CONSUMER INITIATIVES TO IMPROVE CHILD SAFETY IN EUROPE

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ABSTRACT

Safe transport of children in cars is the joint responsibility of parents, child restraint suppliers and vehicle manufacturers. Responsible parents and caregivers must ensure that children are properly restrained in a correctly installed child restraint system (CRS) that is appropriate for the size and weight of the child. Child restraint suppliers make certain their products meet local regulations, offer adequate protection and can be fitted easily and correctly in all cars. Finally, it is the vehicle manufacturers' obligation to guarantee that children are as well protected as adults in the event of crash and that special any provisions needed for children are offered as standard. In practice, this joint responsibility leads to a set of complex interactions and a patchwork of solutions that make it difficult for average consumers to know how their child is carried in the best and most safe way.

In Europe, two independent consumer-oriented programmes work cooperatively to help consumers find the best answer for their unique situation. Child restraint testing is carried out by European consumer groups under the umbrella of International Consumer Testing and Research (ICRT) and the Automobile Clubs. The program publishes ratings based on standardised dynamic sled tests and an ease-of-use assessment, amongst other items. The European New Car Assessment (Euro NCAP) rates vehicle performance and equipment availability for new cars on the market. Its Child Occupant Protection assessment includes full-scale crash tests with child test dummies in child restraints and evaluates the availability and functionality of attachments and provisions for safe transport of children. Collectively, these programmes address one of the most pertinent and persistent challenges in child safety: the risk of misuse and incorrect installation of a child restraint system in a vehicle.

Child restraint testing is based on body-in-white setup applying standardised pulses. This set up only broadly approximates real life use in actual cars. In-vehicle testing comes closer to actual crash circumstances, but the result only applies to the combination of car model and CRS type. Both approaches are complementary, and both are needed to improve child safety in cars.

INTRODUCTION

Since May 2006, it has been compulsory to use safety belts and United Nations Regulation No. 44 type-approved child restraint systems in all vehicles in Europe [1]. It is also mandatory to use child car seats within the EU for children up to the heights of 1.35m or 1.5m - depending upon the country. Thanks to these laws and increased consumer awareness and compliance, child deaths in motor vehicle crashes have steadily declined over the last decades [2] (Figure 1).

Child Restraint Systems

The European Test Standard for Child Restraints [3] was introduced in 1982. From this time onwards, only seats displaying the European Standard orange label, indicating approval to UN Regulation No. 44, may be used or sold. Child restraint systems approved under R.44 are classified into five mass groups. For children up to 9kg they must be side- or rearward facing. Most common are rearward facing infant carriers up to 13kg. For the groups up to 18kg these child restraint systems have an integrated harness or shield system. The groups for heavier children up to 36kg mostly use the vehicle's safety belt for restraining. Approvals are based on several criteria, the foremost of which is the child restraint's performance in a simplified dynamic sled test, representing a frontal impact.

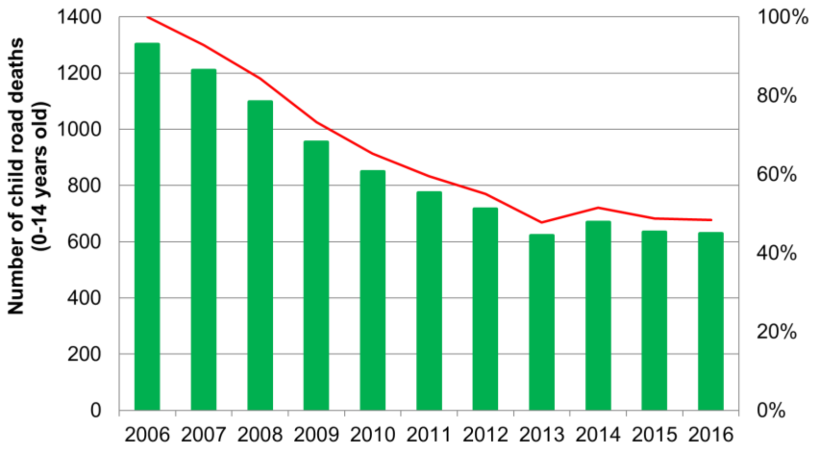

Figure 1. Development in the number of child road deaths in 27 EU countries over the period 2006-2016 (ETSC, [2])

UN Regulation No. 44 has been amended and updated many times since the 1980s. To facilitate correct installation of child restraints, the ISOFIX [4] standard for attachment points and connectors for child safety seats in passenger cars was introduced in 1997. ISOFIX became a standard in 2004, but only became mandatory in the EU for all new models launched from November 2012, and in all vehicles manufactured after November 2014 [5]. ISOFIX child seats can be either "Universal", approved for use in all vehicles that meet UN Regulation No. 14[1] [6] and No. 16 [7], or "Semi-Universal" or "Vehicle Specific" for use in specified vehicles.
The Reg.44 standard for child restraints can appear complicated from a consumer point of view. It covers belted, ISOFIX, Universal, Semi-Universal & Vehicle Specific approvals as well as having confusing overlaps in the weight groups. This has led to a kaleidoscopic of product offerings on the market that can easily cause parents to make the wrong choice for their child. Despite the availability of ISOFIX, there still are many mistakes made when installing a child restraint in the car or the child in the seat [8]. Furthermore, the standard allows forward facing transport as of 9 kg and does not encourage rearward facing transport of toddlers (>13kg), nor does it require child restraints to offer adequate protection in side crashes. These concerns, amongst others, have been addressed by the new UN Regulation No. 129 that came into effect in 2013 [9]. Even though i-Size clearly delivers superior child seats, UN Regulation No. 44 (currently R44.04) and UN Regulation No. 129 (currently R129/03) have been allowed to run side by side, at least for the time being. For the consumer, the situation on the ground therefore remains very confusing.

For more than 50 years, consumer groups under the umbrella of International Consumer Research and Testing (ICRT) and Automobile Clubs have been testing child restraint systems in order to guide consumers into buying the best seat for their child. Initially run as separate programs in various countries, they joined forces in 2003 by forming the European Testing Consortium (informally referred to as "ETC"). The main partners are ADAC (D), ÖAMTC (AT) and TCS (CH) on behalf of the automobile clubs and Stiftung Warentest (D), Which (UK), Consumentenbond (NL), Test Achats (B) and Que Choisir (F). The program is fully independent and funded by partners. Test results are published by more than 30 organisations across Europe (and beyond) in different presentation formats (Table 1). Twice a year a batch of new CRS models is tested, and the results are published by the end of May and October. On average some 50 models are published each year. Benchmarking testing has become a powerful tool to drive improvements in CRS design, as a good ETC rating is a must for child seat manufacturers to be successful in the market.

Passenger Cars
In Europe a type approval is applied by national authorities to certify that a vehicle meets all EU safety, environmental and conformity of production requirements before authorising it to be placed on the EU market. As the EU is a Contracting Party to the 1958 Agreement of the World Forum for Harmonization of Vehicle Regulations, it generally applies the technical requirements of the UN ECE to verify compliance with safety rules. This is also the case for child occupant protection, which is ensured directly via production requirements on seat-belts, ISOFIX anchorages and top-tethers in Regulation No. 14/145 and No. 16, and indirectly (as testing does not involve child dummies) through the application of mandatory crash front and side impact crash tests for the whole vehicle.

