BEYOND NCAP: PROMOTING NEW ADVANCEMENTS IN SAFETY

Michiel van Ratingen
Aled Williams
Euro NCAP
Belgium
Pierre Castaing
UTAC
France
Anders Lie
Swedish Transport Administration
Sweden
Bernie Frost
Department for Transport
United Kingdom
Volker Sandner
ADAC
Germany
Raimondo Sferco
Ford Motor Company
Germany
Erwin Segers
Honda Motor Europe
Belgium
Christoph Weimer
Hyundai Motor Europe
Germany
On behalf of the Euro NCAP Beyond NCAP Group
Paper Number 11-0075

ABSTRACT

Over the last decade Euro NCAP has become recognised as a reliable indicator of independent consumer information with an acknowledged positive effect on car safety. Most car manufacturers see the positive advantages of ensuring their vehicles achieve the highest possible result in this consumer test program. For Euro NCAP to keep its relevance it is important that the program reflects the improvements made in car safety over time.

Many of today's technological advancements are in active safety, driver assistance or in the combination of primary secondary and tertiary safety. Many of these safety functions are so new that no clear-cut procedures exist to test and rate them. Given this challenge, a system that enables carmakers to receive added recognition for important innovations beyond the star rating could promote the development of superior safety improvements and accelerate the introduction of new technology. Rewarding safety innovations will also keep the carmakers' commitment to Euro NCAP and help improve vehicle safety for the whole community.

The "Euro NCAP Advanced" reward is an addition to today's star rating. With the support of the automotive industry, Euro NCAP has developed a methodology, referred to as "Beyond NCAP", to allow the potential safety benefits of any new safety function to be determined. This process is based entirely on the assessment of scientific evidence presented in a dossier by the car manufacturer. An independent panel of experts reviews the extent of a safety issue which a new safety system aims to address. Through a logical and rigorous analysis of the way in which the technology has been developed, tested and validated, and from any real-world experience that may exist, the system's performance and its expected effectiveness can be estimated and eventually rewarded.

In particular, any submission needs to provide reliable evidence of the tests conducted and any assumptions made in assigning possible benefits for the new safety function. The method used for making these assessments also needs to be scrutinized. The challenge is to understand with an acceptable level of confidence how reliable the data presented is without intimate knowledge and involvement in the development of the technology. This is addressed firstly by selecting independent experts which are able to make judgments about the level of scientific proof provided and whether the benefits claimed are realistic and achievable. Secondly, the credibility of the source of the data is an important indicator of the reliability of the findings. Thirdly, publication in the scientific

literature increases the reliability of the findings, although this may not always be possible at the time of submission for reasons of commercial confidentiality.

The recognition of the potential benefit of these new safety technologies in no way undermines the importance of basic safety assessment expressed by the star rating. For this it is important that Euro NCAP continues to assess vehicle safety using existing test procedures and criteria. It is expected that the Beyond NCAP process will help identify the best assessment methods for upcoming technology. Euro NCAP intends to implement these methods for an improved rating of car safety in the future.

INTRODUCTION

Euro NCAP has been markedly successful in helping to improve the crashworthiness of today's passenger vehicles around the world. Despite increasingly challenging requirements put in place since 2009 [1] many of today's passenger cars achieve a 5-Star overall rating. A recent comparison between Euro NCAP test results and real-world crash data [2] showed significant differences in injury risk between 2- and 5-star Adult Occupant Protection rated cars in Euro NCAP for risk of fatality, confirming that car manufacturers have focused their safety performance on serious crash outcomes.

The change in attitude by manufacturers towards Euro NCAP and the fact that their performance in Euro NCAP tests is frequently used as part of their marketing strategies is further evidence that Euro NCAP tests are taken seriously and deemed relevant. Over the years, interest by consumers across Europe has also grown, indicated by the increasing number of visitors on the Euro NCAP website from across the European Union and beyond. Recently, some European countries have started to use star ratings to provide tax incentives for purchase and use of safe cars or have incorporated a minimum star rating in their fleet buying policy.

Auto manufacturers' critical response to Euro NCAP has moderated considerably since it was introduced. Today, most of them see the positive advantage of ensuring their vehicles achieve high performance in a NCAP test. It is vital that this continues to ensure Euro NCAP's relevance in tomorrow's safety arena.

