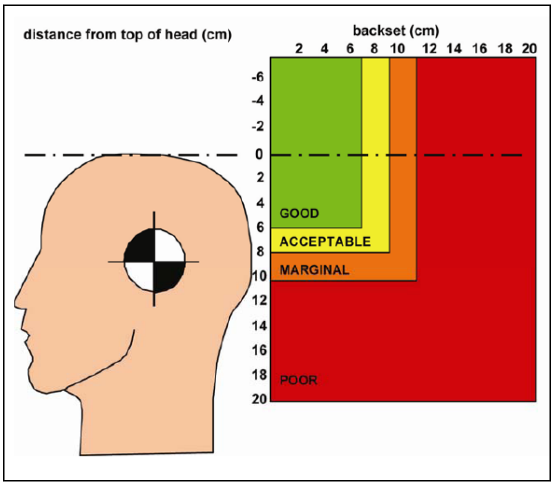

Figure 2. Head restraint rating zones.

Whilst the method of measurement was based on the standard geometric procedure prescribed by the RCAR-IIWPG [1], there were some differences. For example the installation of the HPM and legs was slightly altered to accommodate the smaller occupant space. On initial installation (without weights) of the HPM into the seat the femur angle was recorded. The legs were then fitted at the 50th percentile lengths, and width at the 5th position placing the knees 250mm apart. If there was interference with the feet or legs by some part of the vehicle floor structure or seat, then the legs were adjusted on the width until a clearance of 25mm was made. The knee spacing was kept equidistant. The femur angle was then re-measured to see if the HPM base pan was being raised off the seat, since this would indicate an unstable installation making it difficult to accurately record head restraint measurements. If the femur angle was ±1° of the initial installation then the legs remained at 50th percentile length. If the femur angle was increased to +1° above the level of the initial installation, then the legs were shortened incrementally until the initial femur angle was matched to ±1°. If it was found to be impossible to fit the legs and feet of the HPM, then these were omitted from the installation. In the majority of vehicles the centre tunnel in the rear seat footwell precluded fitment of the legs. The exceptions to this were MPVs that have a more spacious leg area in the rear so that the centre seat matches the outboard seats and there was room to install the legs (examples included the Volkswagen Sharan and the Citroen C4 Grand Picasso).

Another difference between the front seat geometric procedure and the rear seat measurement method was the installation of the height probe. In some cases the height probe could not be fitted due to interference with car interior, e.g. roof lining, as shown in Figure 3. Therefore in these cases the height probe was removed and reversed for fitment, as shown in Figure 4. In these cases 25mm was added to the height measurement to compensate for the reversed probe level.

Figure 3. Height probe interference with roof lining.

Figure 4. Height probe reversed.

Finally if the height probe is reversed and it is still found to be impossible to fit the HRMD in order to make a geometric assessment due to inability to level the HRMD (see Figure 5), then an assessment of the head restraint height can be made by using the standard HPM head room probe and the geometry of the HRMD relative to the H-Point (see Figure 6) [9]. This method was not used in this study, but there could be vehicles where rear accommodation is so restricted that it is necessary to use this method instead of using the HRMD, and the proposed method is as follows. In the case where the HRMD cannot be levelled, it should be removed along with the supplementary torso weights. The 4 standard torso weights should be installed to the HPM, and the torso angle recorded.

The backset is calculated as follows, and is shown in Figure 7 and Figure 8. The head room probe is inclined to 90°, the vertical height at which measurement is taken is calculated, and the horizontal distance is measured between the probe and the head restraint 'X'. The backset is then calculated as (1.):

$$\textbf{Backset} = X - (504.5 \sin \theta + 71) \qquad \textbf{(1.)}$$

Figure 5. HRMD cannot be levelled, alternative measurement method required.

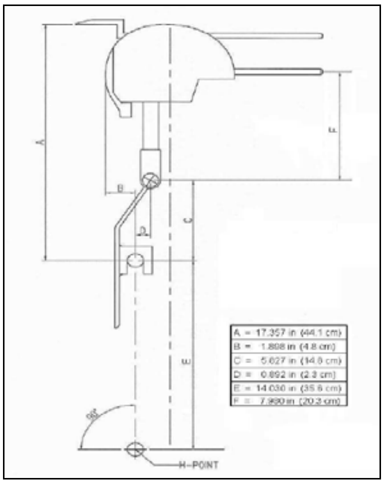

Figure 6. HRMD geometry in relation to the H-Point.

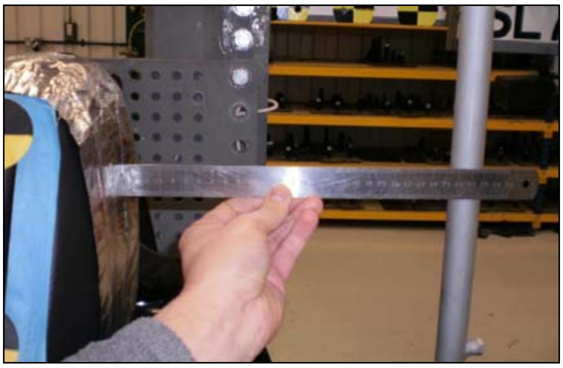

Figure 7. Backset measurement X.

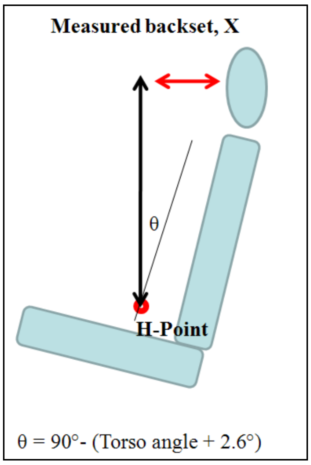

Figure 8. Backset calculation using HPM head room probe.

To measure the height of the head restraint, a similar method is used, and is shown in Figure 9 and Figure 10. The head room probe is inclined to 90°, the vertical distance between the top of head restraint and H-point aligned to the height probe 'Z' is measured. The height is then calculated as (2.):

$$\textbf{Height} = (504.5 \cos \theta + 293) - Z \qquad (2.)$$

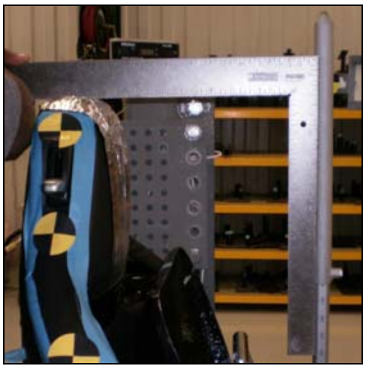

Figure 9. Height measurement Z.

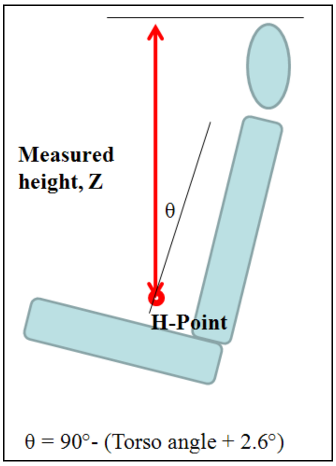

Figure 10. Height calculation using HPM head room probe.

115 rear seats were rated from a variety of mainstream cars, with the top sellers selected for each vehicle manufacturer. Both the outboard and centre seats were rated where applicable. In a few cases the seat was impossible to measure because the HPM with HRMD could not be installed in a stable manner, and these are marked as "N/A".

RESULTS

115 rear seats have been measured in this feasibility study, for both the outboard and centre seats, and these ratings are given in Table 1. The distribution of the ratings for the outboard seats are summarised in Figure 11, and for centre seats in Figure 12. Only 9% of outboard seats rated as Good, but 2% of centre seats. 42% of the outboard seats rated as Poor, but for centre seats this was increased to 69%.

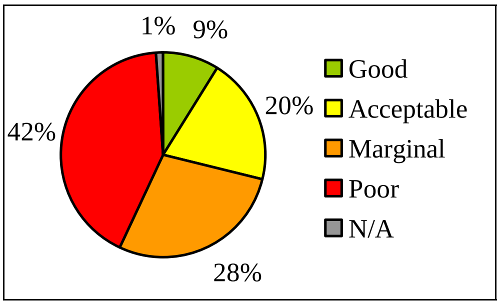

Figure 11. Outboard seats.

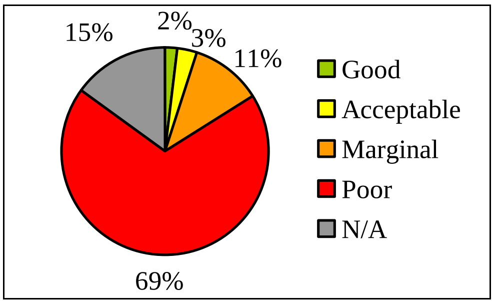

Figure 12. Centre seats.

There were 12 models that had no centre seat position available, so these could not be rated. There were some seats where the HPM could not be stably installed, so these also were not rated, but instead marked as "N/A". These N/A ratings only accounted for 1% of seats in the outboard position, but 15% in the centre position.

Table 1.
Rear seat outboard and centre geometric head restraint ratings.

Manufacturer	Model	Outboard	Centre
Alfa Romeo	159 Sportswagon	Marginal	Poor
Alfa Romeo	Giulietta	Poor	Poor
Alfa Romeo	GT	N/A	N/A
Alfa Romeo	MiTo	Poor	N/A
Audi	A1	Acceptable	N/A
Audi	A3	Poor	Poor
Audi	A4 Saloon	Marginal	Poor
Audi	A5 Coupe	Marginal	Poor
Audi	A5 Sportback	Marginal	Poor
Audi	A6 Avant	Poor	Poor
Audi	Q5	Poor	Poor
Audi	Q7	Good	Poor
Audi	S3	Poor	Poor
BMW	1 Series	Good	Poor
BMW	3 Series Saloon	Marginal	Poor
BMW	5 Series Saloon	Acceptable	Poor
BMW	X3	Marginal	Poor
Citroen	C1	Poor	-
Citroen	C3	Poor	Marginal
Citroen	C3 Picasso	Acceptable	Marginal
Citroen	C4 Hatchback	Acceptable	Poor
Citroen	C4 Picasso	Acceptable	Acceptable
Citroen	C5 Saloon	Marginal	N/A
Citroen	C-Crosser	Marginal	Poor
Citroen	DS3	Poor	Marginal
Citroen	Grand C4 Picasso	Acceptable	Acceptable
Citroen	Nemo Multispace	Marginal	Marginal
Fiat	500	Acceptable	-
Fiat	500 C	Acceptable	-

Manufacturer	Model	Outboard	Centre
Fiat	Bravo	Marginal	Poor
Fiat	Grande Punto	Marginal	Poor
Fiat	Panda	Poor	-
Fiat	Panda 4x4	Poor	-
Fiat	Punto Evo	Marginal	Poor
Fiat	Qubo	Marginal	Marginal
Fiat	Sedici	Good	N/A
Ford	C-Max	Marginal	Good
Ford	Fiesta	Acceptable	Poor
Ford	Focus	Marginal	Poor
Ford	Mondeo	Good	Marginal
Honda	Civic 5 door	Poor	Poor
Honda	Insight	Poor	N/A
Honda	Jazz	Poor	Poor
Hyundai	i10	Poor	N/A
Hyundai	i20	Marginal	Marginal
Hyundai	i30	Poor	Poor
Hyundai	ix35	Marginal	Poor
Hyundai	Santa Fe	Poor	Poor
Jaguar	XF	Marginal	N/A
Kia	Cee'd	Poor	Poor
Kia	Picanto	Poor	N/A
Kia	Sportage	Marginal	Poor
Kia	Venga	Marginal	Marginal
Land Rover	Discovery 4	Acceptable	Poor
Mazda	2	Acceptable	Poor
Mazda	3	Poor	Poor
Mazda	5	Marginal	Poor
Mazda	6	Poor	Poor

Manufacturer	Model	Outboard	Centre
Mazda	CX-7	Poor	Poor
Mercedes	A-Class	Poor	Poor
Mercedes	B-Class	Poor	Poor
Mercedes	C-Class	Marginal	Poor
Mercedes	E-Class	Acceptable	Poor
Mini	Clubman	Poor	Poor
Mitsubishi	ASX	Marginal	Poor
Nissan	Cube	Poor	N/A
Nissan	Leaf	Poor	Poor
Nissan	Micra	Acceptable	N/A
Nissan	Note	Poor	Poor
Nissan	Pixo	Marginal	-
Nissan	Qashqai	Marginal	Poor
Peugeot	107	Poor	-
Peugeot	207	Poor	Poor
Peugeot	308	Poor	Poor
Peugeot	3008	Marginal	Poor
Peugeot	5008	Marginal	Marginal
Peugeot	207 SW	Acceptable	Acceptable
Peugeot	Bipper	Marginal	Marginal
Renault	Megane CC	Acceptable	N/A
Saab	9-3 Convertible	Marginal	-
Saab	9-3 Saloon	Poor	Poor
Saab	9-5 Saloon	Poor	Poor
Seat	Alhambra	Poor	Poor
Seat	Exeo	Poor	Poor
Seat	Ibiza 5 door	Poor	Poor
Seat	Leon	Poor	Poor
Skoda	Fabia Hatchback	Poor	Poor
Skoda	Octavia Estate	Poor	N/A
Skoda	Roomster	Poor	Poor
Skoda	Superb Estate	Poor	Poor

Manufacturer	Model	Outboard	Centre
Skoda	Yeti	Poor	Poor
Suzuki	Alto	Marginal	-
Suzuki	Grand Vitara	Marginal	Poor
Suzuki	Splash	Good	N/A
Suzuki	Swift	Acceptable	-
Suzuki	SX4	Good	N/A
Toyota	Aygo	Poor	-
Toyota	Land Cruiser	Poor	Poor
Vauxhall	Agila	Good	N/A
Vauxhall	Antara	Acceptable	Poor
Vauxhall	Corsa	Poor	Poor
Vauxhall	Insignia	Poor	Poor
Vauxhall	Astra	Poor	Poor
Vauxhall	Meriva	Acceptable	Poor
Vauxhall	Zafira	Good	Good
Volkswagen	Golf	Poor	Poor
Volkswagen	Passat Saloon	Good	Poor
Volkswagen	Polo	Marginal	Poor
Volkswagen	Sharan	Poor	Poor
Volvo	C30	Acceptable	-
Volvo	S40	Acceptable	Poor
Volvo	S80	Good	Marginal
Volvo	V50	Acceptable	Poor
Volvo	XC60	Acceptable	Poor
Volvo	XC90	Acceptable	Poor

Note:
"-" ratings indicate no centre seat.
"N/A" indicates that the HPM/HRMD could not be set correctly to take measurements, due to space constraints or not remaining stable, i.e. sliding forward.

NON-USE POSITIONS

A current feature of some rear seat head restraints is the 'non-use' position. This is a position where the head restraint is stowed, and not designed for protection of the head. Examples are shown in Figure 13. This non-use position should discourage use with an occupant in the seat, and it should encourage an occupant to adjust the head restraint to its proper use position.

Figure 13. Two examples of use and non-use head restraint positions.

However in the real world some occupants do not adjust the head restraint to its correct use position, and simply leave it stowed despite the possible discomfort caused. For example, the lower example in Figure 13 might not cause enough discomfort to the occupant to make them adjust the height of the head restraint properly; whereas the upper example would clearly be extremely unusable. The difference is the level of discomfort caused, and whether the seat becomes so uncomfortable that it becomes unusable. Some non-use positions for head restraints seem to be less successful in discouraging occupants from using them. This issue is of relevance because in a non-use position a head restraint is not effective in protecting against whiplash injuries. A front seat head restraint offers some level of protection, even if unadjusted; whereas a rear seat head restraint in the non-use position in unlikely to even offer that basic level of protection. Also, since the rear seats might yield less under the forces of the occupant in a rear crash, the risk of injury with an unadjusted head restraint might be higher for the rear seat than for the front seats.

Another real world usage issue is that if a head restraint in its non-use position interferes with the fitment of a child restraint system, then people might remove the head restraint entirely. This is not a problem if the head restraint is then replaced when the child restraint is removed. However if the head restraint is removed completely from the car, and is not needed for several years, then there is a risk that it might be lost or never returned to the vehicle, in which case the rear seat occupants will have a higher risk of injury. Therefore the head restraint design must not only consider use and non-use positions, but also how the head restraint interacts with child seats.

Regulatory requirements are beginning to address the issue of non-use positions. For example ECE 17 [10] allows displacement of the head restraint, but only if the position is 'clearly recognisable to the occupant' as not being included for the use of the head restraint. Some examples are given in Figure 14 how different vehicle manufacturers seem to have responded to this requirement by providing various labels to inform the occupant of the use and non-use positions. These labels have different locations, one on the rear head restraint itself, one on the back of the seat in front, and one on the rear window behind the row of front seats. These labels will have differing levels of effectiveness in informing the occupants, based on their clarity and their visibility. However the FMVSS 202aS [11] is clearer, requiring that the non-use position provides an 'unambiguous physical cue'. This physical cue proposed was defined as a torso angle change of 10°, although that was not accepted into regulation [12]. The data sheet [11] states that if the head restraint does not automatically return to a use position when occupied by a 5^{th} percentile female, then it must rotate at least 60° for the non-use position. The provisional GTR [9] defines the previously mentioned 10° torso angle change and 60° rotation of the head restraint, as well as a 'discomfort' metric. This discomfort metric defines the minimum protrusion of the head restraint, and the position of its lower edge, in order to specify a non-use position. Overall, the regulatory requirements indicate that there is a need to address the issue of providing non-use positions that properly discourage use, in order to best protect the occupant. However the ECE regulation only requires the non-use position to be 'clearly recognisable', which is difficult to quantify and assess. The requirements of the regulations are also only enforced if a head restraint is fitted in the rear, so there is a risk that vehicle manufacturers might simply cease to fit rear head restraints, and therefore the occupant is offered no protection against injury.

	Label on side of head restraint
	Label on rear quarter window, behind row of rear seats
	Large label on back of front seat

Figure 14. Examples of labels describing use and non-use positions for rear head restraints.

DISCUSSION

In comparison to the front seats the rear seat ratings were much poorer. Based on static geometry ratings from the 2010 model year the front seats have 91% rated Good, and 0% rated Poor. However nearly half the rear seats measured in this study are rated Poor, and under 10% are rated Good. This highlights the potential difference in protection offered by head restraints in the front seats compared to the rear seats.

It is of interest that insufficient height adjustment of the rear outboard head restraints is the reason for most Poor ratings. Analysis of the outboard backset measurements reveals that 67% of the head restraints achieve a Good rating (when height is excluded from consideration, see Figure 15). So in order the gain a better rating, and to better protect occupants against whiplash, the vehicle manufacturers' first improvement could be to improve the height adjustment range of the rear head restraints. One possibility is therefore to have a rating system that only considers the height of the head restraint. However many research studies have established that reduced backset of the head restraint can help to reduce whiplash injuries [2,3,4,5], and the HRMD is an established tool for head restraint measurements. Furthermore, the centre seat generally has a larger spread of backset (Figure 16), and if only the height adjustment were increased there would be less improvement to overall geometry. Therefore it is important to consider both backset and height of the rear head restraints, as this feasibility study has shown, in order to provide protection to the rear seat occupants.

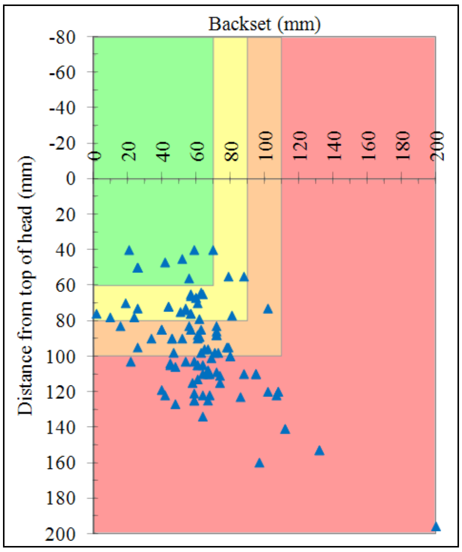

Figure 15. Outboard seats: Only 10% have Poor backset.

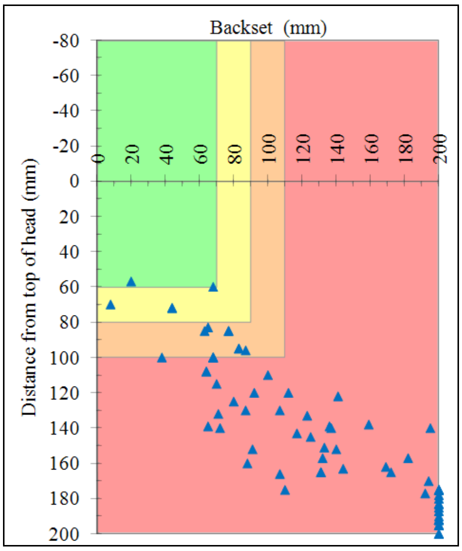

Figure 16. Centre seats: Greater range in backset and height than outboard seats.