[1] In 2017, ISOFIX and child restraint system anchorage provisions were separated from UN Regulation No. 14 and included in Regulation No. 145.

Table 1.
Publishing partners distributing ETC test results in European countries (2018)

Country	Partner	Country	Partner
Austria	ÖAMTC, VKI	Luxembourg	ACL
Belgium	Test Achats/Test Aankoop	Netherlands	ANWB; Consumentenbond
Bosnia & Herzegovina	BIHAMK	Norway	Forbrukerrådet
Croatia	HAK	Poland	Świat Konsumenta
Czech Republic	dTest	Portugal	ACP; DECO Pro Teste
Denmark	FDM; Forbrukerrådet	Romania	APC Romania
Finland	Autoliitto; Kuluttaja	Slovenia	AMZS; ZPS
France	Que Choisir	Spain	RACC; RACE; Oficina de Co. Universitaria
Germany	ADAC; Stiftung Warentest		
Hungary	Kosár; Magyar	Sweden	Råd & Rön; Motormännen
Italy	Altroconsumo	Switzerland	TCS
Lithuania	LNVF	United Kingdom	Which?

Since 1997, Europe's type approval system is complemented with the new car assessment programme Euro NCAP, which provides motoring consumers with a realistic and objective assessment of the safety performance of the most popular cars sold in Europe [10]. Euro NCAP encourages manufacturers to exceed the legal requirements by applying more stringent and/or additional test conditions and by extending the assessment to new areas of vehicle safety. At present the organisation has 12 members representing the citizens and consumers in the whole of Europe. These include the Member State governments of the United Kingdom, Germany, France, Sweden, the Netherlands, Luxemburg and the regional government of Catalonia; the International Automobile Federation FIA; motoring clubs ADAC and ACI; International Consumers Research and Testing; and the Motor Insurance Centre Thatcham Research. In the 22 years of its existence, Euro NCAP has published ratings on over 700 different vehicles, including superminis, family cars and MPVs, roadsters, SUVs, pick-up trucks, hybrids and full electric vehicles.

From 2003, Euro NCAP has specifically addressed the protection of children in the event of a crash. The child occupant protection star rating aims to help consumers choose the best car for their family, to motivate all car manufacturers to deliver improved child protection and to facilitate a better dialogue between car manufacturers and child restraint suppliers. In 2009, the Child Occupant Protection rating became part of the overall safety rating, making a good child protection score a prerequisite for 5 stars [11].

METHODS

Consumer test programmes such as ETC and Euro NCAP give consumers the ability to hold manufacturers to account, by giving them more control over the product which they need. They make sure that markets work properly so that competition between manufacturers drives down prices and sparks innovation from which consumers benefit. Central to their mission is to provide data and tools to inform, educate and, if necessary, support consumers when they must make difficult choices, such as buying a child seat for their firstborn, or the safest car for the family.

Both consumer programmes have a wide scope, covering more aspects than what is legally considered, to reveal hidden product properties and to promote best practice. They share an underlying philosophy that children should benefit from at least the same level of protection as adults/their parents. Despite their complex technical assessment, ETC and Euro NCAP have adopted a simple communication language to explain the results, using "stars" or easy to understand labels. Their test methodologies are regularly reviewed and updated considering regulatory and market changes. In the case of ETC, industry is consulted in hearings at Stiftung Warentest (the so-called "Fachbeirat"), whereas Euro NCAP has invited vehicle manufacturers and seat suppliers to its working group on child safety.

Child Restraint System Test Methodology (ETC)

The main aim of the ETC test is to inform parents of the best solution to transport their child: the child seat that offers the best protection, is easy to handle, comfortable for the child and is free from hazardous substances. For this purpose, ETC has developed its own test methodology that assesses (1) dynamic performance, (2) ease-of-use, (3) ergonomics and (4) the presence of hazardous materials (Figure 2). Seats from all five mass groups (0, 0+, I, II, III) in UN Regulation No 44 and all size ranges in UN Regulation No. 129 are tested. If a seat covers several mass groups, a wide size range or different installation modes, all modes are tested and rated. The test results are combined into one overall rating per product. Where there are several installation modes, the overall rating will be based on the worst-case performance of the product. However, because it is expected that ISOFIX products will usually be used in ISOFIX mode, ISOFIX results will be prioritised over belted results. A well-known example of this "worst-case performance" policy is that booster seats with detachable backrests are unable to score well owing to their lack of side impact protection when used as cushion only.

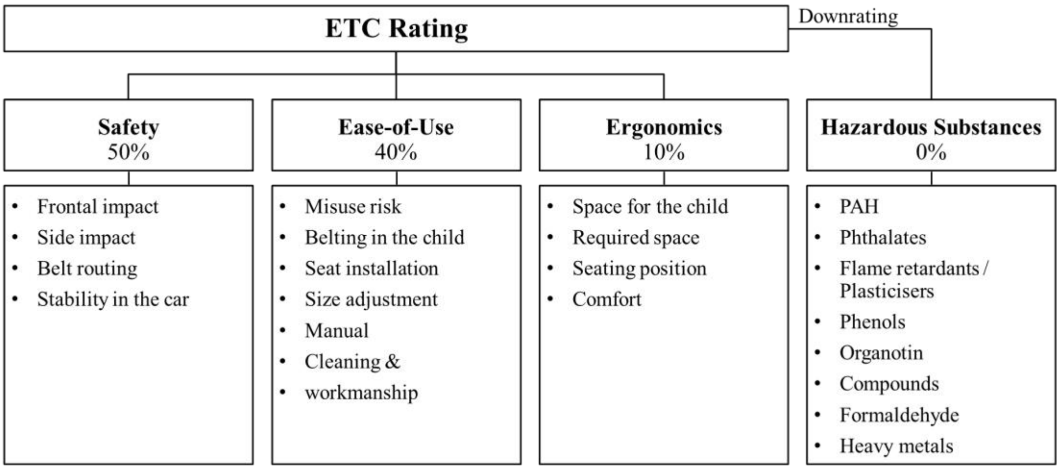

Figure 2. ETC Test overview (2018)

To ensure that results are representative, test samples are exclusively procured in retail point of sales, without the prior knowledge of the child seat supplier. From time to time, the testing procedure and the assessment are adapted based on the latest findings. For example, in 2007, the P-series dummies (except P10) were replaced by Q-series dummies; in 2011, the test of hazardous substances was implemented; and, in 2015, a side impact test with an intruding door, the Q10 dummy and Q3 abdominal load sensors were introduced.

Dynamic tests The latest dynamic test matrix includes fontal impact tests on Body-in-White (BIW), side impact tests on a test bench derived from Regulation No. 129, and an assessment of belt routing and seat stability in the car (Figure 3). A summary of tests is given in Table 2.

