European Commission

Safety Ratings 2016

European Road Safety Observatory
www.erso.eu

Transport

CONTENTS

1 Overview

This summary presents an introduction to the safety rating systems in use internationally. Given the wide variety of systems, their different methodologies and the volume of valuable information which they provide, this summary seeks to provide a gateway to the websites which explain these systems in appropriate detail rather than provide comprehensive information.

What are safety ratings?

Safety ratings in use today are objective, essential Safe System tools for benchmarking, targeting and monitoring key aspects of road traffic system safety quality and potential for improvement. The safety ratings in use either predict safety outcomes in key accident scenarios for given designs or provide a retrospective assessment based on accident data.

Who are they for?

The impartial and objective information provided by safety rating systems is designed for use by many sectors. These include policymakers, employers, road and vehicle planners, engineers and operators, road safety professionals, practitioners, and economists in the establishment, implementation and monitoring of road safety targets, strategies and interventions. Safety ratings also assist fleet buyers and car buyers in their purchasing decisions.

Why use safety ratings?

The level of ambition associated with global Sustainable Development Goals, European and national goals and targets and the Safe System approach require greater attention than before to the provision of a safe network, safe vehicles, better emergency care systems and compliance of users with key safety rules. This also involves meaningful leadership, shared responsibility and partnerships on the part of system providers and other key agencies. Safety ratings today address many of these needs and provide a basis for targeting and monitoring results as well as the changes needed to provide them. They can be used as road safety interventions, road safety policy and strategy monitoring tools and for setting specific intermediate outcome targets for road safety strategies around which stakeholders can focus activity and resource.

Safety ratings in use?

A wide variety of safety rating systems are currently in use providing an impartial means of assessing the relative performance of:

- New vehicles in crash tests (e.g. Euro NCAP, Australasian NCAP, US NCAP, Japan NCAP, Korean NCAP (South Korea), China NCAP and Latin NCAP, Asean NCAP and Global NCAP).
- The safety performance of 'on the road' vehicles in accidents (e.g. Folksam car safety rating).
- Different parts of the road network through risk-mapping and road protection scores (e.g. EuroRAP, AusRAP, KiwiRAP, iRAP (now being used widely in low and middle income countries) and usRAP, which is under development as a national scheme.
- Safety equipment: child restraints (e.g. UK TRL Child Seat Rating Scheme, Australia's CREP) and crash helmets (e.g. SHARP).
- National road safety performance in relation to other countries (e.g. ETSC PIN, IRTAD benchmarking)
- The safety quality of commercial road transport operations (e.g. the Q3 - work-related safety ratings in Sweden).
- A model for star rating the safety of school walking routes has been devised and piloted in Australia but requires further testing.

Effectiveness of safety ratings?

Safety ratings are an effective road safety tool. Research and experience shows that, when used in combination with legislative standards either planned or in use, they can contribute to large reductions in road traffic casualties. High quality data are a prerequisite for effective rating systems.

Euro NCAP: Three years after its introduction, Euro NCAP research reported that cars with three or four stars were approximately 30% safer, compared to two star cars or cars without a Euro NCAP score, in car to car collisions. In the last decade, accident data has confirmed that a 50% reduction in the risk of serious injury in car accidents has been achieved in new car models. Research concludes that a good correlation exists between Euro NCAP test results and real-world injury outcomes with 5-star rated Euro NCAP cars found to have a 68% lower risk of fatal injury and a 23% lower risk of serious injury compared to 2-star rated cars.

EuroRAP: A EuroRAP review found some evidence of a link between average accident rates or accident costs associated with increasing Star Rating and vice versa in different models that include elements of both accident protection and accident likelihood and from the model with only accident protection elements While there was some variation between studies, the review reported that the more robust studies showed an accident rate reduction in the region of a third to a half when moving from a 2-star to 3-star rating. The reduction was often found to be less when moving between higher Star Ratings.

Communicating results?