In the front seats there are different types of anti-whiplash system that are design to help reduce the risk of whiplash symptoms and injuries occurring in rear impact. For example, a reactive head restraint (RHR) responds to the rearward motion of the body in the seat so that a mechanism moves the head restraint upward and forward to meet and support the head earlier in the crash. A pro-active head restraint (PAHR) has a similar movement upward and forward, but is actuated by crash sensors around the vehicle in order to provide protection even more quickly. A reactive seat (RAS) design is focussed on energy absorption in the seat back and head restraint; and a passive seat

(PAS) uses passive foam technology to absorb the energy of the crash and allow the occupant to engage the head restraint without neck distortion. All of these four designs might also be feasible for the rear seat. However due to vehicle design the rear seats have less ability to flex in the rearward direction, so designs that rely on rearward distortion of the seat to allow energy absorption might be less feasible. Ultimately the protection offered by the rear head restraint is a compromise with many other factors that a vehicle manufacturer must consider, including the available space, cost, comfort for the occupant, weight etc. Thatcham is monitoring the rear seat designs to identify those that appear to offer the potential to reduce whiplash injury risk.

In the development of the RCAR-IIWPG front seat whiplash procedures, the initial work focussed on the static geometric rating of the seats, and then progressed to development of a dynamic test to assess the performance of the front seats in an impact. Similarly, it is possible to develop a dynamic rear seat test. Thatcham will continue to investigate the feasibility of dynamic rear seat testing. However since the improvements in front seat geometry have been shown to be effective in reducing real world whiplash injuries, the main focus will remain on rear seat geometry.

CONCLUSIONS

Whiplash prevention technologies have focussed on the front seats, but consideration should now be given to the rear seats. The paper offers a new insight into the protection offered by rear seat head restraints against whiplash injuries. It presents a feasibility study of using an adapted head restraint geometric measurement method for the rear seats. This reveals that from 115 models measured, less than 10% rated Good, which highlights the need to improve the level of protection against whiplash injuries offered by the rear seats. The ratings can be used by consumer safety organisations to increase public awareness and this will have two main benefits: firstly to raise public awareness and encourage correct use of the head restraint; and secondly to encourage development of rear seats that can offer protection against whiplash injuries.

LIMITATIONS

The sample of cars rated does not cover the entire current vehicle fleet, however the models selected were the top-sellers for each manufacturer.

This paper presents the RCAR-IIWPG geometry procedure [1] being applied to the rear seats as a feasibility study. The posture used by rear seat occupants might be different to the front seats, and this would need consideration to ensure that the measurements reflect a realistic posture.

The ratings zones defined by the existing front seat procedure are based on the zones in which geometry is proven to have an effect, but these may be different for rear seated occupants. An examination of real world insurance claims in relation to the measurements recorded could help to define zones that are better suited to driving seat designs to protect against whiplash injuries.

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An Insight into Multiple Impact Crash Statistics to Search for Future Directions of Counter-Approaches

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Paper Number 11-0203

ABSTRACT

Multiple impact crashes (MICs) consist of more than 50 percent of all tow-away crashes that occurred on US roadways between 2000 and 2008. The total number of injured occupants with MAIS3+ injury, based on NASS-CDS data for 3-point lap and shoulder belted occupants, without rollover and no-ejection for the model year 2000-08, is 1,571(weighted 109,276). No significant change or variation can be observed with respect to the model year of the vehicle. The probability of higher level of injury (MAIS>3-5) suffered by the occupants inside the vehicle, is more likely to occur in MIC scenario than that in SIC (single impact crash) scenario. As passive safety measures, especially irreversible systems, are generally more effectively designed for occupant protection in single impact, there are opportunities for future advanced active systems as mentioned by Sander (2009).

1. INTRODUCTION

Both crash tests required by legislation and consumer tests reproduce single impact crashes either in vehicle-to-moving carriage or in vehicle-to-fixed object collisions. A multiple impact crash is one in which a vehicle (or surrounding vehicles) undergoes two or more events of impacts during a process of a total crash sequence. The data analysis portion of this research considers only multiple impact crashes that do not involve rollover, where the drivers were not ejected, and where the drivers were belted in the vehicles with 2000+ model year. Neither the initial impact nor the subsequent impact(s) is limited in any direction, sequence, or impacted object. Several recent statistical studies of multiple impact crashes have been published (Digges, 2003, Lenard, 2004, Bahouth, 2005). The purpose of the present study is to introduce in-depth reviews of accident cases involving multiple impacts in order to better understand the percentage of different types of these crashes. The effect of the sequence of impact events in multiple impact scenario have not yet been incorporated in present test procedures. As a consequence, passive safety measures, especially irreversible systems, are generally designed for occupant protection in single impact. The overall economic impact and human toll of multiple impact crashes is significant as mentioned in references (DOT 2000, Fildes 1996). Therefore further basic and applied researches related to accident mitigation and occupant protection based on accident database are necessary to adequately address the counter measures in order to minimize the number of accidents and also the level of injury.

2. OVERALL ACCIDENT STATISTICS

Table 1 shows the percentage distribution of number of occupants with different injury level (MAIS0+ to MAIS5+ and MAIS0 to MAIS5) in tow-away crashes which occurred on U.S. roadways, based on NASS-CDS data. The data refers to impact crashes registered from 2000 through 2008, that do not involve rollover, where the drivers were not ejected, and where the occupants were belted (3-point lap and shoulder) in the vehicles of 2000+ model year (MY). The total number of occupants is 22,795(unweighted) corresponding to a weighted value of 9,126,520 occupants. The values within the bracket "()"correspond to those for individual MAIS(0-5) level.

Table 1: Percentage distribution of injured occupants with different injury level (NASS-CDS, 2000-08, no rollover, no-ejection, MY2000+, belted).

Item	MAIS 0+ (0)	MAIS 1+ (1)	MAIS 2+ (2)	MAIS 3+ (3)	MAIS 4+ (4)	MAIS 5+ (5)
SIC	56% (59%)	51% (51%)	52% (56%)	43% (47%)	34% (34%)	35% (36%)
MIC-MIE=1(Max. injury 1st impact)	27% (25%)	30% (30%)	30% (30%)	32% (30%)	35% (37%)	30% (26%)
MIC-MIE=2+ (Max. injury 2nd+ impacts)	9% (8%)	11% (11%)	13% (10%)	18% (18%)	20% (19%)	22% (23%)
Unknown	8% (8%)	8% (8%)	5% (4%)	7% (5%)	11% (10%)	13% (15%)
Total	100%	100%	100%	100%	100%	100%

With the increase of MAIS+ injury level, in single impact crash (SIC), the percentage decreases from 56% to 35%. In multiple impact crash (MIC) with maximum injury event (MIE) at the event of 1st impact (MIC-MIE=1), the percentage remains more or less constant around 30%. However, for MIC scenario corresponding to maximum injury event in 2nd+ impacts (MIC-MIE=2+), with the increase of injury level from MAIS0+ to MAIS5+, the percentage increases from 9% to 22%. The decrease in SIC and the increase in MIC-MIE=2+ are especially significant starting at MAIS3+ level. Similar trend can be observed for individual MAIS values written within brackets. According to the data extracted in the present study, there is some indication that the probability of higher level of injury (MAIS>3-5) suffered by the occupants inside the vehicle, is more likely to occur in total MIC scenario (including MIC-MIE=1 and MIC-MIE=2+) than that in SIC scenario. The data for MAIS3+ will be discussed in detail in the later section of this paper.

Table 2: Percentage distribution of MAIS3+ injured occupants with different injury level with respect to the MY of the vehicle.

Item	MY 2000+	MY 2001+	MY 2002+	MY 2003+	MY 2004+	MY 2005+
SIC	43%	42%	42%	41%	43%	43%
MIC-MIE=1 (Max. injury at 1st impact)	32%	31%	31%	31%	32%	30%
MIC-MIE=2+ (Max. injury at 2nd+ impacts)	18%	20%	20%	20%	17%	20%
Unknown	7%	7%	7%	8%	8%	7%
Total	100%	100%	100%	100%	100%	100%

The previous data is now plotted in Table 2 by varying the start of model year from MY2000+ to MY2005+, in order to observe the effect of the model year on the percentage distribution of number of injured occupants with different injury level in SIC and MIC scenario basis. The total number of injured occupants with MAIS3+ injury based on NASS-CDS data for belted occupant without rollover and no-ejection for MY 2000-08, is 1,571 corresponding to a weighted value of 109,276 persons. For example, model year range MY2003+ means 2003-2008. No significant changes or variation can be observed with respect to the start of the model year ranges of the vehicle in SIC and MIC scenario over a span of 6years when relatively older cars are gradually replaced by newer cars.

3. MODES OF MULTIPLE IMPACT CRASHES

In CDC code, the severity of damage related to injury of a particular event for each vehicle is classified as "Rank". Here it is assumed that maximum injury is caused at the most severe event "Rank=1" due to maximum damage at that particular event of impact. Figure 1 shows a typical SIC event with maximum injury of the target vehicle V2 occurred at the event of 1st impact at the intersection.

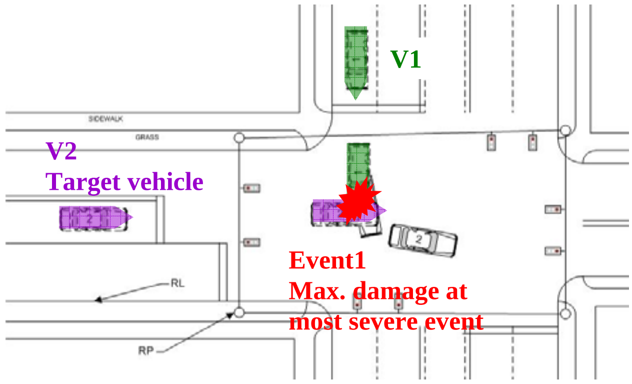

Figure 1: Example SIC: NASS-CDS:2001-045-058

Figure 2 shows a typical MIC event with maximum damage of the target vehicle V1 occurred at the event of 1st impact on the intersection and then pushed away from the center of the road intersection to the ditch/culvert at the road side.

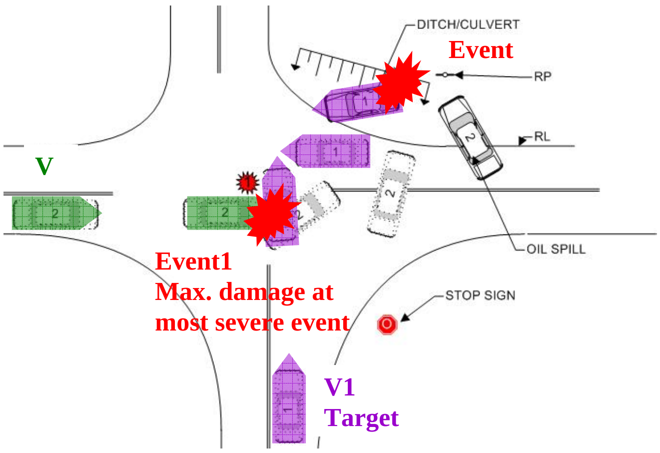

Figure 2: Example of MIC-MI1 NASS-CDS:2000-009-027

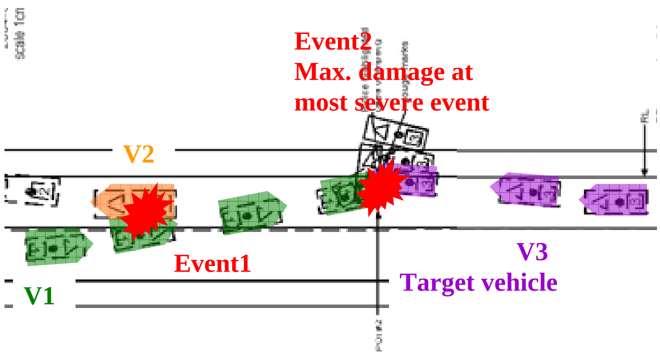

Figure 3: Example of MIC-MI2 NASS-CDS:2004-81-076

Figure 3 is a typical MIC event with maximum damage of the target vehicle V3 which occurred at the event of 1st impact for V3. However, it is the 2nd event within this MIC scenario in which the 1st event corresponds to "V1 hit the left-rear portion of V2" and then the 2nd event is "V1 involved in frontal crash with V3". The above cases are indicated as sample accident cases in the respective areas in SIC and MIC portions of Figure 4 as shown below.

3. MODES OF SINGLE AND MULTIPLE CRASHES

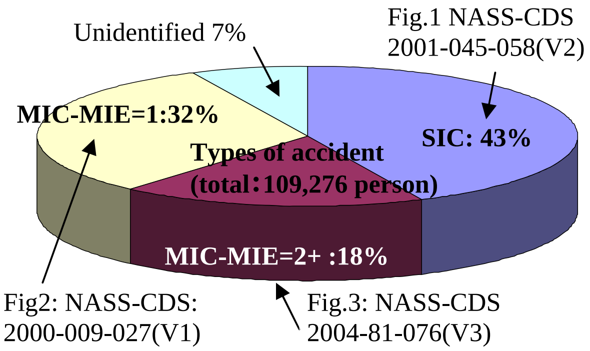

Figure 4: Percentage distribution of SIC and MIC (MAIS3+).

Figure 4 shows the percentage distribution of SIC and MIC related to MAIS3+ cases as highlighted in Table 1. A total of 109,276 persons are involved in these crashes. The percentage of occupants involved in MIC scenario is 50% (MIC-MIE=1: 32% , MIC-MIE=2+: 18%) compared to that of 43% in SIC scenario within a selected set of NASS-CDS dataset as mentioned above. Maximum injury (damage to the vehicle) in those SIC and MIC occurred in the events of first and subsequent second or later impacts, respectively. It also includes small amount about 7% of unidentified cases. Based on the information of NASS-CDS data which indicates the severity of each event, among the above mentioned MIC scenario (i.e., 50%) with MAIS3+ injured occupants, approximately 1/3 (i.e., 18%) of those occupants incurred maximum injury in the event of second or later impacts.

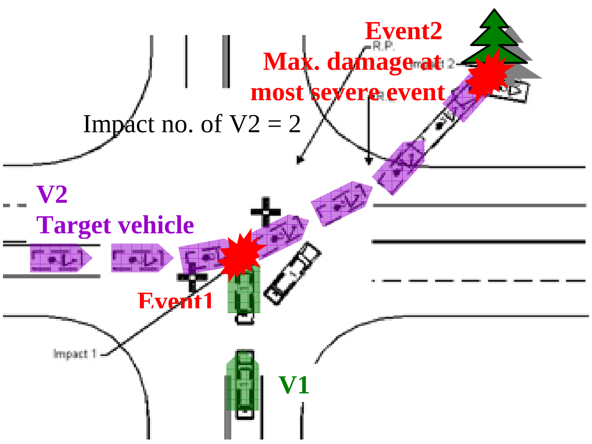

Figure 5: Example of MIC-MIE=2+ NASS-CDS: 2004-12-193.

Figure 5 shows another typical MIC event where the maximum damage of the target vehicle V2 occurred at the event of the 2nd impact against a tree outside the road after being hit at the right front side at the intersection by vehicle V1. Figure 6 also shows another typical MIC event where the maximum damage of the target vehicle V3 occurred at the event of the 2nd

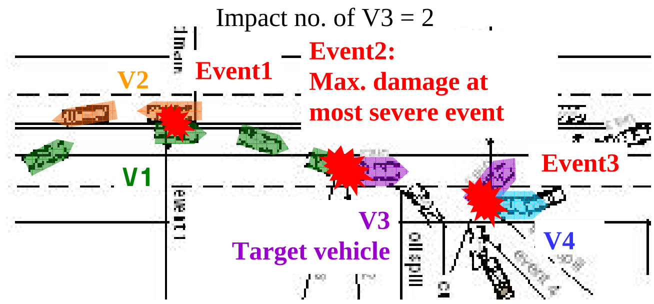

Figure 6: Example of MIC-MIE=2+ NASS-CDS: 2007-012-081.

impact when it is impacted at the rear end by the following vehicle V1. Before this event, vehicles V1 and V2 collided sidewise at the event of the 1st impact. The reference number of the above two cases are indicated in the following Figure 7 and Figure 8 in SIC and MIC portions.

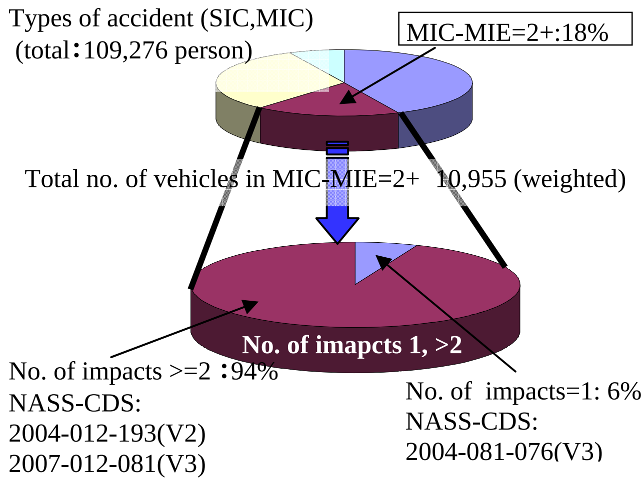

Figure 7: Percentage distribution of number of MIC-MIE = 2+ related vehicles based on number of impacts.

As shown in Figure 7, corresponding to 18% of MIC-MIE=2+ occupants where the maximum injury occurred after the 2nd impact, there are 10,955 (weighted) number of vehicles by counting only once for a particular vehicle even if there are cases where multiple occupants are injured within a single vehicle involved in those MIC scenario. Based on this counting method, 94% of those MIC-MIE=2+ vehicles (for example, NASS-CDS 2004-012-193(V2) or 2007-012-081 (V3) , Figure 5,6) were involved in more than two impacts and the remaining 6% (for example, NASS-CDS 2004-081-076 (V3), Figure 3) of the MIC-MIE=2+ ended up in only single impact preceded by the 1st impact event within the accident scenario. Hence, the probability of being impacted twice or more before the event of maximum injury, is very high in MIC-MIE=2+ situation. One can think of some possible reasons behind these types of phenomena. They are probably due to the fact that (a) considerable amount of kinetic energy remained in the crashed vehicle after the 1st impact event in those MIC-MIE= 2+ scenario and (b) the initial velocity before the 1st impact event might be high enough to encounter or cause subsequent multiple impacts before coming to rest.

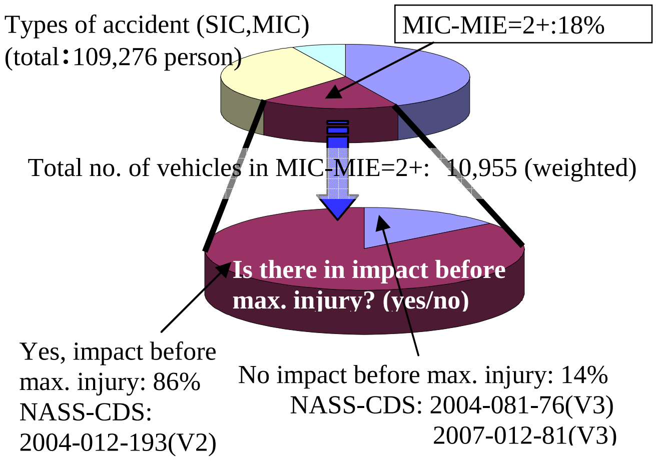

Figure 8: Percentage distribution of number of MIC-MIE =2+ related vehicles based on impact condition before the event of maximum injury.

Based on the previous counting method, Figure 8 shows that 86% of the vehicles in those MIC-MIE=2+ scenario, involved in more than two impacts, there is at least one event of impact before the one which causes maximum injury or damage. The remaining 6% of the MIC-MIE=2+ scenario, do not encounter any impact before the event of maximum damage or injury. Hence, after the 1st impact of the concerned car in that 86% (for example, NASS-CDS: 2004-012-193(V2), Figure 5), there is some possibility of reducing the number of occurrence of consequent accidents and also simultaneously reducing the degree of damage or severity of the accident as a whole. With the progress of future advanced sensing technologies (including vehicle surrounding sensors), accident mitigation may be possible by braking or by intelligent maneuvering (steering action) before and after the impact. This may be one of the different ways of reducing of total number of injuries as well as the degree/severity-level of injuries of the occupants inside those vehicles.