It is clear that Euro NCAP has been successful for a number of reasons. First, the community has grown to accept star ratings, which are easy and accessible, as a legitimate test of safety performance. As safety is now clearly a marketing tool by many manufacturers, it has created competition between many of them in offering the "safest" vehicle on the market. Indeed, many of today's manufacturers see safety as a core part of their brand image, which they would not like to lose.

Because of this success, however, Euro NCAP is in serious danger of becoming obsolete unless it continues to lead this activity. With the advent of rapid technological advancement in both active and passive safety, it is especially necessary to ensure Euro NCAP's assessment is further developed to take account of the safety benefits of new technologies. Knowledge about safety among manufacturers and component suppliers has grown noticeably over the last decade or two, in part, because of the efforts of bodies such as Euro NCAP. Many manufacturers are active in conducting their own safety research but while it would be expected that new innovative safety improvements would lead to increased scores in Euro NCAP ratings, this does not necessarily follow. Many of today's safety improvements are in active safety and many of these features are not taken into account (and do not fit) with the Euro NCAP's current predominately crashworthiness test approach. Moreover, a number of manufacturers exceed today's test criteria for which they receive little added benefit. It is clear that many of today's new vehicles offer safety levels well above those prescribed by government regulations; that is, best practice today exceeds prescribed mandatory levels of safety.

A system therefore that would enable auto manufacturers to receive a recognised reward for safety enhancements would seem to be a positive step forward in both developing superior safety improvements and the introduction of new safety technology. This would also act to increase their commitment to Euro NCAP in the years ahead and to work towards helping improve vehicle safety for the whole community of consumers in the coming years.

While Euro NCAP's work continues to re-examine the suitability, relevance and comprehensiveness of today's tests and threshold values as described in the Roadmap [3], this paper focuses on how the safety organisation is addressing the rapid introduction of new safety technologies, especially those aimed at preventing and mitigating crashes, and supporting the driver or rescue services.

THE PRINCIPLES OF BEYOND NCAP

Euro NCAP crashworthiness tests are based primarily on government regulation tests and injury criteria. In a number of cases, these test criteria are made more stringent to ensure a higher level of safety ensues. The tests are developed by international research organisations with industry and are accepted because of their high scientific validity. It is vital that any expansion of Euro NCAP activities is based on robust scientific procedures and best practices which are open and

transparent. This is critical for ensuring that Euro NCAP maintains its credibility among automotive and parts manufacturers as well as the community in general. It should also be transparent and subject to rigorous assessment to maintain Euro NCAP's leading role in this area.

For it to be appealing and meaningful, the new reward system must have the capability of assigning added benefits to new and innovative initiatives and technologies that are rapidly being developed by manufacturers in their quest to build safer vehicles that are not currently encouraged. Moreover, it must also be capable of fast progress to keep up in this dynamic environment. It is also important that any new development in Euro NCAP be sensitive to any potential misuse. Further, the process should act to encourage manufacturers to apply highest test standards to the safety system to ensure current safety improvement levels will continue.

Hence, the proposed "Beyond NCAP" methodology is an addition to today's assessment (star rating) process. It has the capability of assigning additional reward for any new safety technology introduced by a manufacturer where significant safety benefits can be demonstrated scientifically. Unlike normal NCAP testing, this process is based entirely on the assessment of scientific evidence presented by the car manufacturer. Timing is critical to be sure to keep up with safety advancements. Of course, Euro NCAP continues to assess vehicle safety using existing test procedures and criteria and to work towards reviewing these procedures and criteria as new evidence becomes available.

Safety Issue and Expected Benefit

Road safety has benefited greatly from adopting a scientific approach to problem resolution since the 1960s and 1970s. William Haddon proposed the "Haddon Matrix" as a systematic way of examining road safety problems and issues [4]. More recently, the process of "identification, investigation, implementation and evaluation" have become commonplace in the conduct of successful scientific studies.

In road safety, the first step in the process is identifying significant safety areas and the mechanisms of accidents and/or injuries that govern the problem. Historically governments and research organisations have used the traditional statistical approach. Moreover the manufacturers are playing an increasing role these days using their own in-depth crash data and/or data collected on their behalf, which normally allows a more detailed level of analysis.