There are several issues regarding presentation of results. Safety rating systems need to be built on and promote objective, comparable safety data. It is thus important that the 'messenger' is independent and seen as independent of commercial influence, particularly where the results of safety tests of manufactured products are compared. Most rating systems have achieved this with broad international consortiums of motoring and consumer organisations, governments from several countries and independent experts (See the EuroRAP and Euro NCAP partnerships). The assessment procedures and protocols also need to be transparent. Given the variety of safety rating systems which exist, each publication needs to explain clearly what the particular safety rating in question means and to draw attention to any limitations. Given the wide audience for results, these need to be disseminated widely but targeted at the same time at the road-using public, car and infrastructure providers, fleet buyers and decision makers in general.

2 What are safety ratings?

Safety ratings in use today are objective and influential tools for the assessment and improvement of aspects of the safety of vehicles and crash protective equipment, the road network, work-related road safety and international safety performance.

Safety ratings either predict safety outcomes for given designs or provide a retrospective assessment based on accident data. Different safety rating systems currently in use provide an impartial means of assessing the relative performance of:

- New vehicles in crash tests (e.g. Euro NCAP, Australasian NCAP, US NCAP, Japan NCAP, Korean NCAP (South Korea), China NCAP, Asean NCAP, Latin NCAP). Global NCAP was announced in

June 2011 and serves as a platform promoting the development of NCAPs worldwide and encouraging best practice in the use of consumer information to promote road safety.

- The safety performance of 'on the road' vehicles in accidents (e.g. Folksam car safety rating).
- Different parts of the road network through risk-mapping and road protection scores (e.g. EuroRAP, AusRAP, KiwiRAP, iRAP - now being used widely in low and middle-income countries and usRAP).
- National road safety performance in relation to other countries (e.g. ETSC PIN, IRTAD benchmarking)
- The safety quality of commercial road transport operations (e.g. the Q3 - work-related safety ratings in Sweden).
- Safety equipment: child restraints (e.g. UK TRL Child Seat Rating Scheme, Australia's CREP) and crash helmets (e.g. SHARP).

3 Who are they for?

The impartial and objective information provided by safety rating systems is designed for use by:

- Policymakers, employers, professionals and practitioners in the establishment, implementation and monitoring of road safety targets, strategies and interventions at country or organisational levels;
- Car and equipment manufacturers, so they can benchmark the safety performance of their products against other products and make improvements;
- Road planners, engineers, operators;
- Fleet buyers to inform choice in purchasing;
- Transport economists;
- Road users in general who benefit from the use of safety rating tools in selecting routes, cars and safety equipment.

4 Why use safety ratings?

Over the last decade, safety ratings have been established as an important targeting and monitoring tool in managing for ambitious road safety results.

The global crisis of road traffic injury for low and middle-income countries and the increasing level of ambition associated with global, European Union, national goals and targets and the Safe System approach requires:

- greater attention than before to the provision of a safer network, safer vehicles, better emergency care systems and compliance of users with key safety rules.
- more account to be taken than before of human limitations, speed and kinetic energy in considering road safety intervention and in the institutional arrangements needed to deliver them.
- meaningful shared responsibility to improve safety on the part of system providers (for the road network, vehicles and the emergency medical system) as well as ensuring that users comply with the system rules, focusing particularly on the necessary linkages between different parts of the system.

Safety ratings today address such needs and are used as:

- road safety interventions to improve standards and designs through the publication of impartial information which gives system providers an incentive to make improvements.
- policy monitoring tools.
- sources of data to aid the setting and monitoring of specific interim and intermediate outcome targets for road safety strategies around which stakeholders can focus results-focused activity and resource.

Several countries include EuroRAP/iRAP and Euro NCAP/NCAP protocols and performance indicators in national safety strategies and target-setting.

4.1 Ratings as interventions

The potential contribution of vehicle and road engineering measures to achieving interim national road safety targets and long-term goals is very large (Koornstra et al, 2002), (Broughton et al., 2000; Castle et al, 2007b). Safety ratings can be used as an intervention to identify, promote and encourage improved standards and designs to improve levels of accident protection in vehicles and in the road network.

