CHILD OCCUPANT PROTECTION IN REAR SEATS: AN EXAMPLE OF CRS DEVELOPMENT WITH RESPECT TO EURO NCAP 2016 PROTOCOL REQUIREMENTS

Farid Bendjellal
Britax Childcare Group
Germany

Richard Frank
Martin Haas
Britax Römer Kindersicherheit GmbH
Germany

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ABSTRACT

As of January 2016 Euro NCAP has implemented a new protocol that examines the occupant protection in the rear seats of the car and in particular the protection available for child population using booster seats. In this case the belt restraint system of the car plays an important role as it is used to secure the booster and the child to the vehicle. New dummies, Q6 and Q10 and performance criteria are part of this new protocol. The Q6 dummy is to be restrained in a high back booster while the Q10 is secured in a booster cushion. The choice of the later was aimed at encouraging car manufacturers to introduce innovative restraint systems that protect not only adults but also children. In order to meet the new requirements an increased effort in the OEM/CRS Manufacturer collaboration had to be thought thru in terms of the booster CRS performance and its approval.

To achieve these new requirements a high-back booster was developed based on existing platform, i.e. the KIDFIX XP that is part of the Euro NCAP top pick list. The newly developed seat comprises a detachable cushion that can be used for older children and that is equipped with a belt guide for the vehicle shoulder belt routing. The validation of the seat included CAE modeling, sled and crash tests.

This paper highlights the key aspects of this new Euro NCAP protocol, its rational and the technical and approval challenges associated with it.

INTRODUCTION

Since its introduction in 2003 the child protection protocol in Euro NCAP comprised child restraint systems that were aimed at the child population from birth to approx. 4 year old. The child restraint systems were installed in the car with a 1,5 and a 3 year old dummies. The car was subjected to an offset deformable barrier test and a side impact barrier test at resp. 64 and 50 km/h (1 Euro NCAP, 2014). Most of the CRSs tested had an Isofix attachment and therefore the belt system of the car in the majority of the cases was not used.

The new protocol is focussed on the protection of children that uses booster seats, where Q6 and Q10 dummies are used respectively with a highback booster and a booster cushion (2 Euro NCAP, 2015).

The overall safety rating prioritizes child occupant protection by making it one of the key pillars of the vehicle safety rating. The rating principle covers the following areas:

- CRS installation checks: assessing the vehicle ability to easily accommodate a large range of CRSs. These are summarized in a top pick list as shown in figure 1.
- Safety provision in the vehicle: provisions of 3 pt seat belts, i-Size and top tether marking, passenger airbag warning label and ability to install large isofix CRSs.
- Crash protection: dynamic assessment based on Q6 and Q10 dummy responses in frontal and side impact tests.

Universal Belted CRS:

CRS	Group	Installation
Maxi Cosi Cabriofix	0+	Belt mounted
Maxi Cosi Cabriofix plus Easybase2	0+	Belt mounted with base & supp. leg RF
Römer King II LS	I	Belt mounted
Römer Kidfix XP	II/III	Belt mounted

ISOFIX CRS:

CRS	Group	Installation
Maxi Cosi Cabriofix & Familyfix	0+	ISOFIX mounted with base & supp. leg, RF
BeSafe iZi Kid X3 ISOfix	0+/I	ISOFIX mounted with supp. leg, RF
Römer Duo Plus	I	ISOFIX with top tether mounted
Römer Kidfix XP	II/III	ISOFIX mounted FF

i-Size CRS:

CRS	Group	Installation
Maxi Cosi 2way Pearl & 2wayFix	67cm-105cm ≤18.5kg	ISOFIX mounted with supp. leg RF
	>15months – 105cm ≤18.5kg	ISOFIX mounted with supp. leg FF
BeSafe iZi Kid X1 i-Size	61cm – 105cm ≤18.0kg	ISOFIX mounted with supp. leg RF

Table 1.
Euro NCAP Top pick list of CRSs – 2016 protocol (3 Euro NCAP, 2015)

HOW THE CRASH PROTECTION IS ASSESSED IN EURO NCAP 2016 PROTOCOL?