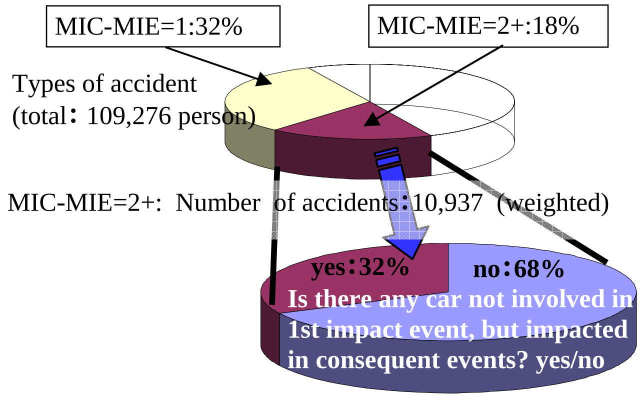

Figure 9: Percentage distribution of number of MIC-MIE =2+ related accidents based on pre-impact condition before the event of maximum injury.

Based on the same counting method as mentioned above, Figure 9 shows that in 32% of those MIC-MIE=2+ scenario, accidents include the vehicle which is not involved in 1st impact event but engaged in accident after the event of 1st impact. Hence, similar benefits may be realized by implementing pre-crash and post-crash braking or controlled maneuvering in those surrounding uncontrolled crashed vehicle after the event of 1st impact.

Advanced systems may also show benefits when it comes to protecting vulnerable road users such as the pedestrians or bicyclists [3, 4]. But the accident report of vulnerable road users are not available in NASS-CDS accident database. However, every year, it is observed that there exists a few number of such MIC related secondary accidents involving pedestrian and bicyclist as recorded in FARS database.

4. CONCLUSION

Overall accident statistics related to the percentage distribution of number of occupants with different injury level in tow-away crashes occurred on U.S. roadways, based on NASS-CDS database are discussed. The data refers to impact crashes registered from 2000 through 2008, that do not involve rollover, where the drivers were not ejected, and where the occupants were belted in the vehicles of MY 2000+ model year. The total number of occupants is 22,795 (unweighted) corresponding to a weighted value of 9,126,520 occupants.

1) When considering MY 2000-2008, no significant changes or variation can be observed with respect to the start of the model year ranges of the vehicle in SIC and MIC scenario.

2) The probability of higher level of injury (MAIS>3-5) suffered by the occupants inside the vehicle, is more likely to occur in MIC scenario than that in SIC scenario.

3) There is some opportunity left for future advanced active safety systems to play an important part in multiple impact crash scenario.

The above study is purely based on accident data of NASS-CDS database system and no definite conclusion can be drawn at present about the effect of such new systems as mentioned above without carrying out detail experiments in various scenario.

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ENCOURAGING SAFER VEHICLES THROUGH ENHANCEMENTS TO THE NCAP RATING SYSTEM

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ABSTRACT

Since 1999 the Australasian New Car Assessment Program (ANCAP) has tested and rated vehicles using essentially the same protocols as Euro NCAP. This produces a rating out of 5 stars for front occupant (driver and front passenger) protection. More than half of the model ratings published by ANCAP in that time have been based on at least one set of crash test results from Euro NCAP. Crash test data from Europe is therefore an important component of ANCAP model coverage. Euro NCAP recently changed its rating system to encourage better performance in other areas, such as whiplash protection, child occupant protection and pedestrian protection. Euro NCAP also introduced a Safety Assist component of its rating system to encourage certain safety features.

The changes to Euro NCAP's rating system, together with the requirements of other World NCAP organisations have been evaluated by ANCAP and a Roadmap has been prepared. This takes into account the automotive regulatory and marketing environments in Australia and New Zealand. The process included consultation with the local automotive industry.

This paper describes the changes to the rating system that ANCAP will progressively introduce in coming years. These include recognition of a wide range of vehicle safety features and minimum performance in tests of pedestrian protection, whiplash protection and roof strength.

INTRODUCTION

This document sets out the approved 2011-2015 ANCAP Road Map and provides details to industry and ANCAP stakeholders of what is required under the Road Map year by year.

BACKGROUND

Since 1999 ANCAP has tested and rated vehicles using essentially the same protocols as Euro NCAP. This produces a rating out of 5 stars for front occupant (driver and front passenger) protection and a separate rating (originally out of 4 stars) for pedestrian protection.

More than half of the model ratings published by ANCAP in that time have been based on at least one set of crash test results from Euro NCAP. Crash test data from Europe is therefore an important component of ANCAP model coverage.

Euro NCAP also published a rating for child occupant protection but this was found to be unsuitable for ANCAP as different child restraints are supplied to the Australian market, when compared with Europe.

This Road Map has been developed in consultation with Australian and New Zealand automotive industry.

AIMS OF THE ROADMAP

- To promote and reward improvements in vehicle safety beyond that covered by the 2010 ANCAP rating system
- To implement key priorities of ANCAP members in the field of vehicle safety
- To provide consumers with information about the availability of safety features and vehicle performance that go beyond regulatory requirements
- To provide the automotive industry with guidance of future ANCAP requirements to assist with the design and specification of new models.

CHANGES TO EURONCAP RATING SYSTEM

Early in 2009 Euro NCAP introduced major changes to its rating system. This combined previous ratings and a new "Safety Assist" category into an overall rating out of 5 stars. Euro NCAP no longer publishes separate star ratings for front occupant, pedestrian or child occupant protection but continues to conduct the tests to the same protocols and continues to provide ANCAP with the test data. It is therefore possible for ANCAP to continue using the previous rating system and still republish results from Europe. A possible criticism is that ANCAP ratings might no longer match those by Euro NCAP but this has been the case since 2008 when ANCAP introduced a requirement for ESC as a pre-requisite for a 5 star rating. Several models in Australia have missed out on a 5-star rating due to a lack of ESC.

The Safety Assist component of the new Euro NCAP rating system currently covers three safety features: electronic stability control, speed limitation devices (initially manual systems) and seat belt reminders. Points are assigned to each feature. A minimum Safety Assist score is required for each star rating. For example, in 2009 a minimum Safety Assist score of 60% was required for a 5 star overall rating.

OTHER NCAP TESTS

In addition to the offset frontal, mobile barrier side impact and side pole tests, several other types of ratings are conducted by NCAP organisations around the world:

- Pedestrian protection - conducted by Euro NCAP, ANCAP, KNCAP and JNCAP
- Child occupant protection - conducted by Euro NCAP (vehicle crash tests), Australian CREP (sled tests) and JNCAP (sled tests)
- Rear seat adult occupant protection - conducted by JNCAP from May 2009
- Whiplash rating - conducted by Euro NCAP, IIHS, NRMA Insurance and KNCAP
- Rollover propensity (cornering test) - conducted by US NCAP (NHTSA) and KNCAP
- Roof strength - static strength test conducted by IIHS since March 2009. Dynamic rollover tests are under development in the USA and research will soon commence in Australia.
- Dynamic braking tests - conducted by JNCAP and KNCAP
- Safety assist (active safety features) - conducted by Euro NCAP since 2009 and proposed by US NCAP

There are some variations in test and rating protocols amongst these organisations.

NCAP TEST AND RATING PROTOCOLS

Based on NHTSA criteria, for NCAP purposes, a performance test needs to be:

a) Repeatable and equitable amongst the full range of vehicles that will be subjected to the test
b) Discriminating (showing a clear difference between best and worst performers in each class)
c) Where possible, correlated with the outcomes of real-world crashes/injury outcomes
d) Economically feasible (the need for fabrication of a test rig needs to be considered, as well the destruction of test vehicles)
e) Credible with the automotive industry and consumers

These criteria are similar those applying to regulation performance tests (although many more conditions apply to regulations). Indeed, most NCAP performance tests are associated with a regulation test.

The availability of a suitable test protocol that meets these criteria is an important factor is the decision to introduce a new NCAP test.

CHANGES TO ANCAP'S TESTING REGIME

The ANCAP Road Map sets out a new testing regime for the assessment of vehicle safety and the awarding of an ANCAP star rating. Progressively over the life of the Road Map, ANCAP will be introducing new tests, new calculation methods and new safety assist technology ("SAT") requirements.

The Offset Frontal, Side Impact, Side Pole and Pedestrian tests will be retained. Adding to the physical test regime will be Whiplash tests (based on work currently undertaken by NRMA Insurance) and Roof Crush Strength tests (based on work undertaken by IIHS since 2009).

In relation to SAT, both mandatory and additional SAT will be required, with the requirements generally becoming more stringent each year.

Calculation of the overall ANCAP star rating is illustrated on Figure 1. All physical crash test results and the SAT elements will be included in the calculation of the overall ANCAP star rating.

Full details of the Road Map's revised star qualifiers can be found in Appendix A.

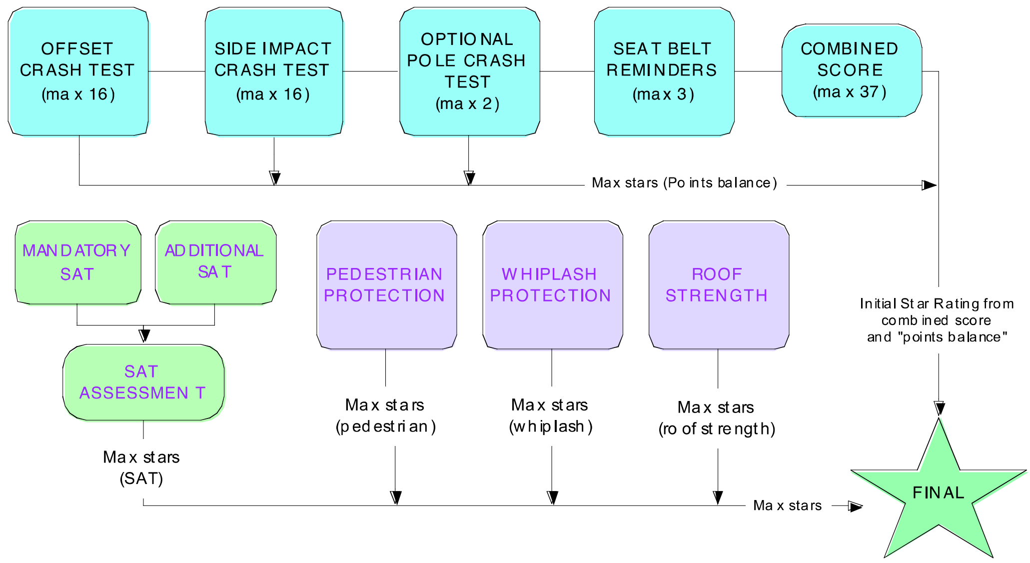

Figure 1. Calculation of ANCAP Rating.

A description of each mandatory SAT is included in Table 1. A description of all current SAT is included in Appendix B. Additional SAT may be selected from Appendix Table B1 or B2. Items in Appendix Table B3 do not count as Additional SAT.

Table 1.

Mandatory SAT

Feature (see appendix for definitions)	Comment
Electronic Stability Control (ESC)	Required by ANCAP for 5-stars since 2008. To be extended to other star ratings
Seat Belt Reminders (SBR) for fixed seating positions	Common on front seats for 5-star vehicles. It will remain part of the star rating score, as well as a SAT requirement. To be extended to other star ratings and to rear seats
Head-protecting technology - side airbags (HPT)	Required by ANCAP for front seats for 5-stars since 2004 (pole test). To be extended to other star ratings and to rear seats
Emergency Brake Assist (EBA)	Common on most 5-star vehicles
3-point seat belts for all forward facing seats (3PSB)	Common on most 5-star vehicles

ROAD MAP REVIEW

The ANCAP Road Map will be reviewed, updated and extended annually (in June) on 5 year rolling program basis. The review will be conducted by ANCAP in consultation with the automotive industry.

Updates will be published on the ANCAP website following each review.

SAFETY ASSIST TECHNOLOGY (SAT)

The ANCAP Road Map includes both mandatory and additional SAT. All SAT are detailed in Appendix B For a vehicle to achieve a star rating it must meet the appropriate minimum requirements of the physical crash tests and have as standard fitting the minimum mandatory SAT - it must also have the required number of additional SAT. These additional SAT can be selected by the manufacturer/importer from the list of SAT set out in Appendix A.

Note that mandatory SAT must be standard equipment on the rated variant. Additional SAT will be scored at full value if fitted as standard equipment and at half value if fitted as optional equipment. It is possible that variants will have different star ratings due to differences in standard equipment. This situation has existed since 2008 where ANCAP has published two ratings for a model - with and without ESC.

CONCLUSIONS

A workable Roadmap has been developed in consultation with the local automotive industries. This will encourage improvements in vehicle safety beyond the occupant protection focus of the previous rating system, while providing continuity with that previous system.

A key feature of the Roadmap is that it encourages a wide range of safety features, all of which can be expected to reduce road trauma to some degree. Manufacturers are given flexibility in the choice of additional safety features to supplement the mandatory features. This avoids the need to rank safety features, with the inevitable debate that such ranking would generate.

APPENDIX A – NEW ANCAP STAR QUALIFIERS

Table A1.

ANCAP Road Map 2011 – 2015

Year	Minimum Frontal Offset Score	Minimum Side Impact Score	Minimum Side Pole Score	Minimum Combined Score[4]	Minimum Pedestrian Rating	Minimum Whiplash Rating	Minimum Roof Strength Rating	Mandatory SAT[1]	Minimum Additional SAT[2]
Requirements for 5 Star Rating									
2011	12.5	12.5	1	32.5	-	-	-	ESC, 3PSB, HPT front seats	-
2012	12.5	12.5	1	32.5	Marginal[3]	Acceptable	-	ESC, 3PSB, HPT front seats	2
2013	12.5	12.5	1	32.5	Marginal[3]	Acceptable	-	2012 + SBR front seats, EBA	3
2014	12.5	12.5	1	32.5	Acceptable[3]	Good	Acceptable	2013 + HPT 2nd row seats	4
2015	12.5	12.5	1	32.5	Acceptable	Good	Acceptable	2014 + SBR 2nd row fixed seats	5
Requirements for 4 Star Rating									
2011	8.5	8.5	-	24.5	-	-	-	-	-
2012	8.5	8.5	-	24.5	-	-	-	ESC	-
2013	8.5	8.5	-	24.5	-	-	-	ESC	1
2014	8.5	8.5	-	24.5	Marginal[3]	Acceptable	-	2013 + 3PSB, HPT front seats	2
2015	8.5	8.5	-	24.5	Acceptable[3]	Acceptable	-	2014 + SBR front seats, EBA	3
Requirements for 3 Star Rating									
2011	4.5	4.5	-	16.5	-	-	-		
2012	4.5	4.5	-	16.5	-	-	-	-	-

2013	4.5	4.5	-	16.5	-	-	-	ESC	-
2014	4.5	4.5	-	16.5	-	-	-	2013 + 3PSB	1
2015	4.5	4.5	-	16.5	-	-	-	"	2
Requirements for 2 Star Rating									
2011	1.5	1.5	-	8.5	-	-	-		
2012	1.5	1.5	-	8.5	-	-	-	-	-
2013	1.5	1.5	-	8.5	-	-	-	-	-
2014	1.5	1.5	-	8.5	-	-	-	ESC	-
2015	1.5	1.5	-	8.5	-	-	-	"	1
Requirements for 1 Star Rating									
2011	-	-	-	0.5	-	-	-	-	-
2012	-	-	-	0.5	-	-	-	-	-
2013	-	-	-	0.5	-	-	-	-	-
2014	-	-	-	0.5	-	-	-	-	-
2015	-	-	-	0.5	-	-	-	-	-

Notes:

1. Must be standard on the variant being assessed.
2. For additional SAT to score the full value, the particular SAT must be fitted by the manufacturer as standard equipment. SAT fitted by the manufacturer but specified as optional (extra) equipment only scores half value.
3. Vehicles with a seating reference height of 700mm or more may meet one grade less for pedestrian protection (eg “poor” instead of “marginal” and “marginal” instead of “acceptable”.)
4. The Combined Score includes up to 3 points for seat belt reminders (1 for driver, 1 for front passenger and 1 for all 2nd row seats - this is separate from the SAT scoring)

APPENDIX B - SAFETY ASSIST TECHNOLOGIES

The coloured text indicates it has been copied from Euro NCAP sources.

TBA = assessment method to be advised

Table B1.

Existing Technologies (well established)

NAME	DESCRIPTION	ASSESSMENT METHOD
DAYTME RUNNING LIGHTS (DRL)	Dedicated daytime running lights, preferably combined with auto headlights that automatically switch on at dusk	ADR76 or European Commission Directive 2008/89/EC
DRIVER KNEE AIRBAG	Extra airbags designed to cushion the knees of the driver. Although a knee airbag contributes to the offset crash test score (by reducing upper leg loading and eliminating knee hazards) there are extra benefits that justify inclusion in the SAT list.	Observe after offset crash test
ELECTRONIC BRAKEFORCE DISTRIBUTION (EBD)	Distribution of braking forces is optimised to maximise the available friction	Functional definition (based on ADR 31)
ELECTRONIC STABILITY CONTROL (ESC)	Detects if vehicle is nearing the limits of traction during cornering and braking and adjusts braking to individual wheels and engine torque to improve stability.	Functional requirements of the GTR
EMERGENCY BRAKE ASSIST	Detects fast brake application. Provides emergency braking assistance	Functional definition. Possible Euro NCAP Advanced (pending)
EMERGENCY STOP SIGNAL (ESS)	A signal to indicate to other road users to the rear of the vehicle that a high retardation force has been applied to the vehicle relative to the prevailing road conditions. The emergency stop signal shall be given by the simultaneous operation of all the stop or direction indicator lamps. All the lamps of the emergency stop signal shall flash in phase at a frequency of 4.0 ± 1.0 Hz. However, if any of the lamps of the emergency stop signal to the rear of □the vehicle use filament light sources the frequency shall be 4.0 +0.0/- □1.0 Hz.	ADR 13/00 (ECE 48)
FATIGUE REMINDER	Monitors hours of driving and encourages rest breaks (trip timer)	Functional definition (+ road test?)
HEAD RESTRAINTS FOR ALL SEATS	Head restraints with a geometry designed to protect an adult in a collision from the rear	Vehicle inspection
REVERSING COLLISION AVOIDANCE	Visual aids (e.g. camera) to improve the rearward field of view plus sensors detect objects in the path of a reversing vehicle. Parking sensors alone would not meet the requirements	Functional definition based on RTA Technical Specification No 149 Possible NHTSA rule
SEAT BELT INTERLOCK/	Require driver to put on seat belt before the vehicle can be driven (interlock), or provide alert to driver	Reminder: Euro NCAP protocol

REMINDER	that seated occupants do not have seat belts connected	Interlock: TBA
SIDE AIRBAGS WITH HEAD PROTECTION	Side airbag or curtain airbag deploys in side impact and protects the head	Extra observation after a pole test using geometric assessment (e.g. whether a rear-seat occupant would have had head protection). No extra dynamic test is proposed.
THREE-POINT SEAT BELTS FOR ALL SEATS	Lap/sash seat belts in all forward facing seating positions	Vehicle inspection
TYRE PRESSURE MONITORING	Detects when a tyre drops below designated pressure and alerts driver	US FMVSS 138 (other standards may be accepted)

Table B2.