Table 2.
Summary of ETC Child Restraint Dynamic Tests & Assessment (2018)

Load Case	**Test Parameters**	**Assessment**
Frontal impact	• VW Golf VII BIW – child seats on rear seat • VW Golf VII ODB B-pillar pulse (Euro NCAP) • All available installation and adjustment possibilities and child sizes (5 tests on average)	• Q-dummies • Head, neck, chest and abdominal loads (Q3) • Belt routing • Seat stability
Side Impact	• Regulation No. 129 bench, 80° impact angle • VW Golf VII AE-MDB barrier pulse (Euro NCAP) • Intrusion depending on installation and adjustment possibilities and child sizes (3 tests on average)	• Q-dummies • Head, neck and chest loads

The dynamic tests are more demanding than legally required, thereby highlighting the extra protection the seat offers. The crash severity is comparable to Euro NCAP full scale tests, which nowadays are survivable types of crashes. All products tested are measured to the same yardstick irrespective to their (Regulation No. 44 or No. 129) approval. Dynamic tests are carried out at ADAC Technical Centre and the result contributes to the overall score with a weight of 50%.

Ease-of-use test In the ease-of-use tests, several handling aspects are assessed. These include misuse risk, the ease of strapping the child in the seat, ease of seat installation (by experts and laymen) and size adjustment, clarity of the user's manual and cleaning & workmanship aspects. In the latest version, three car models are used: Opel Adam 3-door, Golf VII 5-door and Ford C-Max. Ease of use assessments are carried out at ÖAMTC (Vienna) and the result has a weight of 40% in the overall score.

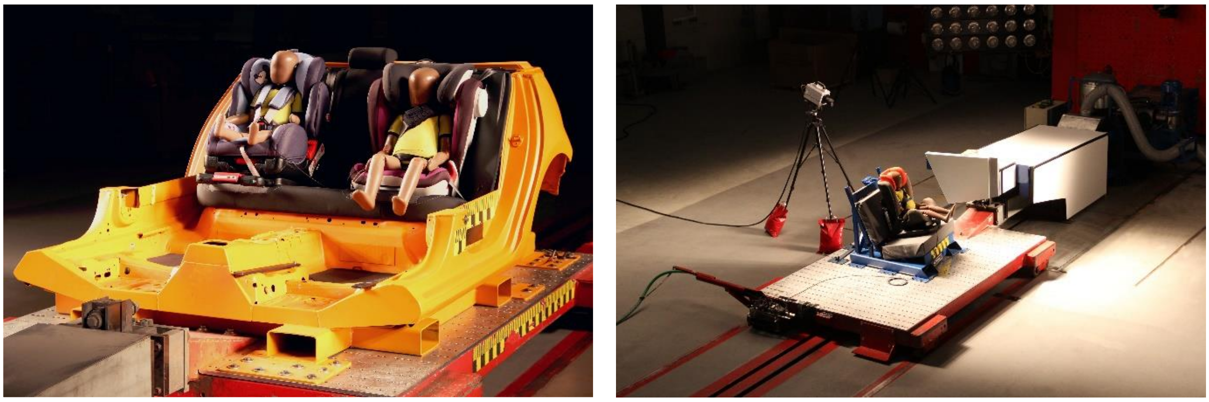

Figure 3. ETC front (left) and side (right) impact test © 2018 ADAC

Ergonomics test Expert and layman tests are carried out to verify the space available for the child, the required space inside the vehicle for installation, the resulting seating position, and comfort. The Opel Adam 3-door, Golf VII 5-door and Ford C-Max are used for these assessments as well handling dummies and actual children. Ergonomics checks are carried out at ÖAMTC and TCS and the result has a weight of 10% in the overall score.

Hazardous substances test Finally, all parts of the seat that are in contact with the child are screened for the presence of the following substances: Polycyclic aromatic hydrocarbons (PAH, based on the AfPS GS 2014:01 PAK document), Phthalates (based on Regulation EC No. 2005/84, Directive 76/769/EEC, Oeko-Tex Standard 100, and RAL-UZ textile toys), Flame retardants (based on Oeko-Tex Standard 100, EN 71-9 and Directive 2014/79/EU), Phenols (based on Oeko-Tex Standard 100), Organotin compounds (based on Oeko-Tex Standard 100), Formaldehyde (based on EN ISO 14184-1 and EN 71-9), and Heavy metals (based on EN 71-3). The findings do not contribute directly to the overall score but may be used to downgrade the overall score in case of pollution.

Child Occupant Protection Assessment Methodology (Euro NCAP)

Up until the nineties, car manufacturers relied on the makers of child restraints to provide protection for children in cars. Very few offered child restraints through their dealerships or provided any recommendation to their customers, and there were almost no special provisions in the vehicle, over and beyond the basic requirements in Regulation No. 14/145 and No. 16, for the safe transport of children. It has become clear, however, that there are many aspects of child protection which cannot be influenced by the child restraint manufacturer alone and which require action on the part of the car manufacturer as well. For this reason, Euro NCAP developed a specific assessment of the vehicle’s ability to safely transport children.

From the beginning, the Euro NCAP Child Occupant Protection (COP) rating focused on three main elements: (1) the protection offered in front and side crash tests, (2) the interface between vehicle and child seat and (3) the special provisions for children in cars (Figure 4). The test results are converted into item scores, which are summed to form the COP score. Up until 2008, this score was communicated as a separate star rating. From 2009, the COP score, along with the Adult Occupant, Pedestrian Protection and Safety Assist scores, has been used to calculate the overall safety rating of the vehicle. Euro NCAP most commonly follows a VIN selection method [12] to source test vehicles, while child seats for testing are provided by either supplier or manufacturer.

Dynamic tests The frontal off-set deformable barrier and the side mobile deformable barrier test have formed the backbone of Euro NCAP’s crashworthiness assessment since the start of the programme in 1997. Initially, the 3-year old and 18 months old P-series dummies were used to check dynamic performance. As test results improved over time, the focus shifted to the protection of older children. Since the latest revision (2016), the more biofidelic 10-year old and 6-year old Q-series dummies are placed on the rear seat (Q10 behind the passenger in the frontal impact test, behind the driver in the side impact test). The Q6 dummy is seated on booster seat appropriate for its mass or stature and recommended by the vehicle manufacturer. The Q10 dummy is placed on a booster cushion from a list of preselected products, even if a high back booster is recommended by the vehicle manufacturer in the user manual. The reason for this somewhat unusual set-up is the low use rate of high back boosters in real-life for children of 8 years and up. The use of the booster cushion will verify if adequate protection is offered by the vehicle’s restraint systems alone.