Solutions often follow the identification of accident problems and causes. As with many scientific studies, the challenge often comes down to having reliable and plausible evidence available for analysis. In other words: How do you judge what the potential safety benefit is likely to be for any new safety advancement and what reward does one assign to this innovative measure? Assigning safety benefits without real world evidence of crash or injury savings is often fraught with difficulty. Nevertheless, governments and manufacturers are expected to make these assessments regularly when considering the introduction of new safety countermeasures. In passive safety, the most common method is to conduct a series of crash tests and convert the results into injury mitigations via injury assessment functions. Hence the assessment of the likely harm (deaths, injuries, and property damage) saved can be an effective means of expressing the safety benefit ahead of real world experience.

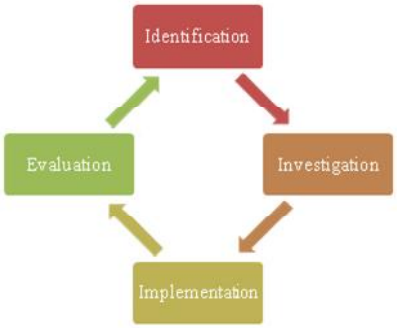

Figure 1 Scientific approach underlying the Beyond NCAP methodology.

While it is recognised that for active safety innovations the proposed safety benefit might be more complex to evaluate before introduction, the estimate of the expected real-world benefit based on a closed-loop "identification, investigation, implementation and evaluation" process is paramount to the "Beyond NCAP" methodology.

Assessment Procedures

A key chain in linking the safety issue with the expected benefit for a certain technology is the test procedure designed to verify the system's intended performance. Reliable evidence of the tests conducted, simulations run and any assumptions made in assigning safety benefits for the new technology need to be provided. The method used for making these assessments would also be required in order to evaluate its credibility. For Euro NCAP to know with an acceptable level of certainty how reliable these savings data are without intimate knowledge and involvement in the conduct of the study, the following is ensured:

Independent assessments Independent evaluators, typically experts in the area of interest are used to review the data provided. If conducted properly, peer-review processes can highlight

strengths and limitations in the processes followed during the analysis. Experts are able generally to make judgements about the level of scientific proof provided and whether the benefits claimed are realistic and achievable.

Best practice Best practice can be another means of assessing scientifically the potential safety improvement of new advancements. Methods applied that follow a best practice approach recognised by the scientific community may increase the levels of confidence that can be put on the data provided.

Data sources, references and citations The credibility of the source of these data is also an important indicator of the reliability of the findings. Independent test houses with an established reputation would generally be more likely to provide unbiased assessments of benefits than those with a vested interest in the results. Publication in the scientific literature is a good indicator of the reliability of the findings, although this may not always be possible at the time of submission for reasons of commercial confidentiality.

Witnessed demonstration In case of doubt in the test results and/or injury reductions claimed after a peer-review, or to enhance the information provided in the dossier, the manufacturer may be asked to demonstrate the system's functionality on the vehicle in the presence of one or more independent assessors.

The likelihood of potential harmful side effects is always difficult to judge from test data alone. Conducting a randomised control trial is often difficult to organise prior to the introduction of new safety technology, hence the need for ongoing monitoring of the real world experience using crash, performance data and/or user feedback. Without such analyses, it is impossible to judge whether the expected benefits from the technology have been, or are likely to be, realised.

PROTOCOL

Between the years 2006 and 2009 Euro NCAP members and industry representatives have developed a protocol documenting the "Beyond NCAP" assessment method [5]. The result is a procedure on how to verify and assess any new safety systems currently not already included in the rating scheme. The complete process is based on the notion that the manufacturer provides documentation (the "dossier") in a predefined and logical order, and that Euro NCAP will verify this documentation with regards to completeness, validity and reliability. The verification will be performed by an independent panel of experts, referred to as the Assessment Group, in two stages, involving the manufacturer in the consensus discussions at the end of each stage. Sensitive parts of the dossier can be made confidential at the manufacturer's request. If a robust case has been made by the manufacturer, the verification process will result in the decision to reward the manufacturer for the technology available on the vehicle at hand. This so-called "Euro NCAP Advanced" reward is limited to cars tested by Euro NCAP achieving at least three stars in the overall rating scheme (or in adult protection for cars tested before 2009).