New and Emerging Technologies

NAME	DESCRIPTION	ASSESSMENT METHOD
ADAPTIVE FRONT LIGHTING SYSTEMS	Headlights and associated lights that adjust their direction and intensity to provide additional illumination on curves, turns, and hills and to highlight potential hazards.	ADR 13
ADDITIONAL OCCUPANT PROTECTION AIRBAGS	Additional airbags that are not associated with the crash tests conducted by ANCAP (e.g. centre console between front seats, rear seat frontal airbag, rear seat thorax side airbags). Each type of airbag system will count as one SAT (if standard).	Functional definition plus manufacturer's crash test data.
ALCOHOL /DRUG IGNITION INTERLOCK	Require driver to perform and pass a breath alcohol test before the vehicle can be driven	State government requirements? Possible Euro NCAP Advanced (pending)
ATTENTION ASSIST (FATIGUE DETECTION)	Attention Assist is a drowsiness detection system that warns drivers to prevent them falling asleep momentarily whilst driving. It will prompt them to take a break before it's too late.	Euro NCAP Advanced (pending?)
AUTOMATIC EMERGENCY CALL (eCall)	Alerts emergency services (or a contractor) if a severe collision occurs Automatic Emergency Call (eCall) is a system giving an automatic message to an emergency call centre in case of a crash of the vehicle. The Public Safety Answering Points are not yet set and equipped to receive the message in the European standardized format in all European Countries.	Euro NCAP Advanced
AUTOMATIC HIGH BEAM	Maximises use of the headlamp high beam facility to improve driver vision significantly during night conditions. It also makes use of the forward-looking camera to detect light sources ahead and, in the case of oncoming vehicles, automatically switches the	TBA

	lights to low beam to avoid glare. Additionally, the system will detect red tail lights ahead, even those with lower luminance, to make sure motorists in front are not distracted by high beam lights shining in their rear view mirrors. The high beam is also automatically deactivated in urban areas.	
AUTONOMOUS EMERGENCY BRAKING	Detects distance and closing speed of objects in path of vehicle and automatically decelerates if driver does not heed warning Many accidents are caused by late braking and/or braking with insufficient force. A driver may brake too late for several reasons: he is distracted or inattentive; visibility is poor, for instance when driving towards a low sun; or a situation may be very difficult to predict because the driver ahead is braking unexpectedly. Most people are not used to dealing with such critical situations and do not apply enough braking force to avoid a crash. Several manufacturers have developed technologies which can help the driver to avoid these kinds of accidents or, at least, to reduce their severity. The systems they have developed can be grouped under the title: Autonomous: the system acts independently of the driver to avoid or mitigate the accident. Emergency: the system will intervene only in a critical situation. Braking: the system tries to avoid the accident by applying the brakes.	Euro NCAP Advanced
BLIND SPOT MONITORING	Detects distance and closing speed of objects in adjacent lanes and alerts driver if a collision is imminent On a motorway, a car which is far behind can be clearly seen in the rear view mirrors. However, as the car approaches, a point is reached where the car cannot be seen in either the interior or exterior mirrors. Typically this occurs when the car is just behind and to one side of the vehicle it is overtaking. It is a common mistake for drivers to change lanes when there is a vehicle in this so-called “blind spot”, a manoeuvre which causes many accidents on European motorways. Several manufacturers have developed systems which monitor the blind-spot and help a driver change lanes safely. Some systems are camera-based, others rely on radar. Either way, the area to one side and rearward to the vehicle is monitored and the driver is warned when there is a vehicle in a position where it	Euro NCAP Advanced

	may not be seen in the rear view mirrors.	
ELECTRONIC DATA RECORDER (EDR)	Continuously records vehicle speed and other parameters and stores this in the event of a collision or for other analysis ("Black box" recorder)	TBA - standards available in USA
HILL LAUNCH ASSIST	Using the braking system, HLA is engaged when the car is stationary to prevent it from rolling. Effective on both uphill and downhill gradients, HLA provides a delay when the driver moves their foot from the brake pedal to the accelerator pedal, as the system maintains pressure to the braking system. The HLA feature avoids the need for the driver to go through an awkward sequence of events involving the handbrake to hold the car momentarily whilst on a hill. Once sufficient engine torque is reached the HLA feature automatically releases the brake system in a controlled manner.	TBA
INFLATABLE REAR SEAT BELTS	Inflatable seatbelts have tubular inflatable bladders contained within an outer cover. When a crash occurs the bladder inflates with a gas to increase the area of the restraint contacting the occupant and also shortening the length of the restraint to tighten the belt around the occupant, improving the protection. The inflatable sections may be shoulder-only or lap and shoulder. The system supports the head during the crash better than a web only belt. It also provides side impact protection. Only rear -seat nflatable seat belts are counted as a SAT. Front-seat inflatable seat belts are not considered as these would be assessed through the performance requirements of the frontal offset crash test.	TBA. Could be superseded by crash tests with adult dummy in rear seat (e.g. Japan NCAP). Inflatable front seat belts are not counted and they contribute to performance in the offset crash test.
INTERSECTION COLLISION WARNING	Detects vehicles approaching from the side at intersections. Alerts driver if a collision is possible	Under development?
LANE SUPPORT SYSTEMS	Recognises lane markings and alerts driver if the lane boundary is crossed Lane Support Systems can assist and warn you when you unintentionally leave the road lane or when you change lane without indication. **Lane Departure Warning** Several manufacturers have developed technologies which warn the driver when the car is getting close to a lane marking. Different systems use different warnings: some give an audible signal while others use a vibrating steering wheel to simulate the feeling of the car running over a 'rumble strip'. The intention is simply to make the driver aware that the car is in danger of crossing the line. Some systems need a line only on one side of the vehicle while other systems rely on having a distinct marking on either side. Lane departure warning systems rely on distinct lane	Euro NCAP Advanced

	markings: their effectiveness if reduced if lines cannot be clearly distinguished such as in heavy rain or fog, or if the road markings are obscured by mud or snow. In such cases, an indication is given to the driver that the system is unable to assist´. **Lane Keep Assist** Lane-Keep Assist systems address similar accident situations to lane departure warning. However, whereas warning systems rely on the driver to take corrective action, Lane Keep Assist also proactively steers the car back into the lane. When the car is close to a marking, the system gently steers the car away from the line until it is safely within the lane. The system can steer the car either by applying gentle braking to one wheel or, in the case of electric steering systems, by applying a direct steering input.	
NIGHT VISION ENHANCEMENT	Generally uses technology (e.g. infra-red lights) to enhance driver vision	TBA
PRE-CRASH SYSTEMS	Detects imminent collision. Deploys safety devices such as seat belt pretensioners Manufacturers take care to ensure that their safety systems are effective for occupants of different sizes and for those sitting in different positions. However, the very best levels of protection can be achieved when the interaction between occupant and restraint systems is optimised. Several manufacturers have developed systems designed to allow a vehicle's protection systems to operate most effectively during an impact. Some of these systems react immediately following or during the impact to optimise occupant safety. For example, they may not directly restrain the occupant but may control the occupant's movement so that the restraint systems work most effectively. Other systems may predict when an accident is about to happen and in a split second prepare the vehicle and its occupants for the collision. Predicting the accident can be done in a number of ways: vehicle dynamics and driver actions can be monitored for panic reactions, or radar sensors can detect obstacles in front of the car. The actions which the systems take can also vary but, typically, slack will be removed from seatbelts, seating positions may be quickly adjusted to optimise airbag performance and windows shut to prevent ejection. In such cases, the actions taken are reversible in the event that the accident is avoided.	Euro NCAP Advanced
ROLL STABILITY SYSTEM	Detects imminent rollover and initiates corrective (avoidance) action	Functional definition based on ESC GTR?
ROLLOVER OCCUPANT	Detects a rollover situation and deploys occupant protection systems such as inflatable curtains	TBA

PROTECTION SYSTEMS		
ROLLOVER WARNING	Alert drivers when the lateral forces or vehicle dynamics indicate a risk of rollover (this is mainly a heavy truck application).	TBA
SMART LICENCE	Vehicle will not operate without an appropriate electronic licence. This might have speed or time-of-day restrictions.	TBA
SPEED ALERT SYSTEMS (ISA)	Determines current speed limit (mainly from digital map) and alerts driver if the limit is being exceeded (passive ISA) or limits the speed of the vehicle (active ISA). Excessive speed is a factor in the causation and severity of many road accidents. Speed restrictions are intended to promote safe use 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. Greater adherence to speed limits would avert many accidents and reduce the severity of those that occur. Excessive speeding is sometimes unintentional. Drivers who are tired or otherwise distracted may allow their speeds to drift above the maximum allowed for that road. Others may inadvertently miss a traffic sign alerting them to a change in the speed limit, such as when entering a built-up area. Speed alert or Intelligent Speed Assistance (ISA) systems help drivers to keep their speeds within the recommended limits. Some systems display the current limit so that the driver is always aware of the maximum speed allowed on that road. The speed limit may, for example, be determined by software which analyses images from a camera and recognises traffic signs. Alternatively, satellite navigation is becoming increasingly accurate and could be used to provide information to the driver. However, this relies on the most up to date digital maps being available at all times. Systems may or may not issue a warning to the driver when the speed limit is being exceeded and current systems are voluntary: they can be switched off and they rely on the driver responding appropriately to the warning.	Euro NCAP pending or ANCAP's proposed amendment to ECE Regulation 89 (http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0378.pdf)
SPEEDOMETER SCALE AND DISPLAY	Speedometer maximum speed and scale match Australian maximum speed limits (e.g. 130km/h maximum)	Functional definition - see Top Speed Limiter
SPEED ALARM (MANUAL)	Alert drivers when the vehicle speed exceeds a pre-set limit (driver selects a speed for an audible alert)	Very limited proper use, compared with ISA.
TOP SPEED LIMITER	Vehicle is incapable of traveling above a set speed for prolonged periods. Recommended setting is 120km/h. PIN override could be allowed for each	Functional requirement TBA.

	trip, to cater for Northern Territory. It is preferred that the system also limits the top speed in reverse to 10km/h A top speed limiter would discourage theft and car-jacking	Nearly all vehicles already have a top speed limiter but it is set unrealistically high.
TRAFFIC SIGN RECOGNITION	Optical recognition of traffic signs for assisting driver	TBA
TRAILER STABILITY CONTROL	The trailer stability control system ensures superior stability and safety when towing. With increasing speed, trailers tend to swing from side to side, and may even swing out of control. This is especially the case for heavier trailer loads or if the weight of the trailer load is not distributed evenly: even at relatively low speeds, a swaying motion can arise. This can destabilise both the trailer and the towing vehicle unless a stabilising measure quickly intervenes. The trailer stability control system recognizes the early signs of this dangerous swinging motion. It activates the brakes immediately to slow the trailer down and return stability. It discerns this danger by constantly monitoring the rotation movement of the vehicle using special sensors. If these values exceed the safe limit, trailer stability control activates the brakes and simultaneously, the engine output is reduced. The resulting drop in speed brings the trailer back to stability. As soon as stability is restored, the driver is again in full control of the vehicle's speed.	TBA
VEHICLE2 VEHICLE COMMS	Standards for exchange of information between vehicles and roadways.	TBA
WORKLOAD MANAGER	Filters and prioritises the information made available to the driver. Postpones or cancels certain distractions, such as non-urgent vehicle warnings or integrated mobile telephone calls.	TBA

TABLE B3.

Technologies that are not counted as SAT

NAME	DESCRIPTION	COMMENT
ABS BRAKES	Prevents individual wheels from lock up during heavy braking (or on slippery surfaces) and subsequently assists driver to maintain control	Already part of ESC
ADAPTIVE CRUISE CONTROL (ACC)	Detects distance and speed of preceding vehicle and maintains appropriate headway	See Autonomous Emergency Braking (Not a separate SAT)
ACTIVE HEAD RESTRAINTS	Seat design responds to rearward collision by moving head restraint forward and other actions that reduce the risk of whiplash type injuries. Electronic detection of collision may offer better protection, compared with mechanical systems.	Superseded by dynamic whiplash tests. Do not include
BONNET FOR PEDESTRIAN PROTECTION	Detects collision with pedestrian and either deploys external airbag or raises bonnet to lessen impact	Now part of Euro NCAP pedestrian protection assessment. Do not include
FOLLOWING DISTANCE WARNING	Detects distance to preceding vehicle and alerts driver if the gap is less than recommended headway for the current speed	See Autonomous Emergency Braking (Not a separate SAT)
NAVIGATION SYSTEM (GPS)	Displays dynamic map of roads. Some give voice instructions for route following. Some give known hazard warnings such as blackspots.	Speed limit alerts already covered by ISA. No other major safety benefits.
PARKING ASSIST SYSTEMS	Automated reverse park system	Primarily to reduce risk of property damage.
OFF-ROAD ASSIST SYSTEMS	Features designed to assist off-road driving such as hill-descent control	Primarily for off-road use
TRACTION CONTROL	System detects potential wheel spin due to excessive driving torque and limits this torque.	Already part of ESC

INCREASING THE UPTAKE OF KEY VEHICLE SAFETY FEATURES – A CONSUMER FOCUSED APPROACH.

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ABSTRACT

In 2006, having developed successful brand and on-going campaign on which to create demand for more crashworthy cars, (www.howsafeisyourcar.com.au), the Transport Accident Commission (TAC) in Victoria, Australia looked at what opportunities were available to it, to further increase the safety of the Victorian vehicle fleet. The TAC is a government owned and operated, third party injury insurer that invests heavily in road safety initiatives to help meet its legislative responsibility to reduce the incidence and severity of transport injury on Victorian roads. In 2006, evidence around the effectiveness of, Electronic Stability Control (ESC) and Curtain Airbags (CA) in reducing crashes and injuries respectively, had firmed, yet compared with European and US vehicles the uptake of these lifesaving features in Australia was very poor.

Method: The TAC built a business case to extend its howsafeisyourcar.com.au campaign, to specifically create awareness of and develop demand for ESC and CA. A mass media campaign was developed that included TV, radio and on-line advertising, outdoor billboards and point of sale promotions at events such as the Melbourne Formula 1 Grand Prix and the Melbourne Motorshow. Demonstrating how these usually invisible technologies worked to reduce crashes (ESC) and prevent serious injury (CA). The campaign was launched early in 2007 and continues to be used to this day.

Results: Since the development of the campaign, fitment rate of ESC and CA has increased dramatically, with Victoria outstripping the rest of Australia and is comparable to Europe in relation to standard fitment of the technologies. In addition, many vehicle manufacturers have made ESC standard in popular models and most importantly, the Victorian Government announced ahead of all other Australasian jurisdictions, the mandatory fitment of ESC on new cars registered after 31December 2010.

Discussion: This paper will outline the development of the ESC and CA campaign. The barriers faced along the way and the outcomes.

INTRODUCTION

The Transport Accident Commission (TAC) in Victoria, Australia is a government owned and operated third party injury insurer. In order to meet its legislative responsibility to reduce the incidence and severity of transport injury on Victorian roads, the TAC invests heavily in road safety initiatives. In 2006, the TAC having developed a successful on-going campaign and brand in www.howsafeisyourcar.com.au on which to create demand for safer cars, looked at what opportunities were available to further increase the safety of the Victorian fleet.

At this time, the evidence around the effectiveness of Electronic Stability Control (ESC) and Curtain Airbags (CA) in reducing crashes and deaths/injuries, respectively had firmed. ESC, an active vehicle safety technology which can assist drivers to avoid crashes by reducing the risk of skidding and losing control through selectively braking individual wheels to bring the vehicle back on track [1], has the potential to reduce single vehicle injury crashes by up to 30%. [2] No other active safety feature has the potential to reduce single vehicle crashes like ESC.

CA a passive safety feature, is designed to protect a vehicle occupant's head in the event of a side impact crash by forming a cushion between the occupant's head and the window and/or other objects such as trees and poles[3]. Research by the Insurance Institute for Highway Safety [4] estimated that head protecting airbags can reduce driver deaths in the event of a side impact crash by up to 40%, CA can make the difference between life or death.

Despite the lifesaving potential of these two technologies, the uptake rate of both were very poor, with only approximately 22% and 24% of new cars sold in Victoria with ESC and front CA fitted, respectively in 2006 (refer to Fig. 1). According to TAC market research, only 1% and 5% of participants sought out ESC and CA respectively in their past vehicle purchase in 2006 [5]. These results indicated a potential lack of awareness of the existence and safety benefits of ESC and CA on the part of the consumers. The TAC has since built a business case to extend its www.howsafeisyourcar.com.au campaign to specifically create awareness of and stimulate consumer demand for these critical safety features.

METHOD

Between 2007 and 2009, the TAC developed and launched three public education campaigns in relation to ESC and CA to educate consumers about the lifesaving potential of these two technologies. The campaigns included:

Four Little Words

With the assistance of Holden (GM Australia) and Bosch Australia, an advertisement was developed to highlight the difference between a vehicle with and without ESC in an emergency situation. The aim of this campaign was to firstly educate consumers about what ESC is and its safety benefits and secondly, to encourage consumers to ask for this technology on their next vehicle purchase. The recall rates of the campaign were between 19%-25%.

Everyday Expert

This was an emotive and instructional advertisement in which the benefits of CA were discussed by an actress posing as a brain injured victim. The aim of this campaign was to educate consumers on the lifesaving potential of CA and to encourage consumers to demand CA in their next purchase. This campaign achieved good consistent recall, with recall rates between 63%-71%.

James

This instructional advertisement urged buyers to cross off on their list any cars that did not have both ESC and CA. This campaign aimed to encourage consumers to put their safety first and to purchase a car only if it had both ESC and CA. The recall rates of the two tracked waves of the campaign were 19% and 24%.

Besides the TV advertisements, the public education campaigns included radio and on-line advertising, outdoor billboards and point of sale promotions at events such as the Melbourne Formula 1 Grand Prix and the Melbourne Motorshow. All TV advertisements and supporting activity directed consumers to www.howsafeisyourcar.com.au for more information. The first of the ESC and CA campaigns was launched early in 2007 and continues to be used to this day. The TAC was also involved in a number of partnerships that assisted in increasing awareness of ESC and CA among the general public and also acted as a support for the TAC's public education campaign. These included:

- working with road safety partners to raise awareness of the safety benefits and availability of ESC through the use of an ESC simulator
- continued support for the Australasian New Car Assessment Program
- funding and support for the development of ESC testing facilities.

More details on these partnership activities can be found in another paper by Truong and colleagues. [6]

RESULTS

The public education campaigns in relation to ESC and CA created greater awareness of and stimulated consumer demand for the technologies and contributed to two significant results. The first was the increased fitment of the two technologies as standard features in new vehicles sold and the second was the Victorian mandate of ESC.

Fitment of ESC and CA in new vehicles sold

Since the development of the ESC and CA campaigns, the standard fitment rate of the two technologies has increased dramatically with Victoria outstripping the rest of Australia. The fitment of ESC and front CA in new vehicles was 22.2% and 24.2% respectively in 2006 and has risen to 71.3% and 59.5% respectively in 2010 (refer to Fig. 1). These results are comparable to Europe in relation to standard fitment of the technologies. In addition, many vehicle manufacturers such as Ford and Holden (GM Australia) have made ESC standard in popular models, boosting fitment rates considerably

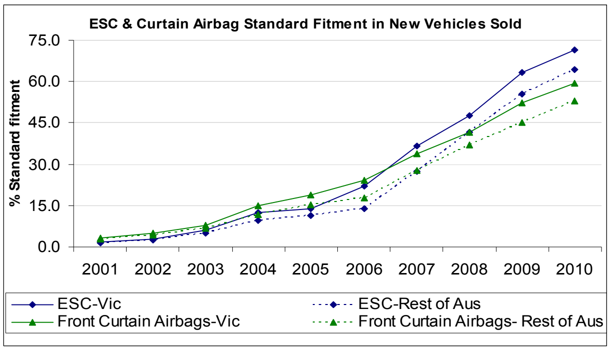

Figure 1 – ESC and Curtain Airbag Standard Fitment Rate in New Vehicles Sold

[Source: R.L. Polk Australia]

Victorian Government ESC Mandate

One of the most important developments since the launch of the ESC campaigns was the Victorian Government announcement of the mandatory fitment of ESC on new cars registered (with the exception of light commercial vehicles) after 31December 2010.

Although fitment rates for ESC had been steadily rising, the TAC welcomed the mandate, as it knew it would accelerate availability and uptake, and ensure that consumers purchasing new vehicles from 2011 would have the extra safety protection offered by ESC. The overall Victorian fleet will also benefit from the mandate once these new vehicles enter the second hand market.

The Victorian Government recognized the life saving benefits of ESC and introduced the mandate ahead of all other jurisdictions in Australia. However, the Federal Government soon followed Victoria's lead and announced that all new models of passenger vehicles must be fitted with ESC from November 2011, with all models to have the technology from November 2013, bringing the rest of Australia in line with Victoria. ESC mandation is an important development that will greatly increase the safety of the Australian fleet.

DISCUSSION

Since the commencement of the TAC's public education campaigns specifically promoting ESC and CA, uptake of the two technologies has increased dramatically. Importantly, the increased awareness of the safety features and their benefits made it easier for the Victorian Government to announce, ahead of all other Australasian jurisdictions, the mandatory fitment of ESC on new cars registered after December 31 2010.

There were however, a number of issues faced along the way. These included:

Bundling of safety features

Often safety features such as ESC and CA were offered as a package, usually in conjunction with other non-safety related items such as leather seats or 6 stacker CD players. The cost of these packages was not insignificant and formed a barrier to the easy uptake of key safety features the TAC was promoting.

Safety features offered as optional extras

ESC was often not a standard feature on new cars, but available as optional extras. Depending on the make and model of the car, this could add $800-$1200 to the purchase price. Besides the additional cost being a disincentive, the immediate availability of cars with ESC was also a barrier to consumers. Imported cars ordered with ESC as an optional extra, would sometimes take up to 3 months to be delivered. A long time to wait when non-ESC equipped were available on the car lot to driver away immediately!.

Safety features not offered in Australia

When promotional activities commenced in 2006, the fitment rate of ESC and CA were only 22.2% and 24.2% respectively in 2006 and were seriously lagging behind Europe. Some safety features available on cars in Europe were not offered to consumers when the same cars were imported to Australia. For example, the Toyota Corolla was available in the Northern European market with ESC but the car imported into the Australian market did not have ESC available.