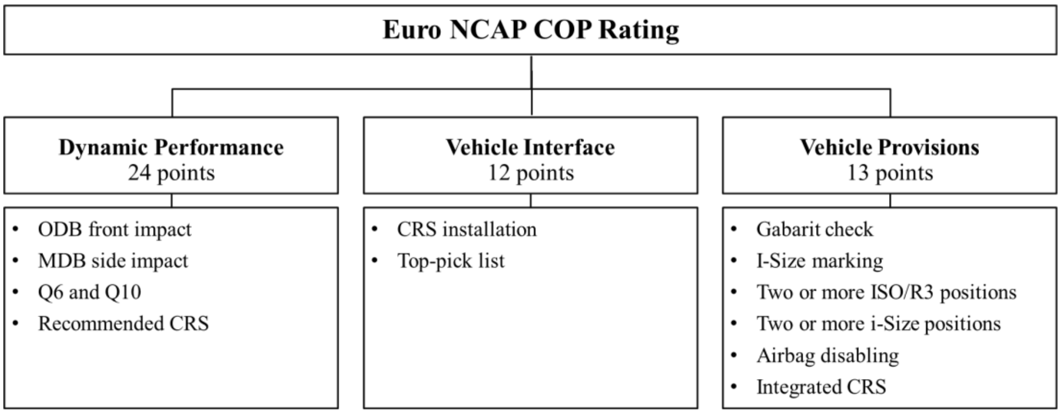

Figure 4. Euro NCAP Child Occupant Protection overview (2018)

Overall, for a good dynamic score in Euro NCAP's tests, vehicle manufacturers must ensure children are well protected by providing, amongst other things, robust seat attachments, good belt geometry and head protection. They also must correctly inform parents about the best child seat to use for all ages and ensure that these seats are available on the market.

A summary of the Euro NCAP dynamic tests & assessments is given in Table 3.

Table 3.
Summary of Euro NCAP Dynamic Tests & Assessment (2018)

Load Case	Test Parameters	Assessment
Frontal impact (ODB, 64 km/h)	• Instrumented Q6 in recommended booster seat (ISO 13499, position 4) • Instrumented Q10 on booster cushion from top-pick list (ISO 13499, position 6)	• Q6 and Q10 dummies • Head, neck, chest* • Contact, excursion, ejection
Side Impact (AE-MDB, 50 km/h)	• Instrumented Q6 in recommended booster seat (ISO 13499, position 6) • Instrumented Q10 on booster cushion from top-pick list (ISO 13499, position 4)	• Q6 and Q10 dummies • Head, neck and chest* • Contact, excursion, ejection

** Criteria and limits are included in Table 7 and 8.*

Vehicle interface assessment The original vehicle marking and vehicle interface requirements - such as clear vehicle handbook instructions, belt length and correct marking of ISOFIX attachment points – were replaced in 2013 by a Child Seat Installation Check, in which a selection of popular products is used to assess the vehicle's ability to safely and correctly accommodate child seats.

The so-called top pick list contains a sample of widely available, well performing (i.e. ETC rated "good") child seats that represent most common types of products available on the European market. The list is checked annually and updated if seats are no longer available on the market. The installation procedure focusses on typical and known incompatibilities that often lead to misuse in the real world, such as insufficient seat belt length for rearward facing seats; instability caused by child seat contact with head restraint, C-pillar or roof; inaccessible ISOFIX anchorages; and insufficient floor strength for a support leg. Seating positions where, for any reason, child restraints cannot be safely installed should be clearly identified by the manufacturers in the user's manual.

Vehicle based assessment Not all cars offer the same provisions especially when more than one child seat is required. Euro NCAP rewards vehicle manufactures that have clearly designed the vehicle with families in mind and apply best practice solutions. To be eligible for scoring, the information provided in the user's manual should clearly state what is and what is not possible in terms of installing child restraint systems on the different seating positions in the vehicle.

Additional points are available for extra seat belt length, meeting extended i-Size marking requirements, the availability of two or more ISO/R3 positions and offering two or more i-Size seating positions in the vehicle. Similarly, points can be rewarded for automatic and manual Passenger Airbag disabling switches with correct warning marking, and for the installation of one or more integrated child seats as standard.

RESULTS

Trends in Child Restraint System Performance

Since 2003 more than 700 different child seat models have been tested and rated by ETC. Currently about 75% of the tested products are rated "very good", "good" or "satisfactory". All of them far exceed the legal requirements. An overview of the overall ratings of all tested seats since 2003 is displayed in Figure 5. From the figure it can be observed that the number of good performing seats has increased over the last years. It is especially encouraging that two thirds of the tested products achieve a "very good" or "good" safety score even though the ETC frontal impact test energy exceeds the approval test by 50% and side impact testing is mandatory only for products that are approved to Regulation No. 129. This means that most of the seat manufacturers respect the requirements of the consumer test for the development of their products.

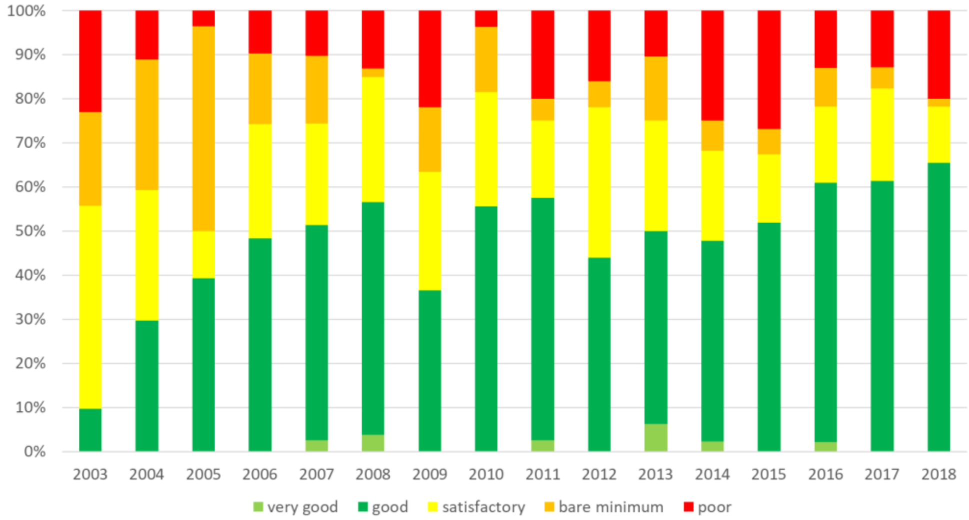

Figure 5. ETC Overall Child Seat Rating results since 2003

Unfortunately, every year there are a few seats tested that fail the tests and cannot be recommended to the consumer. The detailed reasons for the poor safety ratings are listed in Table 4 below.

Table 4.
Problems found in ETC Safety Tests (2015-2018)

Rating year	Total number of seats	Seats with one or more safety critical problem	Description of the problem
2015	52	1 (2%)	• The seat shell partially detached from its base in frontal impact test
2016	46	4 (9%)	• In two of the seats the dummy loadings indicated an increased high injury risk in case of a side impact and the head was not properly contained within the seat • One seat shell partially detached, and a second seat fully detached from its base in frontal impact test
2017	62	6 (10%)	• In two of the seats the lap portion of the seatbelt heavily cut into the abdomen of the dummy during the frontal impact test • In one seat the smallest dummy was ejected during the frontal impact test • One seat shell fully detached from its base in frontal impact test • On one seat one ISOFIX attachment opened within the frontal impact test • One seat was rated poor due to the lack of side impact protection
2018	55	3 (5%)	• In two of the seats the lap portion of the seatbelt heavily cut into the abdomen of the dummy during the frontal impact test • In one seat the smallest dummy was ejected during the frontal impact test • One seat shell fully detached from its base in frontal impact test

Side impact performance was improving long before the side impact sled test became mandatory in legislation (first introduced for Regulation No. 129-approved products in 2013; the share of Reg. 129-approved products tested by ETC test can be found in Table 5). Since 2015, only three of the 215 tested models were rated poor because of the high injury risk during the side impact test. An overview of the safety ratings of all tested seats since 2003 can be found in Figure 6, with an overview of the side impact ratings in Figure 7.