For example, whereas legislation provides a long-discussed minimum statutory standard of safety for new cars, it is the aim of European New Car Assessment Programme (Euro NCAP) to encourage manufacturers to exceed these minimum requirements in a short space of time. Here the basis for rating is continuously updated to reflect the state of the art. Policymakers, practitioners, fleet and car buyers, and road users all need impartial, evidence-based data to inform policymaking, for day-to-day road safety activity, and for purchasing and travel decisions. Car buyers, for example, need to assess the safety claims made by manufacturers made in car advertising. Relevant and impartial information allows consumers to make well-informed decisions when buying a car. When Euro NCAP was first introduced in the late 1990s, a level of safety performance equivalent to a 2-star rating comprised the industry norm. Now, 5-star cars comprise the majority of new cars being offered for sale in EU countries. Such ratings can also encourage manufacturers to make progress in key areas not yet covered comprehensively in legislation such as the fitment of seat belt reminders, speed assistance systems, whiplash prevention systems and other proven driver assistance safety technologies.

Road assessment programmes e.g. iRAP, EuroRAP, aim to help prevent accidents and to make those that occur survivable through its risk-mapping and road protection score methodologies. Responsible, law-abiding drivers are frequently injured fatally or disabled permanently on Europe's roads because of small errors. Safe roads minimise the chance of these situations arising, and when they occur, minimise the severity of the accident.

Crash helmet and child restraint assessment programmes can also be thought about as potential interventions, encouraging buyers to choose the safest equipment currently on the market.

4.2 Ratings as monitoring tools

Vehicle, vehicle equipment and road network safety ratings provide a useful policy tool for monitoring the safety quality of the vehicle fleet and the road network and the related intermediate outcomes of specific interventions adopted and implemented in the national road safety strategy. Such ratings provide more detailed as well as more immediate information

about safety performance than can be achieved by final outcome data on deaths and serious injuries. For countries starting out in road safety and which have not yet set up usable, quality accident injury date systems, then safety rating assessments of the high-volume part of the network will allow intervention work to proceed, albeit when resource and capacity allow. Examples of performance indicators from safety rating systems used in Sweden's last road safety plan are shown in Table 1.

Table 1: Safety rating performance indicators used in Sweden

Percentage of vehicle mileage on roads that fulfill EuroRAP four stars (rural areas)
Percentage of vehicle mileage with vehicles that fulfill Euro NCAP five stars (newly registered)
Percentage of vehicle mileage with vehicles that fulfill Euro NCAP five stars (existing vehicle fleet)

Source: SRA, 2006

Through its risk-mapping methodology and performance tracking protocol, EuroRAP and other road assessment programmes provide an opportunity to produce a regular measure of safety performance on a consistent basis. This shows in detail how risk is changing in different parts of the road network in different countries, and also the potential for improvement in a way that can be linked to specific programmes. EuroRAP also shows how infrastructure improvements in each country can contribute to EU targets for casualty reduction (Lynam et al., 2004).

4.3 Ratings as intermediate outcome targets

Counties with ambitious road safety goals and targets are increasingly using intermediate outcomes (causally related to death and serious injury) for closer safety management. Several countries set such targets using safety rating data. For example, a target can be set to increase the percentage of cars with 5-star Euro NCAP ratings in the national fleet.

Another example is to increase vehicle mileage on roads that fulfill EuroRAP 3 or 4 star ratings in rural areas by a specified percentage over a given time period. The approach to achieving this is likely to be a combination of mass action implementation of effective safety measures, and major upgrading of some parts of the network to a higher standard. EuroRAP thus provides a basis on which to assess both what risk levels are desired, and what changes to the road infrastructure are needed to provide these levels (Lynam et al., 2004).

Examples of the current use of safety rating systems used for intermediate outcome target-setting purposes are given below.