Australian Standards and consumers

It was important to educate consumers that not all cars were 'created equal' and that 'some cars were safer than others'. In some consumers' minds, all new cars were considered safe as they have met the Australian Design Rules (ADRs) applicable to safety. However, as demonstrated by the Australasian New Car Assessment Program (ANCAP), the safety performance of new cars available on the market, all of which passed the ADRs, can still vary greatly. Consumers needed to be educated about the importance of purchasing a car with a good safety rating and technologies such as ESC and CA can further enhance the safety of a car.

Since promotional activities to increase consumer awareness and demand of ESC and CA and the subsequent ESC mandate, many of the barriers mentioned are no longer an issue for new passengers vehicles. However, light commercial vehicles have been exempt from the ESC mandate and fitment of ESC and CA in this sector remain poor. More work remains to be done in increasing the fitment of ESC and CA in light commercial vehicles.

To date, promotional activities have focused more heavily on ESC, however, with the ESC mandate now in place, more effort will be dedicated to CA. The TAC will continue to promote and educate consumers about the availability and safety benefits of CA to further accelerate the uptake of the technology. Promotion of ESC will also continue, but will now be directed at the used car market.

CONCLUSION

ESC and CA are two life saving technologies that were not widely available in Victoria. Through public education campaigns and supporting promotional activities, consumer demand for these technologies was stimulated and a steady increase in the availability of ESC and CA resulted. The demand for these critical safety features and the increased availability paved the way for the Victorian Government to announce the mandate of ESC in new vehicles in 2011 ahead of all other Australian jurisdictions. Many barriers faced when the TAC first started promoting vehicle safety have been overcome and the TAC, seeing the success to date, will continue its efforts in encouraging the uptake of CA, as well as directing promotions at the light commercial and used car markets.

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TECHNICAL PAPER

RELATIONSHIP BETWEEN PEDESTRIAN PROTECTION TEST PROTOCOLS AND A REAL SCENARIO

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ABSTRACT

Of the one and a half million accidents which occur in the Euro-15 area every year, and which cause nearly 40,000 deaths, pedestrians account for 15% of these, i.e. about 6,000 per year. The percentage of pedestrians killed in road accidents is about 12% for Canada, USA and Australia, while in Korea and Japan pedestrian fatalities account for as much as 30% and 40% of road deaths.
Organizations like Euro NCAP, EEVC and the new Regulation, together with vehicle manufacturers are seeking solutions through the development of advanced safety systems and accurate methods for testing these systems.
IDIADA carried out two studies related to pedestrian protection and the relation of protocol to real world accidents. The first study was focused on real world accidents involving pedestrians, and was divided into two parts:

- Assessment of vehicle speed influence. Sixty-two cases, collected by the Municipal Police and the Public Health Service Agency in which pedestrians were involved in accidents were studied in Barcelona city. 75.1% of accidents occurred during the day, with an ISS 4-5 level of injury, and an ISS 3-4 at night.
- Study about speed as a cause of accidents. 75.3% of drivers made a braking avoidance maneuver. The average speed before the accident was 50.8 km/h and the impact average velocity was 24.78 km/h.

As a result, injury level related to vehicle speed was evaluated. The speed threshold between slight and severe injuries is at about 40 km/h. This value is very similar to the impact velocity used in the current tests to evaluate pedestrian protection in passive safety testing, as for example in Euro NCAP.

The objective of the second study was to test the influence of the vehicle design, mainly the front-end, on pedestrian head injuries in the case of run-over. Several accident simulations were performed using the program MADYMO® in which a pedestrian's head was impacted into a different point of the hood depending on the situation.
The head impact position changes according to vehicle category: collisions in compact and roadster sports cars take place within the limits set by Euro NCAP for adult head impactor while, in the off-road 4x4 class, some points are located below the lower limit for the adult head.

If the analysis focuses on the pedestrian's head impact angle and speed against the hood of the car, the following conclusions can be expounded:

- For the same vehicle, impact speed and angle of the adult head against the hood are virtually unchanged although the pedestrian's speed is different.
- If impact speed is higher, the collision involves worse consequences.
- The shape of the front part of the vehicle is not decisive in the severity of pedestrian injuries.
- Further testing is needed to verify that parameters defined by the EEVC, Euro NCAP or pedestrian Regulation are entirely valid according to real world scenarios.

Main conclusion of the study and the analysis of actual accident data was that current pedestrian testing protocols are reliable enough to be taken into account when a vehicle pedestrian protection level is assessed.

INTRODUCTION

In order to reduce the number of deaths due to road accidents, the European Commission introduced the 'White Paper' called 'European Transport Policy

for 2010: Time to Decide'. The main aim was to propose to European Community level the halving of the number of road accidents (reducing the number at 20.000 deaths) for the year 2010 (based on statistics from 2000).
To achieve a reduction in the number of deaths, vehicle manufacturers have been 'forced' to meet certain requirements in order to validate their vehicles with respect to the protection of pedestrians.
Also, at the consumer level, the safety program initiated by the independent organization Euro NCAP, which includes the safety of the occupants, the children and the pedestrians, has become very important in terms of the credibility of information provided and consumer awareness of the importance of acquiring a vehicle that meets minimum standards of safety. Consumers have been found in Euro NCAP a very useful tool to get clear and comparative information on behaviour of vehicles available in Europe under different types of test.
Currently European testing procedures, European Directive testing and Euro NCAP tests, are based on procedures developed by the European Community and the working groups EEVC. In the last decade, vehicle manufacturers have incorporated the protection of pedestrians, by improving external and internal design of the vehicle, into their strategy. Because there are areas of the vehicle which have proven very difficult to obtain a minimum level of protection, vehicle manufacturers have developed other types of assistance to improve the protection offered. New developments in active and passive safety have proven their impact on the reduction of victims, around 15.000 between 1992 and 2002.
Although Euro NCAP has encouraged manufacturers to improve the protection of vehicle occupants in a road accident (currently, most vehicles receive 5 out of 5 stars), incentives to improve pedestrian protection have not had the same consequences (few vehicles received 3 stars from a maximum of 4). With the introduction of European Directives at European level, manufacturers have made more additional efforts to improve pedestrian safety.
The current pedestrian test protocols are representative of situations that can occur in real life, but they do not give an accurate picture. For example, the kinematics of the head in a real test is difficult to reproduce using the head impactor.
For that reason, Applus+ IDIADA has made several investigations and studies to assess both the trial protocols and reproducibility of real accidents in the laboratory of pedestrians, the suitability of the use of new impactors and influence of different parameters on the results of pedestrian tests.
The updating of test methodologies will help manufacturers in the field of pedestrian protection, from passive and active safety point of view. In fact changes in protocols can be made to include the influence of different types of vehicles such as the Off-Road or MPV (Multi Purpose Vehicles) and recommendations for new structural designs of vehicles such as the increased use of plastics and energy absorption in frontal areas, as in lights and bumpers.
The proposed in-depth analysis was divided into two sections and was carried out in Barcelona during 2009.

STUDY OF ACCIDENTS IN ORDER TO PROVIDE A MEANS TO ANALYZE THE ACCURACY OF SPEED IMPLEMENTED IN REGULATION AND EURO NCAP TESTS

The first part of the study shows how the vehicle speed affects the safety of pedestrians in urban accidents. The main aim of this part was to determine what reductions would prevent accidents with pedestrians and, therefore, victims and injuries. This was achieved through the study of vehicle speed as the cause of the accident and the effect of speed on the severity of pedestrian injury.

Influence of Vehicle Speed

The first step of the study was the statistical analysis of accidents in Barcelona. This was made through a selection process of possible cases based on a strict method of filter:

- Initial selection criteria: a vehicle accident which involves at least one injured person who needed medical attention; the collision point is known. 823 cases were selected for this initial evaluation.
- The Municipal Police and the Public Health Service Agency had access to 484 medical files of these cases, from the following hospitals: Hospital Clínic, Hospital del Mar, Hospital Sant Joan de Déu, Hospital de Sant Pau, Residencia de la Vall d'Hebron and the Hospital de la Creu Roja.
- Details of braking distances before and after the impact point and projection distance of the pedestrian after the impact were provided for a total of 93 cases.
- The total number of relevant cases was further reduced as the ISS (Injury Severity Score = Injury Severity Score) could only be provided by the health administration for a total of 62 initial cases.

Speed as Cause of the Accident

The speed of the vehicle, namely excessive speed, is a crucial factor in all accident scenarios. The level of injury in impacts against pedestrians can be scaled as a result of a lack of safety measures. It was observed that 75,3% of drivers of vehicles anticipated the accident and made an evasive maneuver, usually braking sharply trying to avoid collision with the pedestrian. The Figure 1 presents statistically the necessary reduction in speed to achieve a reduction in the percentage of accidents.

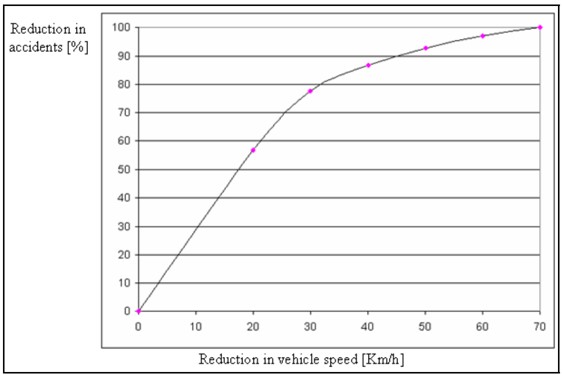


Figure 1. Necessary reduction in speed to achieve a reduction in the percentage of accidents.

It was observed that the average vehicle speed before braking was 50,8 km/h and the average impact speed after the braking manoeuvre was 24,78 km/h. As result from this graph, it was suggested that a 20% reduction in the speed limit in urban surrounding areas would lead to a 60% reduction in accidents involving pedestrians. It is even more significant the fact that a 40% reduction in vehicle speed would lead to 85% reduction of accidents. Accordingly, it is clear that a small reduction in vehicle speeds implies direct consequences on the number of accidents where pedestrians are involved. If this trend was applied, a great rate reduction of the speed could achieve a decrease of the number of accidents almost to zero.
Currently, in the main testing protocols, impactors, which represent different human limbs are thrown at a speed of 40 km/h. These tests are very limited in this regard, as actual impacts may occur at any speed.
In order to assess the impactors velocity at testing (40 km/h), the calculation of impact velocity for all cases studied after the application of filters was carried out. To establish this speed value in a reliable way, other variables such as pedestrian projection distance, braking distance before the collision and braking distance after the collision were determined. The level of severity of the injuries was also included according to data from Public Health Administration database, the information was classified using the parameter AIS (Abbreviated Injury Scale), where injuries are encoded using the ISS method.

Abbreviated Injury Scale (AIS) is an anatomical based scoring system to determine the severity of single injuries based on the survivability of the injury. AIS-Code is a scale of one to six, one being a minor injury and six being life-threatening. An AIS-Code of 6 is not the code for a deceased patient, but the code for an injury with a very high lethality. An AIS-Code of 9 is used to describe injuries for which not enough information is available for more detailed coding, e.g. crush injury to the head.
The AIS scale is a measurement tool for single injuries. A universally accepted injury aggregation function has not yet been proposed, though the Injury Severity Score and its derivatives are better aggregators than a mere look at the maximum AIS-Code (MAIS) as used by most biomechanic researchers.

Table 1.
Abbreviated Injury Scale.

AIS-Code	Injury
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum

Injury Severity Score (ISS) is an established medical score to assess trauma severity. It correlates with mortality, morbidity and hospitalization time after trauma. It is used to define the term major trauma, i.e. a major trauma (or polytrauma) is defined as ISS>15.
The ISS is based upon the AIS. To calculate an ISS for an injured person, the body is divided into six ISS body regions. These body regions are:

- Head or neck - including cervical spine.
- Face - including the facial skeleton, nose, mouth, eyes and ears.
- Chest - thoracic spine and diaphragm.
- Abdomen or pelvic contents - abdominal organs and lumbar spine.
- Extremities or pelvic girdle - pelvic skeleton.
- External.

To calculate an ISS, take the highest AIS severity code in each of the three most severely injured ISS body regions (A, B, C in Equation 1), square each AIS code and add the three squared numbers for an ISS.

$$ISS = A^2 + B^2 + C^2 \quad (1).$$

The ISS scores range from 1 to 75 (i.e. AIS scores of 5 for each category). If any of the three scores is a 6, the score is automatically set at 75. Since a score of 6 ("unsurvivable") indicates the futility of further medical care in preserving life, this may mean a cessation of further care in triage for a patient with a score of 6 in any category. A score between 1-8 is considered mild and between 9-75 is considered severe).

Results

The distribution of impact velocity for ISS parameter can be seen in Figure 2.

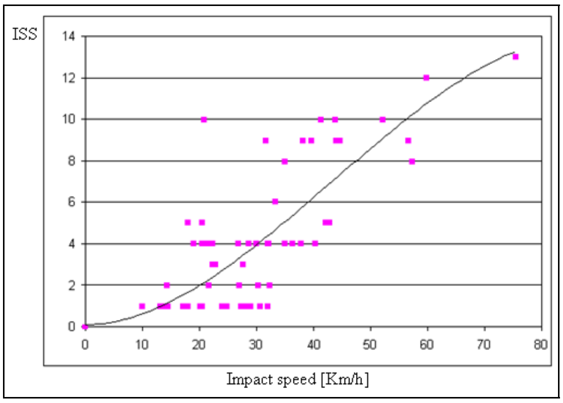


Figure 2. Distribution of impact velocity for ISS parameter.

There is a wide distribution of results. However, it can also be represented as a dual algorithm, as shown. As a result, it was possible to represent the risk probability of injury through a Weibull distribution. Figure 3 shows this distribution, accounting for minor injuries, ISS from 1 to 8, and severe injuries ISS of 9 or greater.

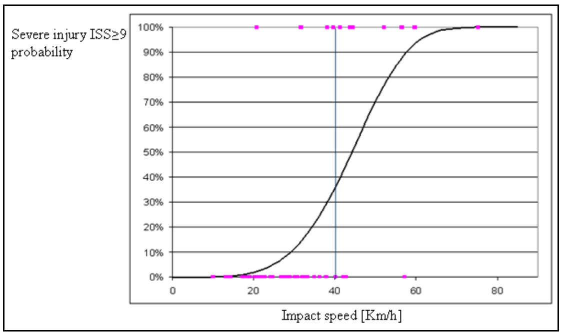


Figure 3. Weibull distribution.

The figure above shows how the distribution is fairly uniform including slight and severe injuries. Slight injuries are the result of low speed impacts while serious injuries are related to impacts at higher speeds. Another important issue shown in this chart is that the boundary between slight and severe injury is at 40 km/h. The fact that the limit matches up with this value, proves that impact speed protocol based on a study of real accidents used in the Euro NCAP test is appropriate.

STUDY OF ACCIDENTS TO DETERMINE THE CORRELATION WITH THE EXISTING IMPACT AREAS IN THE PROTOCOLS AND THE RELATIONSHIP BETWEEN ACTUAL PEDESTRIAN ACCIDENTS AND RESULTS OF THE SAME VEHICLES IN EURO NCAP TESTS

The in-depth study of accidents done to provide data to analyze the accuracy of the speeds currently used in Euro NCAP and European Regulation tests was carried out in Barcelona during 2009 and is divided into 2 sections.
This second part of the study was focused on an in-depth analysis of the influence of the frontal part of the vehicle in the kinematics of the pedestrian's head during an impact. To validate these results, several virtual configurations with different impact positions for head impactor, impact velocity and impact angle were carried out.

Significance of the Shape of the Vehicle's Front

In the previous section of the study it was proved that impact speed of the vehicle has a direct influence on the severity of pedestrian injuries. To understand the importance of the shape of the vehicle's front, the kinematics of pedestrian's head must be considered. This includes the impact position of the head, impact speed and the impact angle of the head against the vehicle. Applus+ IDIADA carried out a study and several virtual reconstructions taking these parameters as variables in order to assess the influence of the vehicle's front in pedestrian injuries.
Aided by the simulation program MADYMO®, pedestrian models to perform the calculations were created. The dummy used for the simulation was a model of the stood up Hybrid III 50%, which is based on the Hybrid III dummy 50% standard but modified to define the lumbar spine, abdomen, pelvis, legs, ankles and feet. Four categories of variables were chosen to evaluate this study (Table 2).

Table 2.
Simulation variables.

Pedestrian speed	0 km/h 5 km/h 10 km/h
Vehicle speed	30 km/h 40 km/h 50 km/h
Vehicle class	Family Car Off-Road 4x4 Roadster sport
Pedestrian position against the vehicle	10% 25% 50%

A schematic illustration of these configurations is shown in Figures 4 and 5. EASI CRASH® and Animador® were the programs used to plot the results.

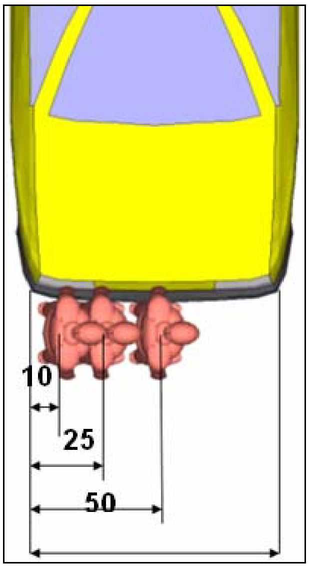


Figure 4. Place of the vehicle's front when the run over occurs.

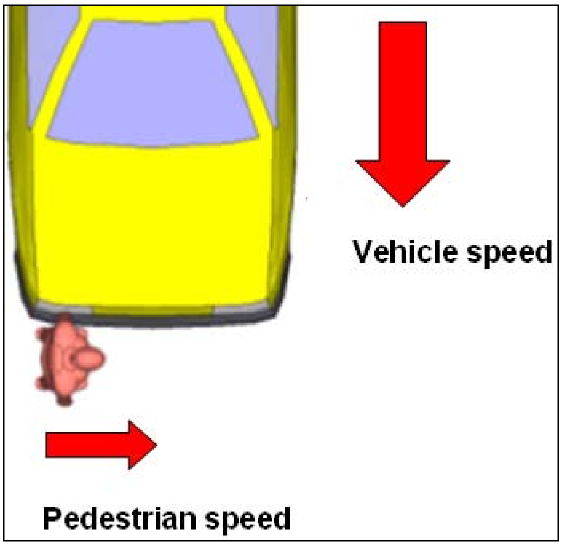


Figure 5. Direction of the pedestrian and the vehicle.

Simulations of the impactor head. The simulation was carried out according to the requirements specified in the Euro NCAP protocol. Standard models for child and adult heads were used. The impact zone for adult head was located between WAL2100 and WAL1500 while boundaries for child head were WAL1500 and WAL1000, as established by this protocol.

Table 3, Table 4 and Table 5 show simulation results depending on the position of impact, vehicle speed and speed of pedestrian.

Table 3.
Simulation results depending on impact position.

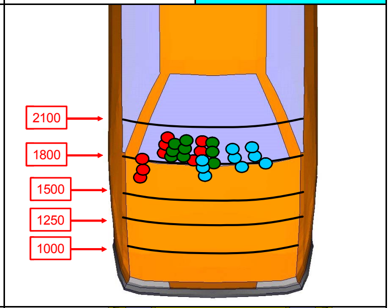
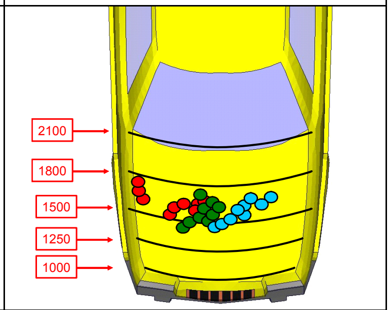
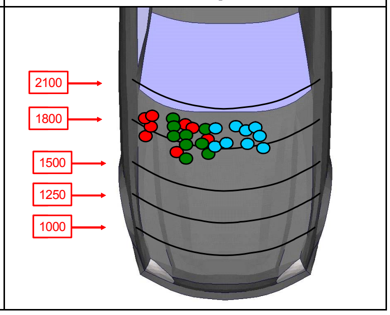
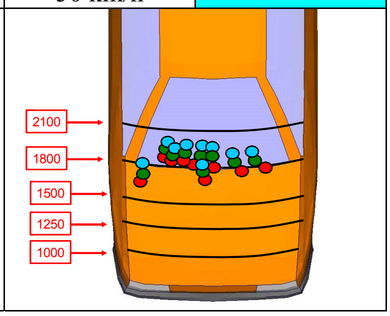
Impact position	10%	(red)
	25%	(green)
	50%	(cyan)
Family Car		
Off-Road 4x4		
Roadster sport		

Table 4.
Simulation results depending on vehicle speed.