Table 5.
Share of products approved under "i-Size" Regulation No. 129 (2013-2018)

Rating year	Total number of seats	Number (share) of i-Size seats
2013	48	0 (0%)
2014	44	1 (2%)
2015	52	6 (12%)
2016	46	13 (28%)
2017	52	18 (29%)
2018	55	28 (51%)

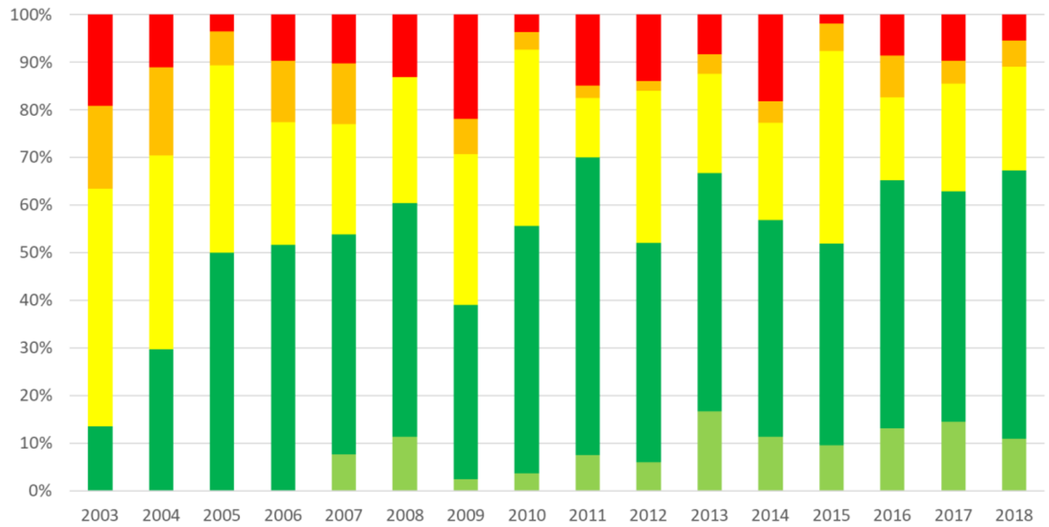

Figure 6. ETC Safety ratings of all tested seats since 2003

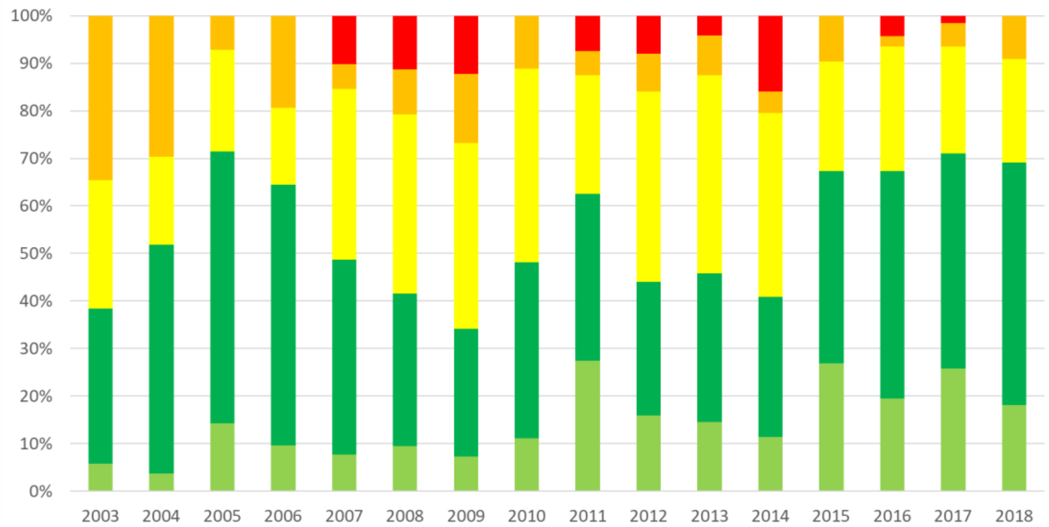

Figure 7. ETC Side impact scores of all tested seats since 2003

Although a rare occurrence, in 2016 the overall rating of one seat was downgraded because of a poor ease of use score. Tightening the integral harness took excessive force and several separate accessories were required to adapt the seat to the child's correct weight. Both facts would result in a high risk of misuse and due to this there is a high potential risk of an inadequate protection in case of a crash. Beside this outlier, the ease of use ratings of most of the seats were favourable. The ease of use ratings of all tested seats since 2003 can be found in Figure 8.

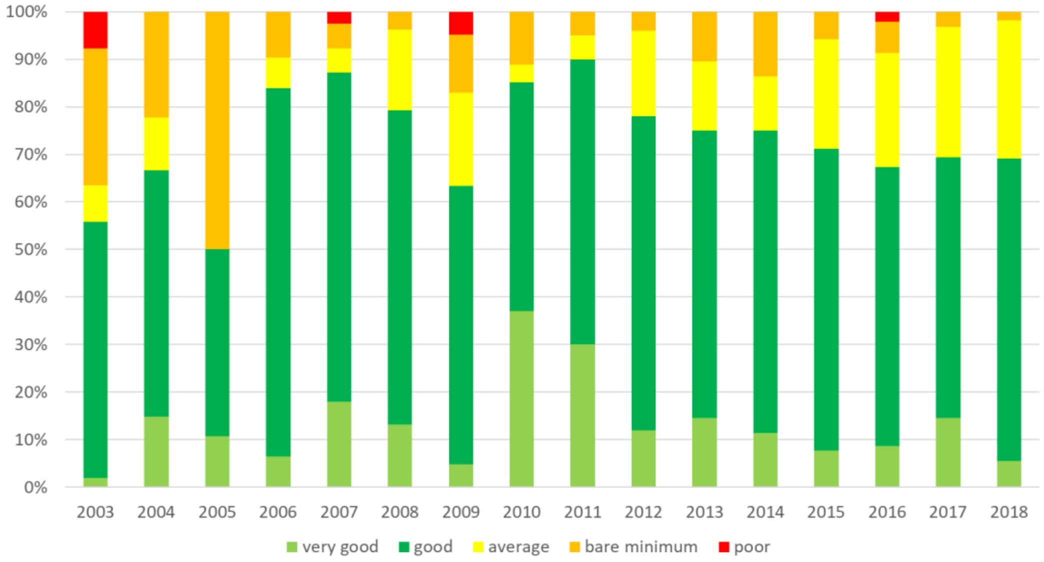

Figure 8. ETC Ease of use ratings of all tested seats since 2003

Since 2011 all fabrics of the CRS that are in direct contact with the child are screened for hazardous substances. If the rating of this criterion is "average" or better, it does not influence the overall rating. A "bare minimum" rating leads to a gradual downgrading of the overall result, and a "poor" rating will downgrade the overall rating to poor. Figure 9 summarises the hazardous substances ratings of all tested seats. After the "safety" rating, the hazardous substances rating is the second most common reason for a poor recommendation for a child seat.