Table 2: Safety ratings used for intermediate outcome targets: Sweden 2015

Indicator/outcome measurement	Starting point	2014	Target to 2020
Share of new passenger cars sales with the highest Euro NCAP score	20%	57%	80%

Swedish Transport Administration, 2015

The Netherlands has targeted a minimum 3-star safety performance on national roads by 2020 and the Dutch automobile club ANWB is financing widespread and long-term road inspection surveys to generate star ratings in a regular basis.

Highways England is working towards the goal of bringing the number of people killed or injured on the network as close as possible to zero by 2040. It has set a target that by the end of 2020 more that 90% of travel on the strategic road network is on roads with a safety rating of EuroRAP 3* (or equivalent). The majority of those roads with 1* and 2* safety rating will be improved to 3* (Highways England, 2015).

5 Safety ratings in use

5.1 Vehicle safety ratings

A wide variety of vehicle safety ratings have been developed since the 1970s and these have evolved largely independently of each other. Predictive systems provide information on the performance of new cars and equipment in various crash tests, whereas retrospective systems inform about the safety performance of cars already on the road on the basis of accident data. Predictive systems provide a more objective assessment of vehicle safety, but only for the conditions tested, whereas retrospective rating systems, when controlling for external factors, offer useful information on performance across the range of accident conditions and for all seating positions. Each system has been shown to usefully contribute to the provision of safety information to the consumer (ETSC, 1995).

5.1.1 Predictive vehicle safety ratings

Predictive systems aim to assess a car's safety performance before it is used on the road. The predictions are based on controlled whole car crash tests of individual models; tests of components of the car which have been proven to be important in accidents; and/or visual inspections and rating of the interior of cars and expert assessments.

Consumer information based on crash tests started in Europe in the late 1980s with German motoring organisation and magazine publication of results of frontal crash tests. In the early 1990s the UK WHICH? Magazine published the results of the Secondary Safety Rating System in Cars – a mix of visual inspection and component testing (Consumers Association 1993). This system later became the European Secondary Safety System which was used by the EU-wide umbrella organisation – the European Consumers organisation (BEUC) and International Testing (IT, 1994).

New Car Assessment Programmes (NCAPs)

New Car Assessment Programmes (NCAPs) are predictive safety rating systems and assess a new car's safety performance before it is used on the road. They have been established in the US, Australia, Japan, Korea, China, Latin America, Malaysia and Europe and are an important catalyst for improving vehicle safety. An Asean and Global NCAP have been established. While tests vary over different NCAPs, predictions can be based on controlled whole car crash tests of individual models; tests of components of the car which have been proven to be important in reducing fatal and long-term injury in accidents; and/or visual inspections and rating of the interior of cars. The aim of this information is to provide objective data to highlight the maximum

level of protection available to car buyers and to complement regulation which, in EU Whole Vehicle Type Approval, should stipulate a high but only a minimum level of protection. The UN's five pillar Global Plan for the Decade of Action recommends that countries should support the "implementation of new car assessment programmes in all regions of the world in order to increase the availability of consumer information about the safety performance of motor vehicles".

- Global New Car Assessment Programme (Global NCAP)
(**www.globalncap.org**)
Global NCAP is the global umbrella body for NCAPs around the world. Global NCAP is a non-profit organisation registered in the UK and was launched in June 2011 in support of the Decade of Action. Its Mission Statement outlines that:

- GNCAP aims to support the development of new consumer crash test programmes in emerging markets where vehicle growth is strong but independent consumer information on crashworthiness is frequently not readily available. To achieve this GNCAP will offer support to New Car Assessment Programmes in emerging economies and regions by offering technical support guidance and quality assurance.
- GNCAP provides a platform for cooperation for NCAPs and like organisations around the world to share best practice, to further exchange information, and to promote the use of consumer information to encourage the manufacture of safer cars across the global automotive market.
- GNCAP carries out research on innovations in vehicle safety technologies, their application in global markets, the range of policies that will accelerate their use and monitor the progress of vehicle safety across the globe.
- GNCAP will also develop a global awards scheme to recognise achievement in vehicle safety, innovation in safety related technologies, and products.