Vehicle speed	30 km/h	(red)
	40 km/h	(green)
	50 km/h	(cyan)
Family Car		

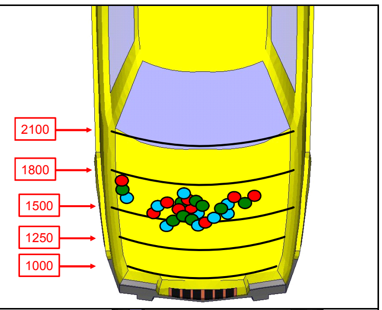
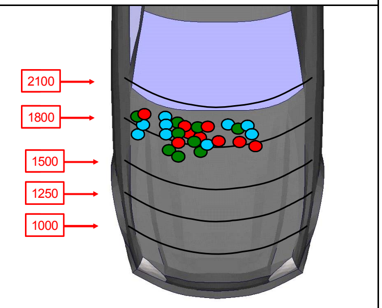
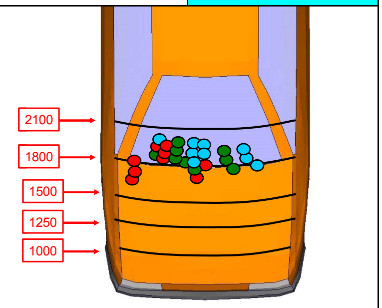
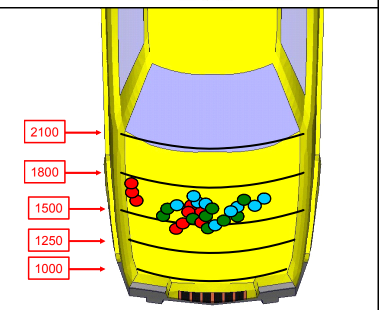
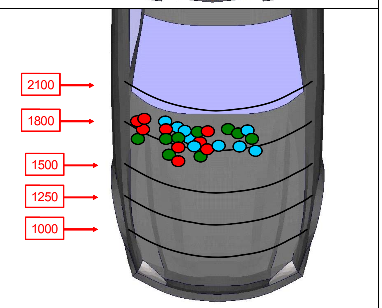
Off-Road 4x4	
Roadster sport	

Table 5.
Simulation results depending on pedestrian speed.

Pedestrian speed	0 km/h	
	5 km/h	
	10 km/h	
Family Car		
Off-Road 4x4		
Roadster sport		

Simulation results show the differences in the impact area between the three classes of vehicles.

All impacts for Family Car and Roadster Sport models are located between the boundaries defined by Euro NCAP for adult head impactor (WAL1500 - WAL2100). In contrast, Off-Road 4x4 vehicles show different results, most impacts are located between WAL1500 and WAL1800. However, some points were located below the lower limit for adult head WAL1500.

Simulation of impact angle and head speed.

The impact angle and velocity of the head were also important parameters for this study. A simulation was carried out altering these parameters and the vehicle speed (30 km/h, 40 km/h, 50 km/h), pedestrian speed (0 km/h, 5 km/h, 10 km/h) and positions of impact (10%, 25%, 50%). The fact that three different classes of vehicles were tested allows the identification of the most influential parameters concerning the vehicle front shape and its effect on the kinematics of the pedestrian's head. Simulation results are shown in Table 6, 7, 8, 9, 10, 11, 12, 13 and 14. The angle of impact (degrees) is in italics while the head impact velocity (km/h) is shown in normal typeface.

Table 6.
Simulation results for impact position of 10% (Family Car).

FAMILY CAR	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*-89.9* 12.24	*-82.0* 18.54	*-58.6* 27.72
40 km/h	*-89.2* 23.76	*-61.1* 36.72	*-48.4* 35.50
50 km/h	*87.5* 30.42	*-52.3* 42.73	*-52.2* 45.18

Table 7.
Simulation results for impact position of 10% (Off-Road 4x4).

OFF-ROAD 4X4	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*-55.5* 19.22	*-68.8* 19.55	*-63.5* 17.46
40 km/h	*-51.3* 30.6	*-83.1* 28.26	*-66.1* 20.88
50 km/h	*-65.6* 36.18	*-85.9* 37.44	*-63.4* 50.26

Table 8.
Simulation results for impact position of 10% (Roadster sport).

ROADSTER SPORT	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*-43.8* 25.09	*-52.4* 30.64	*-52.9* 35.21
40 km/h	*-48.3* 46.44	*-69.0* 30.42	*-47.6* 39.96
50 km/h	*-32.8* 55.44	*-59.9* 34.92	*-47.2* 54.9

Table 9.
Simulation results for impact position of 25% (Family Car).

FAMILY CAR	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*-57.5* 25.56	*-58.4* 31.32	*-55.2* 32.62
40 km/h	*-75.4* 34.99	*-58.9* 39.42	*-58.3* 39.78
50 km/h	*-51.3* 43.56	*-50.9* 48.17	*-54.7* 45.54

Table 10.
Simulation results for impact position of 25% (Off-Road 4x4).

OFF-ROAD 4x4	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*72.2* 8.03	*-59.6* 15.59	*-58.1* 25.74
40 km/h	*77.7* 18.18	*-76.6* 12.6	*-64.7* 34.20
50 km/h	*71.0* 22.32	*-88.1* 23.76	*-67.4* 41.76

Table 11.
Simulation results for impact position of 25% (Roadster sport).

ROADSTER SPORT	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*-52.4* 32.62	*-57.4* 27.40	*-64.1* 24.80
40 km/h	*-49.4* 41.04	*-61.0* 37.19	*-63.9* 44.28
50 km/h	*-50.3* 53.64	*-60.7* 50.04	*-65.4* 49.07

Table 12.
Simulation results for impact position of 50% (Family Car).

FAMILY CAR	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*83.2* 25.20	*-65.6* 18.97	*-63.0* 26.53
40 km/h	*75.4* 21.96	*-55.6* 27.54	*-59.8* 30.96
50 km/h	*-81.1* 32.29	*-58.1* 37.44	*-47.8* 38.16

Table 13.
Simulation results for impact position of 50% (Off-Road 4x4).

OFF-ROAD 4x4	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*-58.2* 21.13	*-53.5* 15.48	*-70.3* 20.27
40 km/h	*-67.0* 35.64	*-68.8* 36.63	*-89.6* 17.10
50 km/h	*-67.2* 28.98	*-69.4* 48.82	*80.9* 26.82

Table 14.
Simulation results for impact position of 50% (Roadster sport).

ROADSTER SPORT	Pedestrian speed [km/h]		
Vehicle speed	0	5	10
30 km/h	*-63.6* 19.98	*-56.6* 27.94	*-63.3* 29.52
40 km/h	*-52.3* 20.16	*-71.2* 21.31	*-56.9* 41.94
50 km/h	*-71.1* 29.52	*-59.9* 42.12	*-60.4* 54.72

The different front shape of vehicles from these three classes results in different points of impact on the bonnet and angle values in terms of speed and head impact.
The results above demonstrate that the shape of the front vehicle is a capital feature in the studied categories.
Some of the results of the studied configurations are close to the parameters defined by the EEVC, Euro NCAP or pedestrian regulation. However, many others are different. This fact suggests that, although the recommendations provided by these organizations are not wrong, further testing should be performed to fully verify these results.
Vehicle speed and impact speed are two of the main important factors in the resulting impact speed in pedestrian run over. This is significant because this increase in the impact speed could end in serious injury or death.
After analyzing the results, it has also been proved that the front of the car is not a crucial factor in causing the injury or death.

CONCLUSIONS

Pedestrian protection issue is currently one of the problems to which organizations and governments are trying to find an answer. Organizations such as Euro NCAP, EEVC and the New Regulation, together with vehicle manufacturers are seeking solutions through the development of advanced safety systems and accurate methods for testing these systems.
This paper presented a double study as follows:

- The first one to evaluate the influence of vehicle speed, where a defined number of cases in the city of Barcelona where pedestrians were involved in accidents were selected. After a filtering process, 62 cases containing the details required to draw conclusions were studied. In these cases, it was found that 75,1% of accidents occurred during the day, with an average level of injury of ISS 4-5 and ISS 3-4 at night.
- The second one was a study of speed as a cause of accidents. It was found that 75,3% of drivers anticipated the accident and made an evasive braking manoeuvre. The average speed before the accident was 50,8 km/h while average impact velocity was 24,78 km/h. A 20% reduction in speed was proposed, as it would involve a 60% reduction in pedestrian accidents on roads. A 40% reduction in speed would get an 85% reduction in pedestrian accident rates.

Finally the level of injury related to vehicle speed was assessed. The boundary speed between slight and severe injuries, using the ISS parameter, was defined at about 40 km/h. This value matches up with the impact velocity used in the tests of organizations such as the Euro NCAP, which show that this is a suitable speed to carry out this kind of trial.
The main aim of the second study was to test the influence of the front vehicle design in pedestrian head injuries in case of run over. To carry out this second study, a series of accident simulations in which the person's head impacted into a different point of the bonnet depending on the scenario have been performed. The parameters changed in these simulations were:

- Vehicle class:
  - Family Car.
  - Off-Road 4x4.
  - Roadster Sports.
- Vehicle Speed:
  - 30 km/h.
  - 40 km/h.
  - 50 km/h.
- Pedestrian speed:
  - 0 km/h.
  - 5 km/h.
  - 10 km/h.
- Impact position of the pedestrian against the vehicle:
  - 10%.
  - 25%.
  - 50%.

The head impact position depends on vehicle class: while in Family Cars and Roadster Sports collisions occur within the boundaries set by Euro NCAP for adult head impactor, in Off-Road 4x4 some points are located even below the lower limit ascribed for adult head.
Regarding the pedestrian's head impact angle and speed against the bonnet of the car, following conclusions can be reached:

- In simulations with the same vehicle speed, impact angle and speed of the adult head against the bonnet were nearly unchanged although the pedestrian speed is different.
- Further testing to verify that such parameters defined by the EEVC, Euro

NCAP or Pedestrian Regulation are entirely valid is needed.

- The impact speed negatively affects pedestrian injury severity; that is, the higher the impact speed, the worse the consequences of the collision.
- The front vehicle shape is not the main cause in pedestrian injury severity.

THE NEWLY ENHANCED U.S. NCAP: A FIRST LOOK AT MODEL YEAR 2011 RATINGS

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ABSTRACT

In 2008, the National Highway Traffic Safety Administration (NHTSA) published a notice detailing changes to its New Car Assessment Program (NCAP), a consumer information program that tests and rates vehicles for safety using an easily recognizable 5-star rating system. In recent years, more vehicles were achieving 4- and 5-stars, which led the agency to recognize the need for a tougher rating system that, in keeping with the program's goal, would encourage continuous advancement of vehicle safety through market forces. With the availability of improved test devices and a better understanding of occupant injuries and crash conditions, the agency was able to develop a more stringent set of criteria for its safety ratings program. The agency began applying this criteria and disseminating the new safety ratings to consumers starting with model year (MY) 2011 vehicles.

This paper details changes made to the crashworthiness tests conducted under the NCAP program and provides analyses of crash test results for MY 2011 vehicles tested during the 2010 calendar year. More specifically, this paper shows that the average star ratings assigned to MY 2011 vehicles are lower than those from recent model years. Despite lower star ratings, based on the MY 2011 rating system and comparing to the extent possible data from previous model years, MY 2011 vehicles on a whole are offering consumers lower injury risks (a higher level of crash protection) than the baseline injury risk used within the new rating system. Driver injury results from MY 2007-2010 Frontal NCAP tests will be directly compared to those from MY 2011 NCAP tests. A comparative analysis of injury data and ratings from vehicles known to be compliant with the upgraded Federal Motor Vehicle Safety Standard (FMVSS) No. 214, "Side impact protection," to those that have not yet been redesigned to meet this upgrade, will also be shown. While some vehicle manufacturers have made changes to comply with the upgraded side impact standard, additional protection for certain body regions may still be needed. The analyses show that while many vehicles are achieving high ratings under the new rating system, others still need to improve their crashworthiness protection.

For ease of discussion, the vehicle rating system that applies to MY 2011 vehicles and beyond (NHTSA 2008a) is referred to as the "new" rating system. The system that applies to MY 1990-2010 vehicles (DOT 2007) is referred to as the "old" rating system.

It is important to note that while this paper makes injury data comparisons between 2011 and previous model year vehicles, the actual star ratings calculated under the new and old systems should not be compared.

FRONTAL NCAP – RIGID BARRIER TEST

In this section, an overview of the new rating program will be discussed. Driver and passenger injury readings and star ratings from MY 2011 will be presented and compared. In addition, driver injury results from MY 2007-2010 vehicles tested under the old NCAP program will be evaluated under the new rating system and compared to those from MY 2011 vehicles tested under the new program.

An Overview of the New Frontal Ratings

Under the new rating system, NHTSA maintains the same speed and type of frontal test (35 mph (56.3 km/h) rigid barrier) as it conducted under the NCAP program since 1979. However, instead of using a 50th percentile male Hybrid III dummy in the front passenger seating position in the test, a 5th percentile female Hybrid III dummy is now seated in that position. The agency's frontal crash ratings were also revised and are now based on different (and more stringent) injury criteria than the previous rating system. Head, neck, chest, and femur injury are assessed under the new rating system. The combined probability of injury to both the driver and passenger in frontal NCAP is comprised of these four body regions. Additionally, the risk curves (with the exception of femur) are based on the chance of an Abbreviated Injury Scale (AIS) 3+ injury rather than an AIS 4+ injury as used under the old system. Detailed information regarding baseline injury risk, injury risk curves and frontal star rating assignments can be found in the appendices of NHTSA's "Final decision" notice (2008a).

Comparing Driver and Passenger Injury Readings from MY 2011 Vehicles in Frontal Tests

It was of interest to see how the driver and right front passenger in MY 2011 frontal NCAP performed, both with respect to one another and with respect to the baseline injury risk. When comparing injury results between the two, however, several factors have to be considered. For one, 50th percentile male and 5th percentile female dummies occupied the driver and right front passenger seating positions, respectively, and represent occupants of different sizes. In addition, these dummies are seated differently in frontal NCAP tests (NHTSA 2010a). Furthermore, the restraint conditions for these two seating positions cannot be compared, in part due (but not limited) to different air bag sizes and deployment strategies. Nevertheless, it was of interest to compare the probabilities of injuries recorded and star ratings assigned for the driver and right front passenger tested under the new MY 2011 program. Table 1 shows the results of this comparison.

Table 1.
Driver and Right Front Passenger Results from MY 2011 Vehicles in Frontal Tests

	Average		Min.	Max.
Occupant	**p (AIS 3+) (%)**	**Star Rating**	**p (AIS 3+) (%)**	**p (AIS 3+) (%)**
Driver (n=49)	11.7	4.24	7.2	20.4
Passenger (n=49)	15.3	3.48	8.8	28.4

The risk of combined injury for the 50th percentile male driver is lower than the risk of injury for the 5th percentile female right front passenger. The difference shows statistical significance at a probability of 0.05. The combined injury risk for the driver in frontal NCAP tests is lower than the new program's baseline injury risk figure of 15 percent (2008a). In addition, the right front passenger now achieves an average combined injury risk of 15 percent, which is nearly identical to the baseline risk.

In terms of star ratings, the average driver rating from MY 2011 vehicles tested under the new frontal NCAP program was 4.24. For model years 2007-2010 frontal NCAP data, using the old rating system, the average driver star rating was 4.71. The average star rating for the 5th percentile female right front passenger from MY 2011 vehicles tested under the new program was 3.48. The average star rating for the 50th percentile male dummy that formerly occupied the right front passenger seating position under the old rating system was 4.68. The star ratings for both the driver and right front passenger from MY 2011vehicles tested under the new program ranged from 2 to 5 stars. There were no one-star ratings assigned to either occupant in MY 2011 vehicles. The decrease in average star ratings for the driver and right front passenger in MY 2011 tests compared to MY 2007 - 2010 was due to the new, more stringent rating system. Figure 1 shows a breakdown of the star ratings assigned to MY 2011 vehicles tested under the new frontal NCAP program.

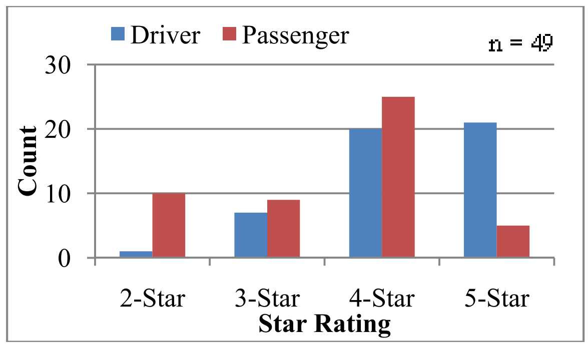

Figure 1. The driver and right front passenger frontal star ratings from MY 2011 vehicles.

It was also of interest to examine the average probabilities of injury for each occupant to the four individual body regions. Table 2 contains this information.

Table 2.
Average Occupant AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Frontal Tests

Occupant	Head	Neck	Chest	Femur
Driver (n=49)	0.5	6.9	3.1	1.7
Passenger (n=49)	1.5	10.3	2.1	2.2

Both the driver and right front passenger exhibit similarly low probabilities of injury to the head, chest, and femur. The large variation seen between the two occupants is in the elevated probability of neck injury, more specifically Nij.

Another approach in comparing the differences between the driver and right front passenger dummy responses was taken by normalizing each injury reading to its appropriate Injury Assessment Reference Value (IARV), which can be found in FMVSS No. 208 (sections S.6 and S.15, respectively). The results of this comparison are summarized in Table 3 and Figure 2 below.

Table 3.
Normalized MY 2011 Driver and Passenger Injury Readings (% of IARVs) in Frontal Tests

	HIC_{15}	Nij	Chest Deflection	Femur
Driver IARV	700	1	63 mm	10000 N
Driver Average	31.3	31.2	39.7	29.4
Passenger IARV	700	1	52 mm	6800 N
Passenger Average	43.8	52.1	33.6	34.4

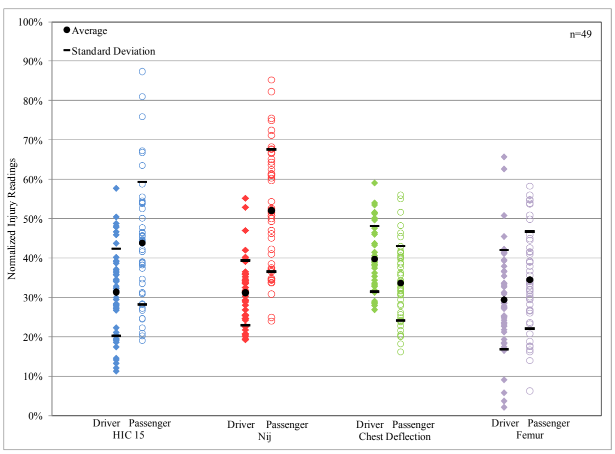

Figure 2. Normalized driver and passenger injury readings from MY 2011 vehicles in frontal tests.

Data for the driver and right front passenger shows similar averages and ranges of injury to the chest and femur with respect to their IARVs. However, the right front passenger head and neck injury readings are much higher on average with respect to their IARV than the corresponding driver injury readings. The standard deviations of these two readings for the right front passenger are also much higher than for the driver, suggesting a larger range of protection to the head and neck being afforded to the right front passenger across the MY 2011 vehicle fleet. This is also aligned with similar observations concerning the range of combined probability of injury for the right front passenger, which was similarly less homogenous than for the driver.

Comparing Driver Injury Readings in Recent Model Years

Although the additional injury readings included in the new frontal ratings were not previously used to determine vehicle star ratings, NCAP has consistently collected this data since it began using the Hybrid III 50th percentile dummy in MY 1995 vehicles. Since the 50th percentile male driver is common between the old and new frontal NCAP programs, the injury responses generated under each can be directly compared. When NHTSA developed the baseline injury risk for the new NCAP rating system, it calculated the combined probability of driver injury as if the new rating system had been applied since MY 1995 (2008a). When the agency analyzed historical NCAP data from model years 1995-2007, it found a steadily decreasing trend in driver injury probability. It was of interest to extend that analysis to include recent NCAP data from model years 2008-2010 obtained under the old program and compare it with MY 2011 data obtained from the new program.

Data from the old program was limited to model years 2007-2010, since 2007 was the model year the agency used to derive the baseline injury risk. Data from the new program is limited to MY 2011 vehicles that were tested and quality control reviewed by the time of this publication.

Similar to the historical trend, the average combined probability of driver injury (shown in Table 4) continued to decrease in recent model years.