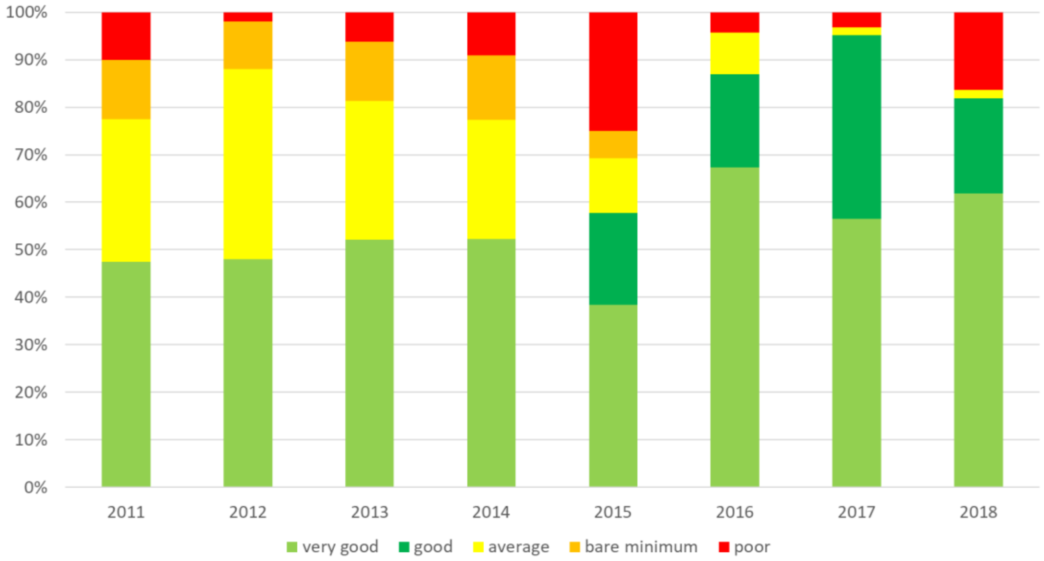

Figure 9. ETC hazardous substances ratings since the introduction in 2011

Trends in Child Occupant Protection

The start of Euro NCAP in 1997 coincided with the introduction of European whole vehicle type approval crash tests, leading to fast improvement of vehicle crashworthiness in the market. Euro NCAP's first COP test protocol strongly emphasised the availability of ISOFIX attachment points - accessible and clearly marked. This served as a market catalyst until ISOFIX lower anchorages and top tether attachments finally became mandatory for all vehicles in 2014 (Figure 10).

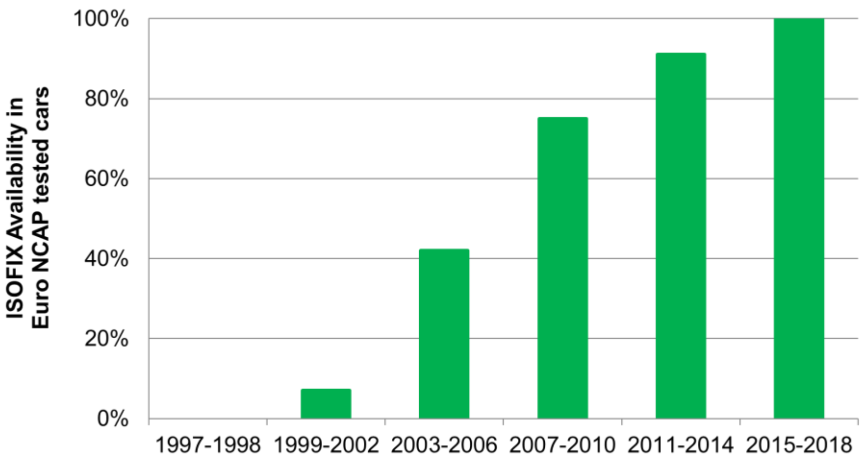

Figure 10. Share of Euro NCAP rated cars, standard equipped with ISOFIX. From 1997 until 2003, Euro NCAP evaluated but not rated child seat performance.

The most challenging part of the early protocol were the dynamic crash tests. To mitigate any risk, manufacturers settled on a handful of recommended child seats, such as the Britax-Römer Baby Safe and Duo Plus, that were known to meet Euro NCAP's labelling requirements and had few test issues. Other requirements such as the availability of integrated child seats and automatic airbag disabling switches were mostly ignored. Overall, however, significant progress was made over the first decade after the introduction in 2003 (Figure 11).

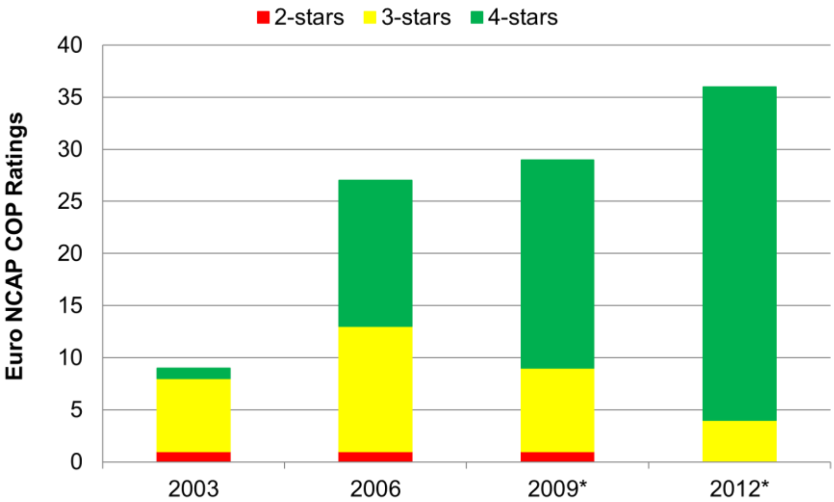

Figure 11. COP Ratings over the years. *For 2009 and 2013, COP percentage scores (used to compute the overall rating) were converted to COP stars using the original thresholds.

From 2013, the assessment of child occupant protection in Euro NCAP has taken a different direction. The objectives of the revision were twofold: firstly, to better address child seat misuse and handling issues through CRS installation checks and the promotion of i-Size; and secondly, to enhance the test relevance to real-world by including more biofidelic dummies and addressing more child ages.

Euro NCAP collaborated with ETC to select common installation seats with different characteristics: belt mounted, belt mounted with base & support leg, ISOFIX mounted with base & support leg rearward facing, ISOFIX with Top-tether mounted, ISOFIX mounted forward facing as well as i-Size variants [13]. Each car model has been assessed by installing each seat (in different modes if applicable) on all eligible seating positions in the vehicle.