Typically, NCAPs carry out crash tests on new cars and then make a rating assessment of the vehicle's performance with 'five stars' representing a high score (Global NCAP, 2015). While most cars tested in EU countries receive a 5-star rating, performance globally varies widely. For example, the latest Indian crash test results from Global NCAP released in May 2016 in Delhi indicates that all five models tested rated as zero star. The Renault Kwid, Maruti Suzuki Celerio, Maruti Suzuki Eeco, Mahindra Scorpio and Hyundai Eon all showed low levels of adult occupant protection.

Given the current widely differing make-up of the global car fleet in terms of age and safety performance and the differences in NCAP assessment tools and testing procedures around the world, Global NCAP believes that a single global 'five star' rating is neither feasible nor desirable. The diversity in NCAP testing helps increase knowledge, promote innovation, and can be adapted far faster than regulation. Global NCAP believes that the strongest priority for global harmonisation is with the UN's minimum standards to establish a regulatory floor and level playing field. Until this is achieved, NCAP harmonisation is considered premature. The Global NCAP road map for safer cars globally sets out the following 10 recommended actions to address the 2020 global road safety target (Global NCAP, 2015):

Box 1: Recommended actions by Global NCAP road map

1. That all UN Member States adopt Global NCAP's two stage minimum car safety regulation plan by the end of the UN Decade of Action in 2020. Stage One – Crashworthiness and Child Restraints and Stage Two – Crash Avoidance and Pedestrian Protection
2. All UN Member States with significant automobile production should participate in the World Forum for Harmonisation of Vehicle Regulations to promote a levelling up of the safety standards in an open and competitive market for automobiles and their components.
3. Fleet purchasers both in the private and public sectors and rental companies should adopt Global NCAP's Buyer's Guide and choose 'five star' vehicles wherever possible.
4. Governments and the insurance industry should provide fiscal incentives and discounts to car buyers opting for safer models to encourage more rapid deployment of new technologies through the passenger car fleet.
5. NCAPs should be supported by Governments and donors to extend consumer related testing to include all the world's major automobile markets and the widest range of models especially the most popular and important.
6. Investment should be encouraged in laboratory capacity and skills training to enable homologation, in-use compliance and independent NCAP testing in all world regions.
7. The automobile manufacturers should make a voluntary commitment to apply front and side impact crash test standards (UN Regulations 94 & 95 or FMVSS 208 & 214) to all their new models from 2016.
8. The automotive industry should cease the practice of de-specification and bundling of safety features. Instead they should make available the full range of safety design and devices in all their major markets and price the relevant technologies separately.
9. The automobile manufacturers should improve the content of their sustainability reporting to include data on the applied safety standards of its global vehicle production.
10. To sustain the in-use safety of automobiles UN Member States should, a) apply conformity of production checks to models already approved on their market, b) carry out regular roadworthiness testing and include tyre depth and pressure checks in such PTI requirements, and c) consider using scrappage schemes to remove older unsafe vehicles from the road.

Source: Global NCAP, 2015

- European New Car Assessment Programme (Euro NCAP)
(**www.euroncap.com**)

Euro NCAP was established in 1997 and, over the last twenty years, has adopted progressive methodologies and protocols for assessing new car safety performance under certain conditions. More than 500 car models have been tested by Euro NCAP since its introduction. Euro NCAP provides motoring consumers, with an independent assessment of the safety performance of some of the most popular cars sold in Europe. Through its stringent protocols for vehicle crash testing, Euro NCAP has rapidly become a catalyst for encouraging significant safety improvements to new car design. (See links to the Euro NCAP website throughout for more than summarised information).

Euro NCAP is backed by five European governments, the European Commission as well as motoring and consumer organisations in every EU country. Euro NCAP is acknowledged as the most advanced of all the current NCAP programmes, and several NCAPs such as the Australian New Car Assessment programme have aligned their protocols to it. Euro NCAP provides star ratings of the performance of new cars using state of the art crash tests and inspection protocols.