Table 4.
Combined Driver AIS 3+ Injury Probability (%) from MY 2007-2011 Vehicles in Frontal Tests

Model Year	Average	Minimum	Maximum
2007	14.6	8.9	37.9
2008	14.7	8.7	24.4
2009	14.1	9.8	22.6
2010	12.3	8.0	20.0
2011	11.7	7.2	20.4

Of particular interest is the similarity in the average injury probability for MY 2010 and MY 2011. The range of combined injury probability has also decreased since 2007. Not only are vehicles continuing to offer occupants higher levels of frontal crash protection, the fleet is also becoming more homogenous in the level of protection it is offering.

It was of further interest to determine if certain injury probabilities had decreased or if all four body regions in question had decreased simultaneously. Table 5 shows the results of this analysis.

Table 5.
Average Driver AIS 3+ Injury Probabilities (%) from MY 2007-2011 Vehicles in Frontal Tests

Model Year	Head	Neck	Chest	Femur
2007	0.8	6.9	4.3	3.3
2008	1.2	7.0	4.3	3.0
2009	0.9	6.7	5.0	1.9
2010	0.8	7.0	3.4	1.7
2011	0.5	6.9	3.1	1.7

The data shows that the probability of driver chest and femur injury has decreased while the probability of neck injury has stayed fairly constant. The 2011 MY drivers also experienced the lowest probability of head injury since 2007. Chest injury probabilities from model years 2010 and 2011 are similar while those from model years 2007-2009 are more alike. The probability of femur injury was similar from model years 2007 and 2008 and quite different from model years 2009-2011.

SIDE NCAP - MOVING DEFORMABLE BARRIER TEST

In this section, the new side NCAP moving deformable barrier (MDB) test will be discussed. Driver and passenger injury readings and star ratings from MY 2011 will be presented and compared. Results from vehicles that are certified to comply with FMVSS No. 214, S7.2, "Side Impact Protection, MDB Test with Advanced Test Dummies," will be compared to results from those vehicles that are certified to FMVSS No. 214, S7.1, "Side Impact Protection, MDB Test with SID." An in-depth look at the driver and rear passenger occupants and their main sources of injury will be discussed. Finally, vehicles that have both old and new side NCAP MDB ratings will be examined and their corresponding ratings will be compared.

An Overview of the New Side MDB Ratings

The new side MDB test is conducted similarly to the one conducted under the old program. The test speed is maintained at 38.5 mph (61.9 km/h) and the crabbed angle remains at 27^{o}; however, rather than positioning two 50th percentile male Hybrid III SID dummies in the driver and left rear passenger seats, a 50th percentile male ES-2re dummy occupies the driver seating position and a 5th percentile female SID-IIs dummy occupies the left rear passenger seating position. Under the old program, star ratings for the side MDB test were based solely on injury to the dummies' chests. The new, more stringent side MDB ratings are based on head, chest, abdomen, and pelvis readings for the driver dummy and head and pelvis readings for the rear passenger dummy. The combined probability of injury for each dummy is comprised of these respective body regions. Similar to the frontal NCAP test, risk curves for the new side barrier test (with the exception of the pelvis for the SID-IIs dummy) are based on the chance of incurring an AIS 3+ injury rather than an AIS 4+ injury, as was the case under the old program. The appendices of NHTSA's "Final decision" notice (2008a) provide detailed information regarding baseline injury risk, injury risk curves, and the side MDB star ratings.

Comparing Driver and Passenger Injury Readings from MY 2011 Vehicles in Side MDB Tests

Many factors influence injury readings for the driver and rear passenger dummies in the side MDB tests. Typically, restraint conditions vary for these two positions, particularly in terms of advanced seat belt devices such as pretensioners and the presence of torso or torso/pelvis side air bag protection (common for the front seat, but not for the rear). In addition, the seating procedures for the driver and rear passenger dummies are different (NHTSA 2010b). Regardless, it was of interest to compare the average probabilities of injury and resultant star ratings for the driver and rear passenger dummies for the 48 MY 2011 vehicles subjected to NCAP's side MDB test. Note that there are only 45 ratings total for the rear passenger due to lack of rear seating in three vehicles. The results of this comparison are shown in Table 6.

Table 6.
Driver and Rear Passenger Results from MY 2011 Vehicles in Side MDB Tests

	Average		Min.	Max.
Occupant	**p (AIS 3+) (%)**	**Star Rating**	**p (AIS 3+) (%)**	**p (AIS 3+) (%)**
Driver (n=48)	10.4	4.40	2.1	45.2
Rear Passenger (n=45)	9.3	4.31	0.3	36.8

The average risk of combined injury for the 50^{th} percentile male driver dummy is slightly higher than for the 5^{th} percentile female rear passenger dummy. One reason for this could be that the rear passenger probabilities are limited to head and pelvis injuries. Currently, thoracic and abdominal rib deflections for the 5^{th} percentile female rear passenger dummy are monitored, but they are not incorporated into FMVSS No. 214 or NCAP star rating calculations. A footnote is posted beneath a vehicle's ratings on www.Safercar.gov to alert consumers of instances in which readings for the thoracic and/or abdominal ribs exceed associated IARVs. Similarly, NCAP uses a Safety Concern symbol to note instances in which a lower spine acceleration reading exceeds the performance requirements set forth in FMVSS No. 214.

Average star ratings for the driver and left rear passenger dummies in the 48 MY 2011 vehicles (with rear passenger ratings reduced by three as previously described) were 4.40 and 4.31, respectively. The star ratings for the driver ranged from 1 to 5 stars and the star ratings for the rear passenger ranged from 2 to 5 stars.

Table 7 shows average injury probabilities for body regions used to calculate the star ratings for the driver and rear passenger. When comparing injury risk for the head and pelvis, it is shown that the rear passenger has a greater risk of injury to these regions on average than the driver. The results from Tables 6 and 7 indicate that the chest and abdomen are predominantly influencing the combined injury probabilities for the driver, and therefore, the driver side MDB star ratings. The average probabilities of AIS 3+ injury to the chest and abdomen for the driver are relatively high compared with those to the head and pelvis. The data also suggests that pelvis injury is influencing the star rating for the rear passenger dummy.

Table 7.
Average Occupant AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Side MDB Tests

Occupant	Head	Chest	Abdomen	Pelvis
Driver	0.1	7.7	2.5	0.6
Passenger	1.0	N/A	N/A	8.5

Driver and Rear Passenger Results for Vehicles Certified to FMVSS No. 214, S7.1 vs. S7.2

As shown in Table 6, average injury probabilities for both the 50^{th} percentile male driver and 5^{th} percentile female passenger dummies fall below the original 15 percent baseline risk for side impact crashes. In NHTSA's "Final decision" notice (2008a), the agency analyzed driver and rear passenger data from seven MY 2004-2005 side barrier tests conducted with the ES-2re and SID-IIs dummies to support the upgrade of FMVSS No. 214. It should be noted that, with the exception of test speed, the new FMVSS No. 214 side impact barrier test is nearly identical to NCAP's new side impact barrier test. The test speed for the compliance side MDB test is 33.5 mph (53.0 km/h), whereas it is 38.5 mph (61.9 km/h) for the new side NCAP MDB test. The average risk of injury for the driver and rear passenger dummies in that test series was 9 percent and 12 percent, respectively (NHTSA 2008a). Recall that the MY 2011 test data in Table 6 shows a similar average risk of injury for the driver dummy (10.4 percent) and a reduced average risk of injury for the rear passenger dummy (9.3 percent) when compared to the MY 2004-2005 test data. Considering the MY 2011 side impact barrier test data was collected from tests conducted at a higher speed, it is possible that vehicle manufacturers have introduced countermeasures in recent years to lower the risk of injury to the rear occupant.

Average injury risk for the driver and/or rear passenger dummies for vehicles that have been certified to the new FMVSS No. 214 side impact barrier test (S7.2) was compared to those that have not (S7.1). The data set for vehicles that meet the new requirements (n = 20 driver, 19 passenger) consisted only of passenger cars and SUVs. Therefore, the second data set consisting of those vehicles that did not certify to the new requirements (n = 28) was reduced to include only passenger cars and SUVs (n = 21). Note that the data set for rear passenger ratings for vehicles that meet the new requirements has been decreased by one due to the lack of a rear seating position in one vehicle.

As shown in Tables 8 and 9, average injury risk for vehicles certified to the new side impact barrier test requirements is lower than for vehicles that have not yet been redesigned to meet the new standard. This difference is statistically significant at a probability of 0.05 for both the driver and rear passenger dummies, whose injury risks decrease to 7.6 percent and 5.6 percent, respectively, in those vehicles that have been redesigned. Injury risk for the rear passenger decreased by more than half for vehicles certified to the new test requirements.

Table 8.
Driver Results from MY 2011 Vehicles in Side MDB Tests

	Average		Min.	Max.
	p (AIS 3+) (%)	Star Rating	p (AIS 3+) (%)	p (AIS 3+) (%)
Not Certified to FMVSS No. 214, S7.2 (n=21)	14.5	3.95	3.8	45.2
Certified to FMVSS No. 214, S7.2 (n=20)	7.6	4.70	2.1	19.1

Table 9.
Rear Passenger Results from MY 2011 Vehicles in Side MDB Tests

	Average		Min.	Max.
	p (AIS 3+) (%)	Star Rating	p (AIS 3+) (%)	p (AIS 3+) (%)
Not Certified to FMVSS No. 214, S7.2 (n=21)	14.4	3.76	0.3	36.8
Certified to FMVSS No. 214, S7.2 (n=19)	5.6	4.74	0.8	17.2

Although the minimum values of risk observed for the driver and rear passenger are fairly similar for vehicles that have certified to FMVSS No. 214, S7.2 (2.1 percent and 0.8 percent, respectively) compared to those that have not (3.8 percent and 0.3 percent, respectively), the maximum values are widely different. The maximum risk of injury for the driver dummy in vehicles that have been certified to meet FMVSS No. 214, S7.2 was 19 percent, whereas it was more than double (45 percent) for vehicles that have not yet been redesigned. For the rear passenger dummy, the maximum injury risk for vehicles certifying to FMVSS No. 214, S7.2 was 17 percent, whereas it was 37 percent for vehicles that have not yet been certified to meet the new standard.

The marked decrease in injury risk for vehicles that have been certified to comply with FMVSS No. 214, S7.2 corresponded to an increase in average star ratings for both dummies. Average star ratings for the driver and rear passenger dummies increased from 3.95 and 3.76 to 4.70 and 4.74, respectively. Star ratings ranged from 1 to 5 stars for the driver dummy and from 2 to 5 stars for the rear passenger dummy for those vehicles which were not certified to FMVSS No. 214, S7.2. For vehicles which were certified to FMVSS No. 214, S7.2, the star ratings ranged from 3 to 5 stars for both dummies.

A Closer Look at Driver Results in Side MDB Test

Injury data from the 48 MY 2011 test vehicles was once again divided into two categories: one for vehicles that have not yet been certified to FMVSS 214, S7.2 and the other for vehicles that have been certified to the new standard. As before, the data set for those vehicles that have not yet complied with FMVSS No. 214, S7.2 was reduced to include comparable vehicle types. All injury readings collected for the driver dummy were normalized to associated IARVs (specified in the FMVSS No. 214 final rule) and are shown in Figure 2, along with the average and standard deviation. As mentioned previously, resultant lower spine acceleration has not been incorporated into either FMVSS No. 214 or side NCAP test for the ES-2re dummy. Consequently, this injury criterion will not be included in this analysis.

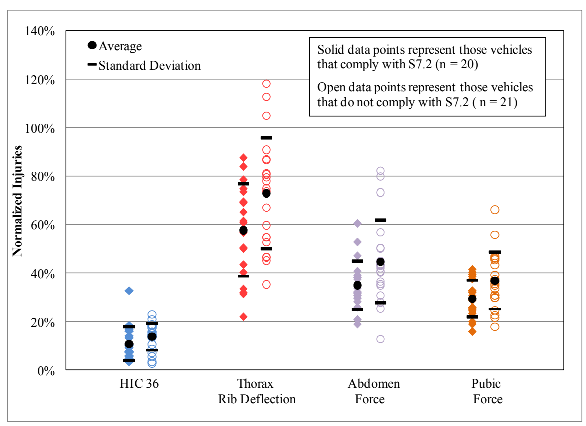

Figure 3. The normalized side MDB driver injury readings for MY 2011 vehicles certified to the new and old FMVSS No. 214.

Figure 3 and Table 10 show improved performance across all body regions for the ES-2re driver dummy in those vehicles certified to FMVSS No. 214, S7.2 (n = 20) compared to those vehicles certified to FMVSS No. S7.1 (n = 21). As shown, not only was the average injury lower for each body region, but in general, with the exception of the head, the standard deviation was reduced as well. For those vehicles certified to FMVSS No. 214, S7.2, Table 10 shows comparable reductions (of approximately 20 percent) in normalized injury readings for all four body regions.

Table 10.
Average Normalized Driver Injury Readings (% of IARVs) from MY 2011 Vehicles in Side MDB Tests

	HIC_{36}	Thor. Rib Defl.	Comb. Abd. Force	Pubic Force
IARV	1000	44 mm	2500 N	6000 N
Not Certified to FMVSS No. 214, S7.2 (n=21)	13.8	72.9	44.8	37.0
Certified to FMVSS No. 214, S7.2 (n=20)	10.9	57.7	35.0	29.6
% Reduction	21.0	20.9	21.9	20.0

The reduction in injury readings for those vehicles certified to FMVSS No. 214, S7.2 translates to a significant reduction in injury probability. As shown in Table 11, the average injury probability recorded for three of the four body regions (chest, abdomen, and pelvis) was reduced by approximately half compared to the respective average injury probabilities recorded for those vehicles that have not yet been redesigned. As mentioned previously, however, it is the thoracic and abdominal injuries that are influencing side MDB ratings for the driver occupant. This is true for the vehicle dataset as a whole, and as shown in Table 11, it is also true for each of the two reduced datasets individually. Although abdominal and pelvic injuries might still be reduced further, as average normalized injuries recorded for those vehicles complied with FMVSS No. 214, S7.2 remain at 35 percent and 30 percent of the associated IARVs, respectively, manufacturers choosing to target the thoracic region may see the largest difference in ratings. The average probability of injury recorded for the thoracic region, 5.6 percent, remains the highest for the four body regions. Additionally, as was shown in Figure 3 and Table 10, normalized injury for the thorax was 58 percent of the IARV.

HIC_{36} readings are already low, as evidenced by the 0.1 percent average probability and average injury readings falling at 11 percent of the IARV. Therefore, it may be unlikely that further improvement for this body region can be achieved. Furthermore, because of the nature of the associated risk curve, a reduction in head injury will likely not result in a higher driver star rating in the side NCAP MDB test. As shown in Tables 10 and 11, for those vehicles that certify to FMVSS No. 214, S7.2, even a reduction in head injury of 21 percent does not translate to a meaningful difference in probability of injury. Accordingly, the star rating for this occupant would not be affected. The same can be said for abdomen and pelvic injuries. Although average readings for the abdomen and pelvis in FMVSS No. 214, S7.2 compliant vehicles were 35 percent and 30 percent of the associated IARVs, respectively, Table 11 shows that these average normalized readings translate to a very low probability of injury for the two body regions.

Table 11.
Average Driver AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Side MDB Tests

	Head	Chest	Abdomen	Pelvis
Not Certified to FMVSS No. 214, S7.2 (n=21)	0.1	10.6	3.8	0.8
Certified to FMVSS No. 214, S7.2 (n=20)	0.1	5.6	1.8	0.4
% Reduction	0.0	47.2	52.6	50.0

A Closer Look at Rear Passenger Results in Side MDB Tests

Injury readings for the SID-IIs rear passenger dummy in the side MDB test were also normalized for the two data sets studied for the ES-2re driver dummy. Normalized readings for each data set are shown in Figure 4, along with the related averages and standard deviations. Average values are also presented in Table 12.

As mentioned previously, injury criteria related to thoracic and abdominal rib deflection for the SID-IIs dummy has not yet been incorporated into either FMVSS No. 214 or side NCAP ratings. However, the agency acknowledged in the FMVSS No. 214 final rule that "thoracic and abdominal rib deflections are a critical part of the [SID-IIs] dummy." Furthermore, the agency contended that it "may undertake future rulemaking to propose to limit thoracic and abdominal rib deflections measured by the SID-IIs in the FMVSS No. 214 MDB and pole tests." As IARVs for each of these criteria have been established, these injury criteria will be included in this analysis. Resultant lower spine acceleration will also be analyzed because, even though this criterion has not yet been adopted into the side NCAP rating scheme for the SID-IIs dummy, the agency has established related performance limits that have been incorporated into FMVSS No. 214.

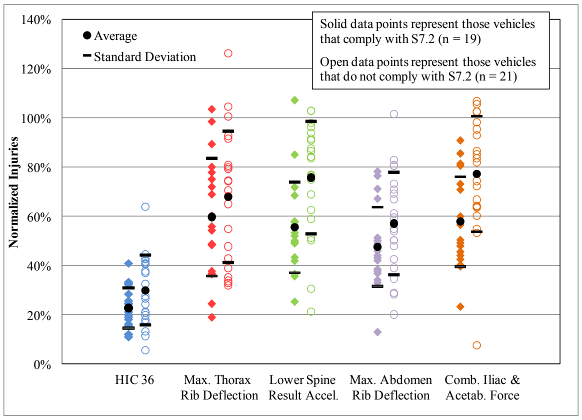

Figure 4. The normalized side MDB rear passenger injury readings from MY 2011 vehicles certified to the new and old FMVSS No. 214.

Similar to Figure 3, Figure 4 shows improved performance for the SID-IIs dummy across all body regions for those vehicles certified to comply with FMVSS No. 214, S7.2 (n = 19) as compared to FMVSS No. 214, S7.1 (n = 21). Average readings were lower for each body region, and associated standard deviations were also reduced.

Table 12.
Average Normalized Rear Passenger Injury Readings (% of IARVs) from MY 2011 Vehicles in Side MDB Tests

	HIC_{36}	Thor. Rib Defl.	Abd. Rib Defl.	Lower Spine Accel.	Comb. Pelvic Force
IARVs	1000	38 mm	45 mm	82 G	5525 N
Not Certified to FMVSS No. 214, S7.2 (n=21)	30.1	67.9	57.1	75.7	77.3
Certified to FMVSS No. 214, S7.2 (n=19)	22.8	59.7	47.7	55.5	57.9
% Reduction	24.3	12.1	16.5	26.7	25.1

Table 12 shows that reductions in average injury readings were most apparent for the head (24 percent), lower spine (27 percent), and pelvis (25 percent). Average thoracic rib and abdominal rib deflections decreased by a lesser extent, 12 percent and 17 percent, respectively.

The reduction in injury readings for those vehicles that are certified to comply with FMVSS No. 214, S7.2 translates to a noticeable reduction in injury probability. Table 13 shows the average AIS 3+ injury probability recorded for the head and pelvis in those vehicles that are certified to FMVSS No. 214, S7.2 and those that are not. The star rating for the rear passenger is currently determined by the probability of injury to these two body regions. As shown, it is the pelvis, not the head, which influenced the rating for the rear occupant. This was true for the vehicle dataset as a whole, as was shown in Table 7, and is also true for each of the two reduced data sets. Average injury probabilities for those vehicles that complied with FMVSS No. 214, S7.2 were reduced by more than 60 percent compared to the respective average injury probabilities recorded for those vehicles that have not yet been redesigned.

Table 13.
Average Rear Passenger AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Side MDB Tests

	Head	Pelvis
Not Certified to FMVSS No. 214, S7.2 (n=21)	1.6	13.1
Certified to FMVSS No. 214, S7.2 (n=19)	0.5	5.1
% Reduction	68.9	61.1

In MY 2011 vehicles that were certified to comply with FMVSS No. 214, S7.2, average head injury readings were recorded at 23 percent of the related IARV, and average injury readings for the pelvis remain at 58 percent of the IARV (Table 12). The average probability of injury for the pelvis, 5.1 percent, remains the higher of the two body regions. Because of the nature of the risk curve, any reduction in head injury will translate to little improvement in the star rating for the rear passenger dummy since the average probability of injury for this body region, 0.5 percent, is already relatively low.

Comparing Side MDB Star Ratings Obtained from the New Program to Those Obtained from the Old Program

Vehicle models that do not receive structural or restraint redesigns that would affect side impact performance are considered carryover models from one year to the next. Although carryover models would not typically be retested for the newer model year, due to the major enhancements to the NCAP program, ratings for those models did not carry over in MY 2011. As the new side impact barrier test remained virtually unchanged under the new program, with the exception of the test dummies and collected injury criteria, it was of interest to see if side impact barrier ratings assigned under the new program were lower, on average, than those assigned under the old program for the same vehicle model.