Table 6 shows the number of vehicles in which one or more critical safety problems were found during the CRS installation check in recent years. A "safety critical problem" points towards an incompatibility between the CRS and the seating position in the vehicle, which could lead to incorrect installation or misuse. Overall, installation problems were found predominantly with universal, belt mounted child restraints, specifically on the front passenger and rear centre seating positions (Figure 12).

Table 6.
CRS Installation Check Results (2013-2018)

Rating year	Total number of cars*	Cars with one or more safety critical problem	Affected seating positions
2013	32	7 (22%)	Front, 2nd row centre and 2nd row outboard
2014	41	7 (17%)	Front, 2nd row centre and 2nd row outboard
2015	42	6 (14%)	Front, 2nd row centre and 2nd row outboard
2016	17	6 (35%)	Front, 2nd row centre and 3rd row
2017	59	20 (34%)	Front, 2nd row centre, outboard and 3rd row
2018	20	3 (15%)	Front, 2nd row outboard and 3rd row

**Excluding twins, partners, dual ratings and re-assessments.*

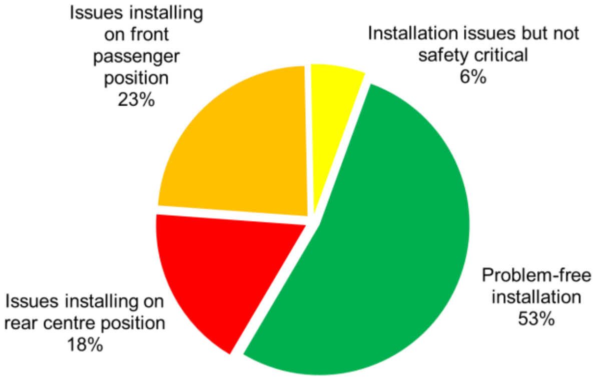

Figure 12. Issues encountered during installation of Universal CRS in Euro NCAP rated cars (N=17, 2016)

The decision to reward vehicle manufacturers for offering two or more i-Size positions has had a profound impact on the availability of the voluntary standard in new cars (Figure 13) in recent years. Within two years of the coming into force of Regulation 129 Phase 1 in July 2013, most cars tested offered two outboard i-Size compatible positions and, increasingly, the front or centre rear seats are also covered.

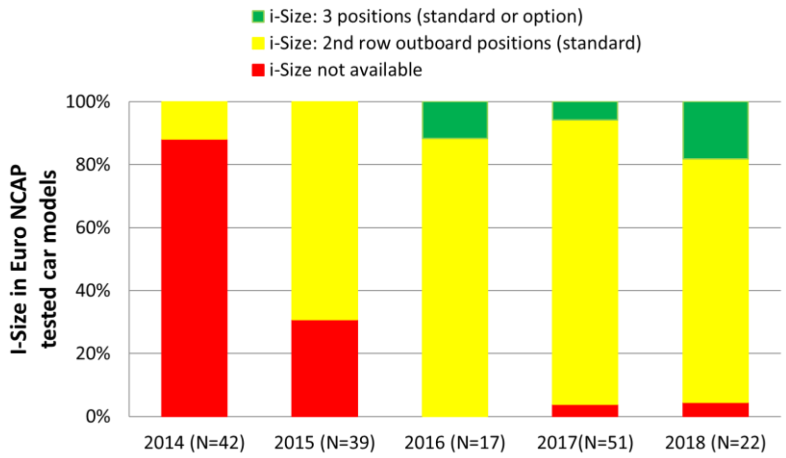

Figure 13. i-Size positions in Euro NCAP tested cars, from 2014 to 2018

If, for any reason children are obliged to travel in the front passenger seat in their child restraint system, it is important (and required by law) that the airbag is disabled. Euro NCAP also encourages automatic disabling of passenger airbag in case a child is detected. However, over the years most vehicle manufacturers have offered either a manual switch or a dealer-disconnect option instead. From 2016 onwards, several cars have been evaluated that offer automatic switches based on pressure-sensing technology in the passenger seat (Figure 14). Euro NCAP

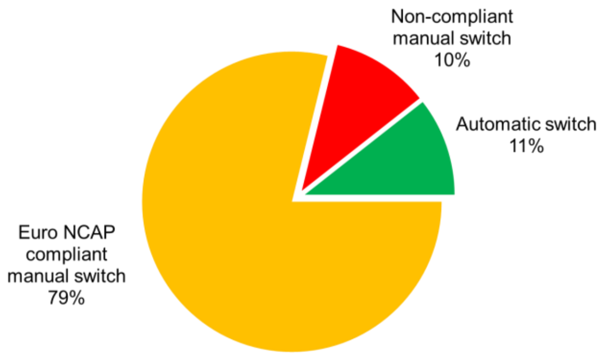

Figure 14. Airbag disabling switches in Euro NCAP tested cars (2016-2018, N=104)

has recognised the need to introduce a standard method of assessment for automatic passenger airbag disabling systems and introduced a laboratory test to check if the following requirements are met:

- Airbag is OFF when using a Rearward Facing CRS.
- Airbag is ON for a 5th percentile (female) occupant and above.

The responsibility for the remaining cases (forward facing CRS or child alone) is for the OEM, and different strategies are allowed. The requirements and test matrix covering a variety of possible occupant sizes and installation modes are listed in Euro NCAP Technical Bulletin 23 [14].

The availability of integrated seats as an option, let alone as standard, remains poor, despite the incentive that Euro NCAP has put in its test protocol. Primarily, large Volvo cars, including the S90/V90 and XC90, were equipped but only as optional equipment. Costs and conflicting design requirements are often cited as the main causes why integrated seats are not more common.

Finally, the new dynamic assessment using the Q6 in a booster seat and, in particular, the Q10 seated on a cushion has brought some new challenges for vehicle and CRS manufacturers [15]. Of the 114 models rated between the start of 2016 and the end of 2018, in 102 cases (89%) the Q6 was placed in a Britax-Römer supplied seat, most cases the KIDFIX XP (SICT) original or manufacturer branded. The seat had a reliable performance in both front and side impact crash tests, which explains its popularity amongst vehicle manufacturers. In general, Q6 results in Euro NCAP crash tests are good (Table 7), demonstrating that a child properly restrained in a CRS rated good by ETC and mounted correctly in the car with ISOFix/i-Size attachment points, is delivering a safe solution. In frontal impact, there were no instances recorded of hard contact with the vehicle interior, ejection or seat failures, and only in one case the Q6 submarined due to large forward rotation of the seat. In side impact, a few cases of hard contact where observed but only in one case did this result in the HIC value grossly exceeding the limit.