Manufacturers can apply to Euro NCAP for safety systems that address all safety areas (primary and/or secondary and/or tertiary) except for those that are covered by existing Euro NCAP protocols. The Euro NCAP Advanced reward applies to the model on which it is fitted. However, it can be applied to other models with the technology provided sufficient additional information is shared on the safety system's functionality on the other models.

In the procedure the following steps are identified:

- Innovation;
- Safety Issue;
- Accident Mechanism / Injury Causation;
- Target Requirement;
- Test Procedures;
- Expected Benefit;
- Real World Evaluation / Experience

Figure 2 shows the relation between the different steps resulting in the assessment.

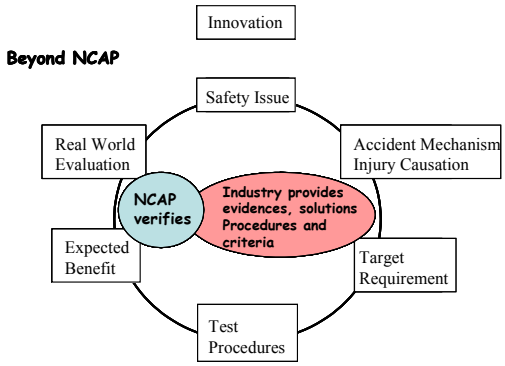

Figure 2. The Beyond NCAP assessment method

In the sections below each process for the assessment is described.

Innovation This first part of the dossier includes a technical description of the components and the functionality of the system. Based on the information provided to Euro NCAP, the dossier will identify if:

- the system is addressing primary and/or secondary and/or tertiary safety;
- a system with similar functionality has been assessed before;
- the system can be assessed with regular procedures (and hence whether it is already

covered by the star rating) or if a new procedure is required.

Safety Issue The next step in the process is to identify the relevance of the safety issue that the safety system aims to address. At this stage, the effectiveness of the safety system and any possible side effects are not considered. The key aspect is identifying the problem at large and the potential size of the safety benefit that the innovation does address in the context of entire Europe (EU-27 countries).

Based on the system's specification given in the first part, the field of application of the safety system has to be defined. This information is then judged by Euro NCAP on the:

- reliability of the methods;
- validity of the used data sources.

If the methods used are reliable and the data sources used are representative, then this will result in an agreement on the potential size of the safety benefit for the specific technology presented.

Note that the information provided here is most likely based on accident data, European or even transferred data could be used, indicating the number of accidents with, for example, severe injuries relevant to the safety system being assessed.

Accident mechanism / Injury causation After defining the type of innovation and identifying how many fatalities or injuries can potentially be saved by the system, the injury mechanisms/crash mechanisms causing the problem to be addressed by the innovation are defined.

Detailed understanding of the accident mechanism and/or injury causation is needed to ensure a correct definition of the target requirement and technical assessment (investigation of the correct phenomena) in a later stage. This investigation will identify:

- the accident mechanism and/or injury mechanism;
- the driver behaviour (if applicable, for instance for ADAS systems);
- the injury risk or transfer functions identifying the main accident parameters governing the system's effectiveness;
- the reliability and the validity of the data;
- the methods and the tools proposed.

This review should result in a deeper understanding of what key parameters are contributing to the accidents and their outcomes and which of these parameters will be used or have to be controlled by the system to deliver the benefit.

Target requirement The target requirements are the requirements set by the manufacturer on the important system parameters, identified in the last section. These form the basis for the criteria used in the test(s) proposed for the system. The target requirement needs to be defined in such a way that it is possible to know what the "innovation" is theoretically expected to do (e.g. keeping a car in the desired lane by a set lateral distance for lane keeping systems, or to keep the load on an occupant's chest below a certain threshold for an airbag).

The output from this part of the procedure is the:

- definition of the target requirement(s) in relation to methods and tools;
- understanding of the relationship between criteria and the system's benefit.

Test procedure This part of the dossier presents the methods by which the manufacturer has verified that the system works in the intended situations and in the designed manner. Evidence is requested that the system meets the manufacturer's own targets, and/or to estimate the technical efficiency on the basis of test series carried out. The test methods and target requirement(s) used to assess the performance of the innovation are reviewed considering the:

- methods and tools used;
- source and independence of data;
- reliability and validity of the results;
- criteria used;
- assessment procedure and results.