The Euro NCAP rating

Euro NCAP has created a five-star safety rating system. The safety rating is determined from a series of vehicle tests, designed and carried out by Euro NCAP. These tests represent, in a simplified way, important real life accident scenarios that could result in injured or killed car occupants or other road users. The five-star safety rating system continuously evolves as older technology matures and new innovations become available. This means that tests are updated regularly, new tests and protocols are added to the system and star levels adjusted. The year of test is thus vital for a correct interpretation of the car result. General guidance as to what safety performance the stars refer to in today's system is provided in Figure 1.

Figure 1: EuroNCAP stars and safety performance

★★★★★	**5 stars safety**: Overall good performance in crash protection. Well equipped with robust crash avoidance technology.
★★★★☆	**4 stars safety**: Overall good performance in crash protection; additional crash avoidance technology may be present.
★★★☆☆	**3 stars safety**: Average to good occupant protection but lacking crash avoidance technology.
★★☆☆☆	**2 stars safety**: Nominal crash protection but lacking crash avoidance technology.
★☆☆☆☆	**1 star** safety: Marginal crash protection.

Since 2009, Euro NCAP has released an overall rating for each car tested with a maximum of 5 stars for nine classes of vehicle from super-minis to large off-road 4x4 vehicles. The rating is comprised of scores in four important areas:

- Adult protection (driver and passenger)
  Points are awarded from frontal, side and pole impact tests. Modifiers are also given to extend the assessment to cover different sizes of people in a variety of seating positions, in particular for the knee contact area. The Adult Protection score is completed with the result of the Whiplash test that is carried out separately on the driver or passenger seat. Euro NCAP ratings are comparable only between cars of similar mass and with broadly similar structures. Euro NCAP groups cars into the following structural categories: passenger car, MPV, off-roader, roadster and pickup. Within each of those categories, cars which are within 150Kg of one another are considered comparable.

- Child protection
  As part of this assessment, Euro NCAP uses 18 month-old and 3 year-old sized dummies in the frontal and side impact tests. As well as studying the results from the impact tests, Euro NCAP verifies the clarity of instructions and seat installation in the vehicle to ensure that the child seat can be fitted safely and securely. The score depends on the child seat dynamic performance in front and side impact tests but also on the fitting instructions for the child restraints, airbag warning labels, and the car's ability to accommodate the child restraints safely.

- Pedestrian protection
  Euro NCAP's results in this rating are achieved through state of the art leg form, upper leg form and child/adult head form tests which are more stringent than the legislative tests coming into force for all new EU registered vehicles in 2015. The original pedestrian protection rating was based on adult and child head form tests and two leg form tests. As of 2009, the pedestrian score has become an integral part of the overall rating scheme and the technical assessment has remained the same. With inclusion of the pedestrian score into the overall rating, Euro NCAP aims to encourage improvement of vehicle performance in this assessment. Euro NCAP believes more effort by manufacturers in pedestrian protection would save the lives of many pedestrians and negate the emotional trauma encountered by many drivers every year as they live with the consequences of injuring or fatally wounding a pedestrian.

- Safety assist technologies
  The introduction of Safety Assist allows Euro NCAP to consider driver assistance systems and active safety technologies. These technologies play an increasingly important role in accident avoidance and injury mitigation. Euro NCAP currently rewards manufacturers for the fitment of electronic stability control, in addition to points given for the presence of a speed limitation device and intelligent seat belt reminders. Over the period 2010-2011, cars had to score at least 60% out of the maximum 7 points to qualify for 5 stars. In 2013, two additional points were allocated to promote Intelligent Speed Assistance systems and the requirement was raised to 65% out of a maximum 9 points.

- Dual safety rating
  From 2016, some cars are awarded two star ratings. One rating is based on a car fitted only with safety equipment which is standard on every variant in the model range throughout EU28. This rating reflects the minimum level of safety normally expected from any car sold anywhere in the European Union. All cars assessed by Euro NCAP have this basic safety rating.