This is based on the criteria such as HIC 15, head 3ms acceleration, head excursion, upper neck tension and chest 3ms acceleration in frontal impact. In side impact HIC 15, head 3ms acceleration, upper neck resultant force and chest 3ms acceleration are considered. The scoring system allows for 8 points in frontal impact and 4 points in side impact respectively for each dummy (2 Euro NCAP, 2015).

Regardless of dummy performance criteria, penalties for poor restraint are applied in the following cases:

- Dummy ejection from restraint
- Failure of restraint system's component
- Submarining of the dummy
- Diagonal belt sleeping off the shoulder during dummy forward displacement

The performance criteria are provided in table 1.

Body region	Dummy measures	64 kph ODB (front)		50 kph (side)	
Head	HIC15 (with hard contact)	500	700	500	700
	Resultant 3ms acceleration	87g	100g	72g	88g
	Excursion Q6 Q10	450 mm	 550mm 550mm		
Upper Neck	Tension Fz Resultant Force Q6 Q10	1.7 kN	2.62kN		 2.4kN 2.2kN
Chest (T4)	Resultant 3ms acceleration	41g	55g		67g

Total Score		**8 points / dummy**	**4 points / dummy**

Table 2.
Crash protection assessment criteria (5 van Ratingen, 2016)

RATIONAL FOR EURO NCAP 2016

The restraint system technology in the vehicle front seats has tremendously improved as a consequence of regulatory crash tests and Euro NCAP test requirements. On contrary the advances in safety technology have lagged in the rear. Front seat technology nowadays includes as standard equipment, belt load limiters, belt pretensioner, front and side airbags, even knee airbags. That's not the case for rear seats (4 Sahraei at al., 2010). The aim of the 2016 Euro NCAP Child Protection Protocol is to encourage improvements of the safety of rear seats and in particular that of the children population that uses booster seats. The child restraint system in this case must be recommended by the OEM.

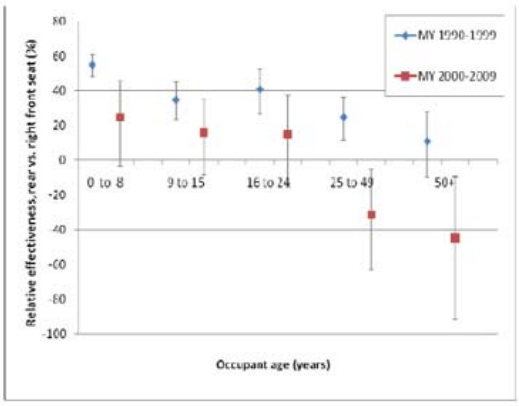

Figure 1. Rear vs. front seat safety FARS, 1990-2009 (4 Sahraei at al., 2010)

STARTING POINT KIDFIX XP BOOSTER SEAT

An existing booster platform, called Kidfix XP, was used as a starting point due to the fact that this booster got a good assessment in the consumer testing program, Stiftung Warentest (5 Stiftung Warentest, 2014). That testing programme includes 3 main demands: dynamic performance in frontal and side impact sled tests, usability and hazardous substances. It should be noted that this consumer program discourage the use of booster cushion as a stand-alone restraint system.

The CRS is restrained to the vehicle using the seat belt and ISOFIX attachments, and in its original form, comprises a booster cushion that is permanently attached to the back part. For this project, a modification was made to the seat to allow the cushion to be detached from the back. In the high back version, the seat also comprises an adjustable head restraint that holds a belt guide. In the cushion version, the CRS comprises a belt guide that is linked to a strap as shown in Figure 2.

Figure 2. Design of the Kidfix XP CRS

THE TECHNICAL & APPROVAL CHALLENGES

The challenges in this project comprised 2 aspects i.e. to develop a booster that meet the new requirements with a capability to sustain the demands of the OEM, and to define the approval process of such a booster under the regulation R44/04. For the technical part, one of the key challenges was to provide a solution that ensures an adequate positioning of the shoulder belt in the booster cushion version. For the approval part, the high back booster was to be approved as universal CRS in R44 04. The booster cushion as a part to be detached from the high back booster was to be approved as a semi-universal CRS. In terms of availability in the market, this CRS is sold only in the OEM network. The approval matrix is summarized in table 2.