The test methods and criteria range from methods used in regulation or Euro NCAP to methods used by the industry internally. Also depending on the innovation and the target requirements, the testing can be performed experimentally, by computer simulation or a combination of both.
For ADAS systems in particular, driver simulator studies are relevant to quantify the effectiveness of the Human Machine Interface. The results will be input for the expected benefit discussions.

Expected benefit Having documented the actual performance of the system in relevant test conditions, and understanding the link between meeting the targets and the potential benefit of the system, the expected benefit of the innovation can be calculated. In the assessment process the following is considered:

- available methods / accepted methods;
- accident data used;
- inclusion of any side effects (e.g. driver adaptation);
- potential level of dissemination (for information only);
- market share (for information only);
- expected benefit evaluation.

Although the expected benefit is derived at the vehicle level (i.e the benefit assuming all cars were equipped with the technology), information is also requested on the potential level of dissemination of the system (is it standard on all variants, is it an option that is available on some variants) and the expected market share (expected number of sold vehicles per year). Note that both the potential level of dissemination and the expected market share are only for information and will not affect the expected benefit (at the vehicle level). However these numbers can be taken as an indication of the manufacturer's confidence in the system.

Real world evaluation / experience The real world evaluation is the final step in the dossier. Only by following up in the real world, can the true effect of safety developments be verified. The effect in real life may be different from the expected benefits in many ways. For instance, the accident or driving scenarios may differ, and drivers from a wide range of backgrounds may use the system in an unpredicted way. Generally, information learned from the follow up exercise can be used as input for the next development loop.

In the Beyond NCAP evaluation approach, the real world follow up is part of the case built by industry. The quality and credibility of the follow up can potentially influence the credit Euro NCAP gives to the innovation under study.

The most suitable method for real world evaluation is the *a posteriori* analysis using representative and detailed accident data. However, such studies are found to be complicated and very time consuming, in particular for avoidance systems. As such, there is an inherent conflict between a good quality real world evaluation process and the need for rapid answers. For systems only recently introduced or not yet available, no data may be available to perform a meaningful real world evaluation study. Especially for these systems, results from fleet studies with a limited number of vehicles and a limited number of drivers, feedback from consumers or even simulation studies can provide some indication of the real world benefit.

Generally speaking, systems with big effects are straightforward to verify, but systems with limited safety benefits are more complicated and time consuming to evaluate. For some systems, long term follow-up is necessary to understand behavioural adaptation.

FIRST RESULTS

Starting from 2010, the Beyond NCAP assessment method has been added to the Euro NCAP car safety program. Several manufacturers have been handed the Euro NCAP Advanced reward to complement the overall star rating achieved for a car model tested previously.

Successful applications represented a wide variety of safety systems recently introduced on the European market, including autonomous braking technologies (Honda CMBS), Lane Departure prevention and lateral assist (Opel Eye, Infinity LDP, VW Lane Assist, Audi Side Assist), pre-crash safety systems (Daimler Pre-Safe / Brake) and eCall systems (BMW Advanced eCall and PSA). In the development of the dossiers, extensive use was made of GIDAS (D) data, where possible supplemented with CCIS (UK), LAB (F) or non-European data. Most manufacturers were forced to make broad assumptions regarding the potential safety benefit for EU-27 due to a clear lack of statistics. This part has proven particularly challenging for those technologies that rely on the road or telecommunication infrastructure (e.g lane markings, GSM coverage).

Where the role of the driver is key in effectiveness of the system (e.g. warning based ADAS), a few manufacturers have referenced driver simulator studies and fleet operational trials, most outside the European Union. Surprisingly, very limited data was been offered regarding real world experience, even for systems that were on the market for longer periods outside of Europe.

DISCUSSION

The Beyond NCAP methodology proposes a new and unconventional way of assessing vehicle safety functions. The process presented here brings about positive aspects but also has its inherent risks. As the system was developed collaboratively between the auto industry, governments and consumer groups, the manufacturers have been committed to the new system from the start. The well structured approach facilitates an open platform of technical dialog between manufacturer and Euro NCAP's stakeholders whereby the manufacturer's in-depth knowledge about the system can be explored and design choices challenged. It will, it is hoped, lead to the identification of acceptable test and review processes as well as addressing issues associated with commercial confidentiality and additional research needs.
On the downside, the system is based entirely on evidence provided by car manufacturers and can easily be perceived as industry biased if not well understood. The process with its strong emphasis on safety benefit is held back by the relatively poor availability of high quality accident data across the European Union and the low market penetration of advanced safety systems on the European market to date.