The second rating is based on a car with an additional 'safety pack' that may be offered as an add-on option to consumers. The additional safety equipment included in a safety pack will boost the car's safety rating and, therefore, the second star rating demonstrates the safety level that the car can achieve, if this additional equipment is included. Not every car has this second star rating, but when available, the aim is to help consumers understand the benefit of additional equipment, expressed in extra stars.

The Euro NCAP tests

The dynamic tests include full-scale frontal and side-impact tests, front-end component tests for pedestrian protection and sled tests for whiplash prevention during rear-end accidents. Seat belt reminders, speed limiters, and electronic stability control also boost a vehicle's rating. See also ERSO web texts on Vehicle Safety and eSafety.

The Frontal impact test is based on that developed by European Enhanced Vehicle-safety Committee as a basis for legislation, but impact speed has been increased by 8Km/h to reflect more real life accidents resulting in severe injury. Frontal impact takes place at 64Km/h (40mph), car strikes deformable barrier that is offset using an offset deformable barrier intended to represent the most frequent type of road accident, resulting in serious or fatal injury. This tests the car's ability to survive the impact without sustaining passenger compartment intrusion.

Readings taken from dummies are used to assess protection given to adult front occupants. Example of a Euro NCAP crash test

A car to car side impact test addresses the second most important accident configuration of car to car side impact although the lower end of severe and fatal accident severity. Euro NCAP simulates this type of accident by having a mobile deformable barrier (MDB) impact the driver's door at 50Km/h. The injury protection is assessed by a side impact test dummy in the driver's set

A pole side impact test addresses head injury in side impact which is the most frequently seriously injured body region in side impacts. In the test, the car tested is propelled sideways at 29Km/h (18mph) into a rigid pole. The pole is relatively narrow, so there is major penetration into the side of the car.

A child protection protocol is used to encourage manufacturers to take responsibility for protecting children and to provide suitable facilities for the fitment of child restraints. Many child restraint users fail to attach the child restraint securely to the car and this compromises the protection afforded to the children. Euro NCAP has encouraged improved designs and the fitment of ISOFIX mounts and child restraints. ISOFIX provides a much more secure method of attaching the child restraint to the car, provided that additional provision is made to prevent rotation of the child restraint, due to seat cushion compression and rebound. In the frontal and side impact barrier tests, dummies representing 1½ and 3 year-old children are placed in the rear of the car in the type of child restraint, recommended by the car manufacturer.

Pedestrian protection sub-system tests based on those devised by the EEVC are carried out to replicate accidents involving child and adult pedestrians where impacts occur at 40Km/h (25mph). A Leg form test assesses the protection afforded to the lower leg by the bumper, an Upper Leg form assesses the leading edge of the bonnet and child and adult Head forms are used to assess the bonnet top area. Impact sites are then assessed and rated fair, weak and poor. Euro NCAP released a separate star rating for pedestrian valid from 1997 to 2009. The pedestrian protection rating was based on the adult and child head form tests and the two leg form tests. As of 2009, the pedestrian score has become integral part of the overall rating scheme but the technical assessment has remained the same. In general, the car industry has still to respond well to these tests in their designs. In order to encourage further progress Euro NCAP has required from 2012 that a minimum 60% score in the pedestrian tests is required for new cars to receive a 5 star rating.

Electronic Stability Control. Since 2008, Euro NCAP has long promoted broad fitment of Electronic Stability Control – ESC – by all vehicle manufacturers. To drive greater levels of fitment, in 2009 Euro NCAP awarded three Safety Assist points to a car if ESC is fitted as standard across the model range, or if it is an option on every variant and the manufacturer also expects to sell at least 95% of cars with the system as standard equipment. Since 2012 Euro NCAP has rewarded equipment which is fitted as standard across the whole of the model range. So far, analyses of real-world accidents have demonstrated that cars equipped with ESC are involved in fewer accidents and less serious ones, than cars without. However, it has not yet been possible to differentiate between the safety offered by different types of ESC systems.