To ensure the most accurate comparison, vehicles for this analysis were limited to those models (n = 13) that were considered carryovers from MY 2010 and were not yet redesigned to meet FMVSS No. 214, S7.2. Furthermore, the carryover data set was further limited to only passenger cars and SUVs (n = 12). Vehicles certified as complying with FMVSS No. 214, S7.2 were excluded because, as has been shown, it is likely that they have already been redesigned with necessary countermeasures that could skew the results. For this study, it was desired to have a more direct, one-to-one comparison to reveal the effect of the new rating system on assigned star ratings.

As shown in Figure 5, for the 12 carryover models that were tested under the old program (MY 2010 vehicles) and again under the new program (MY 2011 vehicles), the star ratings were lower, on average, for both the driver and rear passenger under the new program. In fact, as shown in Table 14, driver ratings were at least one star lower in 8 of the 12 vehicles, and rear passenger ratings were lower in all but five vehicles. Only one vehicle achieved a higher star rating under the new program.

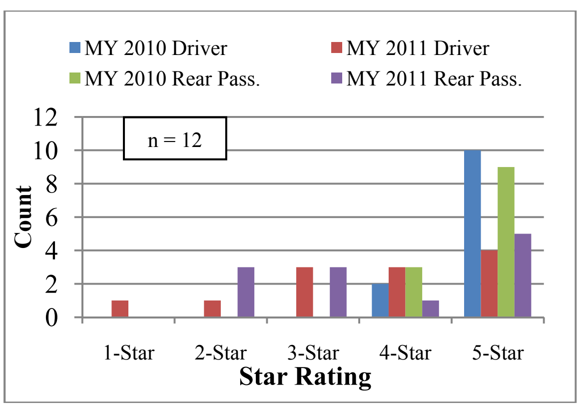

Figure 5. The driver and rear passenger star ratings from both MY 2010 and 2011 carryover vehicles not certified to FMVSS No. 214, S7.2.

Table 14.
Change in Driver and Rear Passenger Star Ratings for MY 2011 Carryover Vehicles Not Certified to FVMSS No. 214, S7.2

	Down 3 Stars	Down 2 Stars	Down 1 Star	Same Star	Up 1 Star
# 2011 Driver Ratings	1	4	3	4	0
# 2011 Rear Pass. Ratings	2	3	2	4	1

As shown in Table 15, for this limited data set of 12 carryover vehicles, the average risk of injury for the driver and rear passenger was 17 percent and 15 percent, respectively, and the overall combined average was 15.6 percent, which is nearly identical to the baseline injury risk used in NCAP's new rating system, 15 percent. Recall that, in Tables 8 and 9, respectively, it was shown that the average injury risk for the driver and rear passenger decreased to 8 percent and 6 percent, respectively, for those vehicles (n = 20 driver, 19 passenger) that have been certified to FMVSS No. 214, S7.2. This suggests that newly redesigned vehicles are offering consumers a level of protection that exceeds the baseline injury risk level under the new rating system.

Table 15.
Driver, Rear Passenger, and Combined Average Injury Probabilities for Carryover Models in Side MDB Tests (n=12)

	Average p(AIS 3+) (%)
Driver	16.6
Rear Passenger	14.6
Combined	15.6

Although it was mentioned earlier that average star ratings were higher for vehicles that have been certified to FMVSS No. 214, S7.2 compared to those that have not, it was also of interest to see what percentage of redesigned vehicles were receiving the highest ratings. As shown in Table 16 below, 75 percent of vehicles certified to comply with FMVSS No. 214, S7.2 received a 5-star rating for the driver and/or rear passenger. This is a sharp increase compared to the 33 percent (4 out of 12) of drivers and 42 percent (5 out of 12) of rear passengers in the carryover data set (n = 12) that received 5-star ratings for MY 2011 as illustrated in Figure 5.

Table 16.
Driver and Rear Passenger Star Ratings from MY 2011 Vehicles Certified to FMVSS No. 214, S7.2

Stars	# 2011 Driver Ratings	% of Driver Ratings	# 2011 Rear Pass. Ratings	% of Rear Pass. Ratings
5	15	75	15	75
4	4	20	3	15
3	1	5	1	5
2	0	0	0	0
1	0	0	0	0
N/A	0	0	1	5

SIDE NCAP - THE SIDE POLE TEST

Driver injury readings from NCAP's new side pole test will be presented in this section. Results from vehicles that are certified to comply with FMVSS No. 214, S9, "Side Impact Protection, Vehicle-To-Pole Requirements," will be compared to results from those vehicles that do not yet meet these requirements. The main sources of injury for the driver occupant will also be revealed and a breakdown of side pole star ratings will be shown.

An Overview of the New Side Pole Ratings

The side pole test is a new addition to the NCAP test series as well as to FMVSS No. 214. For this test, a 5th percentile female SID-IIs dummy occupies the driver seat; there is no dummy in the rear seat. A vehicle, crabbed at 75^{o}, is towed into a 25 cm diameter rigid pole at a speed of 20 mph (32.2 km/h). This test is meant to simulate a vehicle impacting a narrow, tall fixed object such as a tree or utility pole. The dummy's head is aligned with the pole such that, at impact, the head's center of gravity (CG) is aligned with the vertical centerline of the pole. Similar to the SID-IIs dummy in the rear seat for the side MDB test, the SID-IIs driver pole rating is based only on the combined risk of injury to the head and pelvis. Again, risk curves for the SID-IIs dummy in the side pole test are based on the chance of incurring an AIS 3+ injury to the head and AIS 2+ injury to the pelvis. Information pertaining to baseline injury risk, injury risk curves, and the side pole star ratings can be found in the appendices of NHTSA's "Final decision" notice (2008a).

Driver Injury Readings from MY 2011 Vehicles in Side Pole Tests

Because of localized loading, intrusion is a major factor in injury readings measured in NCAP's side pole test. As the side pole rating is based solely on combined injury to the head and pelvis, it is essential that vehicles have sufficient countermeasures to protect these body regions. Since the 5th percentile female SID-IIs driver dummy in the side NCAP pole test sits in a different, more forward position than the 50th percentile male ES-2re driver dummy in the side NCAP MDB test, side curtain air bags must be designed to offer protection to both occupants for each of the two testing scenarios. Side torso air bags that are not also designed to provide pelvis protection may not afford the driver dummy enough protection to attain a high side pole rating.

Table 17 shows the average probabilities of injury and resultant star ratings for the driver dummy in the 48 MY 2011 vehicles subjected to NCAP's side pole test. As shown, the average combined injury probability for the driver dummy was 13 percent, which falls below the original overall 15 percent baseline risk for side impact crashes. The average star rating was 4.15 and the range was from 1 to 5 stars.

Table 17.
Driver Results from MY 2011 Vehicles in Side Pole Tests

	Average		Min.	Max.
	p (AIS 3+) (%)	Star Rating	p (AIS 3+) (%)	p (AIS 3+) (%)
Driver (n=48)	12.9	4.15	1.6	65.1

Average injury probabilities for the two body regions (head and pelvis) used to calculate the star rating for the driver dummy in the side pole test are shown in Table 18. As the average probability of AIS 3+ injury to the pelvis is relatively high compared to that for the head, it can be inferred that pelvic injury is influencing the star rating for the driver dummy.

Table 18.
Average Driver AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Side Pole Tests

	Head	Pelvis
Driver (n=48)	2.3	11.0

It should be noted that the average injury risk for the head (2 percent) and pelvis (11 percent) for the SID-IIs driver dummy in the side pole tests was greater than it was for the 50th percentile male driver dummy in the side barrier test (average risks of 0.1 percent and 0.6 percent, respectively). Localized intrusion, side air bag designs, and occupant size may be contributing factors to the higher readings seen for the side pole test.

Driver Results for Vehicles Certified and Not Certified to FMVSS No. 214, S9

The agency conducted seven MY 2004-2005 side pole tests with the SID-IIs dummy to support the upgrade of FMVSS No. 214. As mentioned in NHTSA's "Final decision" notice (2008a), the average injury risk for this test series was 57 percent. This is in sharp contrast to the 13 percent average injury risk found for the driver dummy in the 48 MY 2011 vehicles included in this study. It should be noted that there were no significant differences between the current side NCAP pole test protocol and the one used for the FMVSS No. 214 test series. This suggests that, in recent years, manufacturers have implemented or improved countermeasures for side pole crashes which provide additional protection for the small occupant. Therefore, similar to the side MDB test, it was of interest to see if the average risk of injury for the driver dummy in the side pole test was considerably lower for those vehicles that have been certified to the new FMVSS No. 214 requirements (S9) compared to those that have not. Injury readings for the 48 MY 2011 test vehicles studied were once again divided into two groups: one for those vehicles that were certified to FMVSS No. 214, S9 (n = 20), and one for those that were not (n = 28). As was done for the previous analyses, the data set for those vehicles that were not yet certified to the new standard was reduced to include only passenger cars and SUVs (n = 21).

Table 19 shows that the average injury risk for the 20 vehicles certified to the new pole test requirements is substantially less (7.2 percent) than for the 21 vehicles that have not yet been certified to the new requirements (17 percent). This difference is statistically significant at a probability of 0.05. Accordingly, the average injury risk recorded for the compliant vehicle set falls below the original overall baseline risk of 15 percent for side impact crashes. It should also be noted that although the minimum risk values were fairly comparable for the two data sets, the maximum values varied considerably. The maximum combined injury risk for those vehicles that do not yet certify to the new requirements was 65 percent. This value is nearly four times the maximum risk recorded for those vehicles that have been redesigned. For those vehicles that have certified to the new pole test requirements, the maximum combined risk of head and pelvis injury was 16 percent. Furthermore, the maximum risk for those vehicles that were certified to comply with the new standard is actually less than the average risk for those vehicles that were not.

Table 19.
Driver Results from MY 2011 Vehicles in Side Pole Tests

	Average		Min.	Max.
	p (AIS 3+) (%)	**Star Rating**	**p (AIS 3+) (%)**	**p (AIS 3+) (%)**
Not Certified to FMVSS No. 214, S9 (n=21)	17.0	3.68	2.7	65.1
Certified to FMVSS No. 214, S9 (n=20)	7.2	4.80	1.6	15.8

The significant decrease in average injury risk for those vehicles that meet the new side pole test requirements resulted in an increase in the average star rating for the driver dummy. The average star rating for the driver dummy in those vehicles (n = 20) that have been certified to the new requirements was 4.80 stars. This is compared to 3.68 stars for those vehicles (n = 21) that have not yet certified to the new requirements. This means that the average driver star rating for vehicles certifying to the new standard is one star higher than the average driver rating for vehicles that have not yet been designed to meet these new requirements. Star ratings ranged from 3 to 5 stars for those vehicles that were certified to the new standard, and from 1 to 5 stars for those that were not.

A Closer Look at Driver Results in Side Pole Tests

Injury readings collected by the SID-IIs driver dummy in NCAP's side pole test were normalized to related IARVs for each of the two vehicle data sets. Figure 6 shows normalized readings for each group, along with the related averages and standard deviations. Average values are also presented in Table 20.

As was previously mentioned in relation to the SID-IIs rear passenger dummy in the side MDB test, injury criteria for thoracic and abdominal rib deflection have not yet been incorporated into either FMVSS No. 214 or side NCAP ratings. That said, as mentioned previously, performance thresholds have been established for each of these criterions; therefore, they will be included in this analysis. Resultant lower spine acceleration will also be part of the discussion. Although this criterion is not currently part of the side pole rating for the driver occupant, the agency has established an IARV for this criterion that has been adopted into FMVSS No. 214, S9.

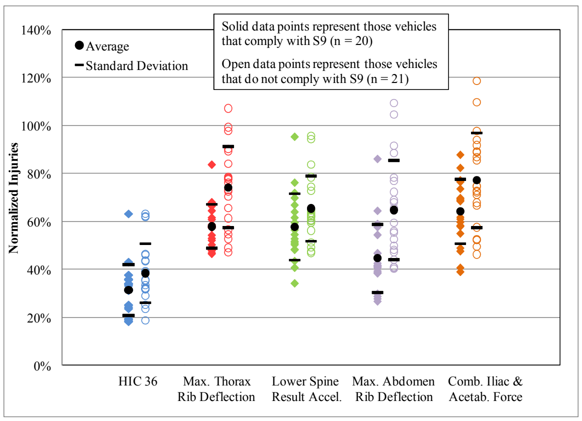

Figure 6. The normalized side pole driver injury readings from MY 2011 vehicles that are certified to the new FMVSS No. 214 pole test and those that are not.

As was the case for the driver and rear passenger dummies in the side MDB test, vehicles that have certified to comply with the new FMVSS No. 214 pole requirements (n = 20) showed improved performance in the pole test for all body regions compared to those that have not (n = 21). For those vehicles certifying to the side pole test requirements, Figure 6 shows that average readings for the SID-IIs driver dummy decreased for each body region. With the exception of lower spine acceleration, associated standard deviations were also reduced. The standard deviation for lower spine acceleration remained essentially constant for those vehicles certifying to the new requirements.

Table 20 shows that contrary to what was observed for the rear passenger SID-IIs dummy in the side MDB test, the most prominent reductions in average injury readings for the SID-IIs driver dummy in the side pole test were seen in the thoracic and abdominal ribs. Injuries to these two body regions were reduced by 22 percent and 31 percent, respectively. Notable reductions in average injury readings were also seen for the head (18 percent) and pelvis (17 percent). This was as expected since these two injury criteria make up the side pole rating for the driver dummy. Lower spine injury readings were reduced by the least amount, 12 percent.

Table 20.
Average Normalized Driver Injury Readings (% of IARVs) from MY 2011 Vehicles in Side Pole Tests

	HIC_{36}	Thor. Rib Defl.	Abd. Rib Defl.	Lower Spine Accel.	Comb. Pelvic Force
IARV	1000	38 mm	45 mm	82 G	5525 N
Not Certified to FMVSS No. 214, S9 (n=21)	38.4	74.3	64.7	65.4	77.2
Certified to FMVSS No. 214, S9 (n=20)	31.4	58.0	44.7	57.7	64.1
% Reduction	18.2	21.9	30.9	11.8	17.0

Reductions in average readings for the head, thorax, and pelvis (18 percent, 22 percent, and 17 percent, respectively) were fairly comparable to the reductions seen for the same body regions for the driver dummy in the side MDB test (21 percent, 21 percent, and 20 percent, respectively). Injury reductions for the abdomen showed noticeable differences between the two tests, however. The driver dummy saw a greater reduction in average abdominal injuries (31 percent) in the side pole test compared to the side MDB test (22 percent). As mentioned previously, intrusion, side air bag designs, and occupant size may contribute to the variation in the severity of injuries recorded for particular body regions in each test.

As shown in Table 21, the reduction in injury readings for those vehicles that are certified to comply with the new side pole test requirements translates to a noticeable reduction in injury probability for the two body regions (head and pelvis) that determine the driver's side pole rating. The average probability of head injury was reduced by 48 percent for those vehicles meeting the new side pole test requirements, and the average probability of pelvis injury was reduced by 61 percent. Similar to what was observed in the rear passenger dummy in the side MDB test, it is pelvis injury that is influencing the side pole rating for the driver dummy. This was true for all 48 vehicles, and is also true for each of the smaller data sets.

Table 21.
Average MY 2011 Driver AIS 3+ Injury Probabilities (%) in Side Pole Tests

	Head	Pelvis
Not Certified to FMVSS No. 214, S9 (n=21)	2.9	14.7
Certified to FMVSS No. 214, S9 (n=20)	1.5	5.8
% Reduction	48.3	60.5

Average HIC_{36} readings were recorded at 31 percent of the related IARV for those vehicles that complied with FMVSS No. 214, S9. This suggests that the average probability of head injury (1.5 percent) may still be reduced. However, manufacturers looking to improve the star rating for the driver dummy may focus on pelvis readings instead. The average pelvic force reading for vehicles certified to FMVSS No. 214, S9 were recorded at 64 percent of the IARV and the corresponding probability of injury was 5.8 percent. Similar to that discussed in earlier analyses, because the average probability of head injury for the driver dummy is already low, even a rather large reduction in head injury will not translate to a meaningful difference in related probability of head injury. This is due to the nature of the associated risk curve. Consequently, the star rating for the driver dummy would also be unaffected.

Side Pole Star Ratings Received Under the New Program

In Table 19, it was shown that the average injury risk for the driver decreased to 7 percent for those vehicles (n = 20) that have certified to FMVSS No. 214, S9. Therefore, similar to that observed for the side barrier test, newly redesigned vehicles appear to afford consumers a level of protection for the side pole test that exceeds the average injury risk level under the new rating system. On average, star ratings for vehicles certified to FMVSS No. 214, S9 were also shown to be notably higher than those for vehicles that have not yet been certified to the new standard. The following analysis will expand upon the earlier work to show the percentage of vehicles that receive the highest ratings for the driver dummy in the side pole test.

As shown in Table 22 below, 85 percent of vehicles that are certified to FMVSS No. 214, S9 received a 5-star driver rating and 10 percent received a 4-star rating. These percentages contrast sharply with those in the data set that consists of only those vehicles that have not yet been redesigned to comply with FMVSS No. 214, S9. For this second group of vehicles, only 46 percent received a 5-star rating and 18 percent received a 4-star rating.

Table 22.
Driver Star Ratings from MY 2011 Vehicles Certified and Not Certified to FMVSS No. 214, S9

		5-Star	4-Star	3-Star	2-Star	1-Star
All Vehicles (n = 48)	**Count**	30	7	2	6	3
	%	62	15	4	13	6
Not Certified to 214, S9 (n = 28)	**Count**	13	5	1	6	3
	%	46	18	4	21	11
Certified to 214, S9 (n = 20)	**Count**	17	2	1	0	0
	%	85	10	5	0	0

It is interesting to note that an identical percentage of vehicles (95 percent) that certified to FMVSS No. 214, S9 and achieved either a 5-star or 4-star side pole rating for the driver also certified to FMVSS No. 214, S7.2 and achieved a 5-star or 4-star side barrier rating for this occupant.

CONCLUSIONS

Although MY 2011 vehicles tested under the new NCAP program generally received lower star ratings than those tested under the old program, the new model year vehicles offered a level of crash protection not seen in previous model year vehicle fleets.

In general, results confirm that the baseline injury risk of 15 percent is higher than the level of injury risk in MY 2011 vehicles tested under the new program. Vehicle manufacturers have, for the most part, responded to the challenge to improve their vehicles' crashworthiness. The following summarizes the major conclusions made from these analyses of MY 2011 vehicles tested under the new program.

For the frontal NCAP program:

1. The average combined injury probability for the 50th percentile male driver dummy from MY 2007 to MY 2011 has decreased.
2. Based on the range of combined injury probabilities and observed percentage of IARVs for the driver from MY 2011 vehicles tested under the new program, the new model year vehicle fleet appears to offer a better, more homogenous level of frontal injury protection than in previous model year vehicle fleets.
3. Based on the range of combined injury probabilities and observed percentages of IARVs from MY 2011 vehicles tested under the new program, those vehicles seem to offer better frontal crash protection for the driver than for the front passenger.
4. The average star rating for the driver in MY 2011 vehicles was 4-stars, while the average rating for the right front passenger was 3-stars. There were no 1-star ratings assigned to either position in MY 2011 vehicles tested under the new program.

For the side NCAP program:

1. The average star rating for driver and rear passenger dummies in vehicles certifying to the new side MDB requirements was 5-stars. It was 4-stars for those vehicles that have not yet certified to the new requirements.
2. For the side MDB test, thoracic and abdominal injuries were found to have the largest influence on star ratings for the driver dummy, while pelvic injuries were shown to have the greatest impact on star ratings for the rear passenger dummy.
3. Reductions in average injury values for the driver dummy in the side MDB test were fairly comparable for all body regions. Reductions in average injury values for the rear passenger SID-IIs dummy in the side MDB test were most apparent for the head, lower spine, and pelvis.
4. For carryover models, the new side NCAP rating system proved to be more stringent than the old side NCAP rating system for both the driver and rear passenger dummies in the side MDB test.
5. The average star rating for the driver dummy in vehicles certifying to the new side pole test requirements was 5 stars; it was 4 stars for those vehicles that did not certify to the new requirements.
6. Pelvic force was found to have the largest influence on the side pole star rating for the driver dummy.
7. The most prominent reductions in average injury values for the driver dummy in the side pole test were for the thoracic and abdominal ribs.
8. Combined injury risks for the 50th percentile male driver dummy in the side MDB test and for the 5th percentile female driver in the side pole test were similar.
9. For the side MDB and side pole tests, the overall average risk of injury for the dummies in vehicles redesigned to meet the new FMVSS No. 214 requirements was reduced by half or more compared to those vehicles that have not yet been redesigned.

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