The Euro NCAP Advanced reward system is open to different technologies but at this stage is unable to discriminate between comparable technologies based on real world effectiveness. A stronger feedback mechanism on real-life performance of systems assessed, involving industry and Euro NCAP, could provide a stronger basis for comparison. Hence, with increasing availability on the market, it is expected that knowledge will come available that would allow Euro NCAP to rate systems, for which the test procedures would be placed in one of the existing rating boxes [1].

CONCLUSIONS

Euro NCAP and car manufacturers jointly developed the Beyond NCAP methodology which allows the potential safety benefits of any new technology to be determined. The assessment is based entirely on scientific evidence and data presented by the vehicle manufacturer. A panel of independent experts looks at the extent of the safety problem which a new technology aims to address. Through a logical and rigorous analysis of the way in which the technology has been developed, tested and validated, and from any real-world experience that may exist, the system's performance and its expected effectiveness can be determined. Over the last year, already 13 systems have been assessed in this way, 11 of which were successful and were rewarded under the Euro NCAP Advanced banner. By rewarding technologies, Euro NCAP hopes to provide an incentive to manufacturers to accelerate the standard fitment of important safety equipment across their model ranges and helps the car buyer making a better informed purchase decision.

The consequence of the Beyond NCAP method described in this paper is that the car industry is given credit for new safety technology and improvements, on a "scientific" basis. The basic work to develop the evidence will be the role of industry, which in turn will make rewarded technology relevant in improving real world safety. When this becomes a natural process, it will also produce an implicit barrier to innovations that are not effective. The method itself will be reviewed and fine tuned from time to time in collaboration with the auto industry.

The recognition of the potential benefit of these new safety technologies in no way undermines the importance of basic safety assessment expressed by the star rating. For this it is important that Euro NCAP continues to assess vehicle safety using existing test procedures and criteria. It is expected that already by 2013 some technologies recently awarded will be included in the overall star rating [3].

Finally, the consumers play an important role in the quest for better safety and it is vital that they are kept informed about what is a desirable as well as an undesirable new technology. Beyond NCAP and the Euro NCAP Advanced rewards offer a mechanism for further advancing knowledge on safety technology in cars among the end users, the importance of which cannot be overstated.

ACKNOWLEDGEMENTS

Members of the Beyond NCAP Group:

Euro NCAP
M. van Ratingen (Chair 2008-2009)
A. Williams (Secretary)

Members and laboratories
P. Castaing, UTAC (Chair 2005-2007)
B. Frost, UK DfT
P. Lemmen, T. Versmissen, R. Corbeij, TNO
A. Lie, SRA
I. Ferrer, IDIADA
R. Ambos, V. Sandner, ADAC
A. Miller, Thatcham

Industry
R. Sferco, Ford Motor Europe
R. Zeitoni, PSA
T. Kreuzinger, M. Ranovona, Toyota
D. Ockel, Daimler
K. Van der Plas, E. Segers, Honda
D. Barberis, Fiat
K. Schmelzer, BMW
C. Weimer, Hyundai
A. Kennedy, Nissan

REFERENCES

[1] Van Ratingen, M. 2008. "The Changing Outlook of Euro NCAP." In Proceedings of the Airbag 2008 9th International Symposium & Exhibition on Sophisticated Car Occupant Safety Systems, (Karlsruhe Dec. 1-3).

[2] Kullgren, A., Lie A. and Tingvall, C. 2010. "Comparison Between Euro NCAP Test Results and Real-World Crash Data." Traffic Injury Prevention, Volume 11, Issue 6 December 2010, pages 587 – 593.

[3] Euro NCAP. 2009. "Euro NCAP 2010-2015 Strategic Roadmap", published Dec. 2009. www.euroncap.com.

[4] Haddon W. 1970. "On the escape of tigers: an ecologic note." Am J Public Health 1970; 60: 2229-34 doi: 10.2105/AJPH.60.12.2229-b.

[5] Euro NCAP. 2010. "Beyond NCAP Assessment Protocol Version 1.1." Published Feb. 2010. www.euroncap.com