Table 7.
Euro NCAP COP Dynamic Test Results for Q6 Dummy (2016-2018)

Criterion	Performance Limits		Dummy Values		
	Higher	Lower	Average	Min	Max
Frontal impact (average B-pillar deceleration, 39g)					
HIC_{15} (with hard contact)	500	700	372	148	913
Head Resultant 3ms Acceleration (g)	60	80	59	40	91
Head Excursion (mm)	-	550	197	51	549
Neck Tension Fz (kN)	1.7	2.62	1.8	0.7	3.0
Neck Extension My with contact (Nm)		36	14	6	36
Chest T4 Acceleration (g)	-	-	47	35	61
Chest Deflection (mm)	30	42	20	13	26
Side impact (average B-pillar acceleration, 29g)					
HIC_{15} (with hard contact)	500	700	136	1	4675
Head Resultant 3ms Acceleration (g)	60	80	35	15	85
Neck Resultant Force (kN)		2.4	0.9	0.3	2.2
Chest T4 Acceleration (g)		67	32	13	54

The Q10 dummy more often caused issues during testing, revealing shortcomings in the rear seat restraint design for taller children. The dummy is placed on a booster cushion using the adult belt. The purpose of the cushion is to raise the seating position and improve the belt fit; the specific design of the cushion is less relevant however. For this reason, the cushion is most often selected from a list of available products.

In frontal impact, poor belt geometry may cause the belt to slide off the shoulder or towards the neck. In some cases, this has led to the dummy becoming unrestrained during the crash or to the dummy submarining, both of which incur a penalty. The Q10 dummy shoulder and barrel-like chest design is partly to blame for this behaviour and Euro NCAP has adopted suggested modifications to the dummy hardware to address this [16].

In side impact, both head contact with the C-pillar and head curtain bottoming out has been observed with high resulting HIC and Head Resultant Accelerations. An overview of Q10 dummy results can be found in Table 8.

Table 8.
Euro NCAP COP Dynamic Test Results for Q10 Dummy (2016-2018)

Criterion	Performance Limits		Dummy Values		
	Higher	Lower	Average	Min	Max
Frontal impact (average B-pillar deceleration, 39g)					
HIC_{15} (with hard contact)	500	700	254	111	908
Head Resultant 3ms Acceleration (g)	60	80	50	36	94
Head Excursion (mm)	450	550	184	40	551
Neck Tension Fz (kN)	1.7	2.62	2.1	1.5	4.1
Neck Extension My with contact (Nm)	-	49	13	5	34
Chest T4 Acceleration (g)	41	55	37	27	53
Chest Deflection (mm)	-	-			
Side impact (average B-pillar acceleration, 29g)					
HIC_{15} (with hard contact)	500	700	211	2	2245
Head Resultant 3ms Acceleration (g)	60	80	49	14	109
Neck Resultant Force (kN)	-	2.2	0.7	0.4	2.32
Chest T4 Acceleration (g)	-	67	50	17	88

DISCUSSION

Nowadays the ETC rating can make or break a product’s success on the market. A good rating can boost child seat sales, whereas products that have failed in the test have been recalled or even withdrawn from the market in the past. For this reason, a good ETC child seat rating is a design aim for many seat manufacturers. The impact of the ETC programme can be explained by its huge outreach to European consumers, but also because the tests are more realistic, more complete and more demanding than the basic regulatory tests. The consortium stands by its decision to withhold the exact details regarding the way that the rating is calculated to ensure that products are not optimised for the test. In other aspects, such as test procedure, supplier meetings, Fachbeirat, etc., ETC is committed to an open and transparent process.

In many cases ETC tests have revealed shortcomings in the regulatory tests and its finding have contributed to enhancements in type approval requirements. A good example is side impact protection, that has been addressed in the ETC test for many years. Consequently, most products on the market provided adequate side protection well before side impact test specifications and requirements were introduced in UN Regulation No. 129. More recently, the consumer groups have raised concerns about the absence of limits on neck tension force in Regulation No. 129, especially for babies in lie-flat infant carriers [17]. Likewise, they have observed inconsistencies with the abdominal load sensor specified in Regulation No. 129 which at present seems to be unable to distinguish between well and poorly designed child seats.

On the downside, ETC has been criticised for its favourable position regarding so-called booster shield systems, that do not require a belt harness to restrain the child. Many international experts do not consider booster shield systems appropriate crash protection for children, as crash investigations have documented ejections, excessive excursions, and shield-contact injuries in rollover, side and frontal crashes. ETC has adopted the abdominal load sensor in its recent tests to improve its assessment of injury risk in the abdominal region, but many still believe that shield systems should not be given the benefit of the doubt, even if laboratory test results indicate good performance. This situation is in stark contrast with the consortium’s red line on booster seats with removable backrest, that are always penalised for the perceived lack of side impact protection.

Euro NCAP is one of a limited number of NCAPs around the world that test child restraint systems in full-scale vehicle test conditions. Whereas the focus of ETC is on improving CRS performance, Euro NCAP addresses the car design, equipment and the interface with child restraint systems. A strong link between the programs has been forged to improve the situation on misuse of child restraints, where Euro NCAP verifies the problem-free installation of popular, well rated child restraints. Incentives for vehicle provisions such as ISOFIX and airbag disabling switches have been effective and their availability as standard has increased significantly as a result. But child occupant protection is only one of four pillars in the Euro NCAP star rating and underperforming in this area can lead to a lower overall rating or jeopardize investments in the other areas of safety. For this reason, Euro NCAP makes its test and assessment protocols public, including the criteria and their limits, generally with a short but adequate lead-time.

A key principle behind the COP assessment is that vehicle manufacturers should take responsibility for safe transport of adults and children alike. Among other things, this means that manufacturers must recommend the best child seats for their car for testing. In practice, this leads to a bias amongst the tested child restraint systems towards high-end products that are usually available Europe-wide and stable in the market. Normally, they only represent a small share of the sales and the dynamic results may be less useful to buyers of child restraints for that reason.

The shift in focus from toddlers to taller children in Euro NCAP testing was aimed at improving car restraints for the "forgotten age" of children. Many European countries require children to be in appropriate child restraints up to 12 years old or 150cm stature. Despite this, the use of CRS and particularly high-back boosters over the age of 8 years old is not widespread, leaving many children exposed to unnecessary risks. Euro NCAP's opinion is that adequate side impact protection may be more achievable with a booster cushion and well-performing vehicle restraint systems than through the enforcement of high-back booster use in the real world. This, however, puts Euro NCAP at odds with ETC.

CONCLUSIONS

Safe transport of children is the joint responsibility of consumers, and child restraint and vehicle manufacturers. The approaches presented in this paper are complementary and both are needed to improve child safety in cars. Both ETC and Euro NCAP can look back at many years of testing which has had a real impact on the situation in the market place. They share many principles, viewpoints and objectives, but they also have different opinions on some points.

In general, both programs will continue to evolve and be updated according to relevant technical developments (such as the availability of new test methods, dummies, sensors and criteria), be guided by societal and market changes and stay aligned with type approval.

As mobility continues to grow and is radically transformed by digitisation, decarbonisation and automation, the opportunities to further improve safety must be seized. This is also true for the safety of children in transport. For instance, child presence detection technology that can sense infants left in cars, are entering the market: built into the CRS, built into the car, or as loose accessories. Many them come with a smartphone app. ETC is exploring if and how this can be implemented in the program, while Euro NCAP will include this technology in the 2022 COP protocol [18].

We can expect that, in the future, communication protocols will allow the CRS and the car to exchange information, such as crash direction and severity, that features built into the CRS can detect [19]. The effectiveness of such technology may also be considered in one or both programmes, as it becomes available.

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