Approval groups per R44 04	**Group II and III**	**Group III**
Type of restraint	Highback booster	Booster cushion & belt strap*
Approval mode	Universal with 3pt belt	Universal with 3pt belt
	Semi-universal with 3 pt belt + Isofix	Semi-universal with 3 pt belt + Isofix + belt strap

* sold only in the OEM network, not as stand-alone restraint system

Table 3.
Approval matrix used for the certification of the Kidfix XP seat

In a recent publication Euro NCAP (6 van Ratingen, 2016) has highlighted the dynamic test results obtained in 17 cars involving various types of non-integral child restraint systems. It is shown that:

- Q6 results in frontal impact: most of the cars are below the HIC15 and the head acceleration limits but a few were at or above the limits for upper neck tension and chest acceleration.
- Q6 results in side impact: all 17 cars are below the limits
- Q10 results in frontal impact: HIC15, head acceleration and chest acceleration are below the limits, while in majority of cases neck tension limit was exceeded
- Q10 results in side impact: HIC15 and upper neck are at or below the limits, while the head acceleration and chest acceleration limits were exceeded in some cases

The above mentioned results reflect the demanding level of Euro NCAP 2016 protocol.

KIDFIX XP IMPROVEMENTS

The original Kidfix XP seat was evaluated using CAE tools and sled tests. Some improvements in the area of the head restraint, side wings and the seat cushion were developed and validated. The solutions were optimized through component testing as well as sled and crash testing.

TETS RESULTS WITH KIDFIX XP IN ONE CAR ENVIRONMENT

The results that were obtained with this version of the Kidfix XP and one car environment are provided (7 Bendjellal et al, 2016). We will highlight here the key findings. In frontal impact the score reached with Q6 and Q10 were respectively 7.85 and 7.71 respectively. In the side impact 4 points were reached with both dummies, leading to a total of 23.7 points or 99% for the dynamic assessment.

- Key motion sequences from the frontal and side impact tests are shown in figure 4
- It can be seen from these sequences that in frontal impact the restraint system for both Q6 and Q10 is doing its "job", i.e. in both cases the dummy lower part and upper torso are adequately restrained.
- In the side impact as the vehicle intrusion is well controlled the Q10 occupant can benefit from the deployment of the side airbag curtain

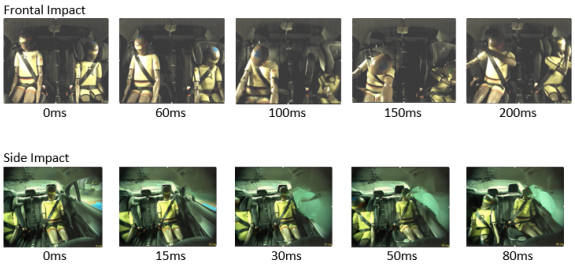

Figure 3. Principle motion sequences selected from frontal impact (upper) and side impact (lower) in Euro NCAP tests with one car and Kidfix XP CRS. Reproduced with the permission of Euro NCAP.

SUMMARY

The 2016 Euro NCAP child occupant protection protocol opens a new era in that, it will contribute to further enhancing the safety of rear seat occupants in general, and that of the child occupants secured with a booster and the vehicle seat-belt. The important point is that the overall restraint performance will be a resultant of the vehicle restraint system and the CRS. It can be noted that 14 cars out of 17 tested by Euro NCAP and reported in (6 van Ratingen, 2016) were equipped with belt load limiters and pretensioners in rear outboard seats.
The study presented in this paper is an illustration of the combination of "Vehicle + CRS" that was capable of achieving the demanding Euro NCAP requirements. Two types of challenges were encountered during the development of this project:

1. Dynamic performance in both frontal impact and side impacts, especially as far the Q10 dummy is concerned, where it is restrained in a booster cushion and
2. the approval modes for the seat in its versions, high back or cushion only.

As Euro NCAP will continue to test in the future such a combination vehicle + CRS, there is a potential for additional safety for children to be expected, i. e. an improvement of restraint technology in rear seats.

The information provided here are those provided by the authors and does not necessarily reflect Britax opinions.

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