Seat belt reminders. Research shows that occupants are much more likely to wear their belts in cars equipped with a seatbelt reminder (SBR) than in those without. Euro NCAP rewards any effort made to ensure that seatbelts are worn. Euro NCAP assesses manufacturers' SBR systems to ensure that they are robust and that they provide clear, unambiguous information to the occupants about the status of their seatbelts. Trained inspectors perform a multitude of tests on each system: the car is driven on a test track and the belts are buckled and unbuckled; the loudness, and duration of the audible signal is assessed; the position and clarity of any visual warning is checked to ensure that it is visible to occupants of different sizes. The assessment tries to recreate every possible scenario where an occupant might be vulnerable by being unbelted, and checks to see if the system responds appropriately. One point is available for each of the driver, passenger and rear seats for those systems that pass the assessment. As of 2017, points will be attributed only if advanced SBR systems are fitted on all seating positions i.e. systems which will detect if a seat is occupied and will be triggered if the person is not buckled.

Speed limitation devices. Euro NCAP rewards systems that help drivers to control their speed. Euro NCAP currently rewards two types of system: those which can be set by the driver and which actively prevent the car from exceeding that maximum; and those which simply warn the driver when the car's speed is above the set maximum. The functionality of the system is considered to make sure that the system can be set and unset easily and without undue distraction to the driver. The clarity of the signals given to the driver are assessed to make sure that there is no confusion about the current set maximum and to ensure that a suitable warning is given if the system is unable to limit the speed to that maximum. For active systems, a check is made to ensure the system is able to limit the speed of a car to the maximum set by the driver. The 2015 protocol gives maximum 1,5 points for Manual Speed Assist systems, where the drivers have to set the speed limit themselves, and maximum 3 points for ISA systems, where the car automatically identifies the current legal speed limit to be used in the warning or speed limitation function.

Rear impact (whiplash). Whiplash injuries are common in rear impacts. While the mechanisms by which the injuries are caused are not fully understood, it is known that seat and head restraint design can influence the risk of injury. Euro NCAP assesses the geometry of the restraint in relation to the head and tests the seats in three severities of impact – high, medium and low – using a dummy specially designed for rear impacts. Seats at the top of the table are likely to offer better protection than those at the bottom. Rating categories are good, medium and poor.

Euro NCAP Advanced. Launched in July 2011, Euro NCAP Advanced is a complementary reward system to the existing star rating system. Cars are eligible for a Euro NCAP Advanced reward only if they have already achieved a creditable three star rating in the overall rating scheme. In response to many new features being offered as options in new cars such as Lane Departure Warning, Blind Spot Monitoring, Attention Assist, Autonomous Braking and Emergency Call, Euro NCAP aims to provide advice to car buyers about the potential safety benefits offered by technologies which have a scientifically proven safety benefit. Many of the technologies are so new that no accepted standards exist to assess them. Euro NCAP has developed a unique methodology which allows the potential safety benefits of any new technology to be determined. Unlike Euro NCAP's well established assessments involving physical tests at a crash laboratory, the new process is based entirely on the assessment of scientific evidence presented by the vehicle manufacturer. An independent panel of experts looks at the extent of the safety problem which a new technology aims to address. Through analysis of the way in which the technology

has been developed, tested and validated, and from any real-world experience that may exist, the aim is to determine the system's performance and its expected effectiveness.

Since 2014 Euro NCAP awards a maximum 3 points to vehicle manufacturers that equip their models with robust forward collision warning and/or automatic braking technology. In 2016 a new test checks the performance of AEB systems that detect and prevent collisions with pedestrians and as from 2018 also AEB that can detect collisions with cyclists.

Quadricycles. Euro NCAP developed special protocols for testing heavy quadricycles in 2014 and which were updated in 2016. These vehicles are not subject to the same legislation as passenger cars, and do not have to be crash tested before they can be sold for road use. Euro NCAP currently bases the star ratings of quadricycles only on the protection they offer to adult occupants in the front seats. In the future, other components may be added to the assessment, such as child and pedestrian protection and driver assistance features. Two full-scale crash tests are performed: a full-width frontal impact at 50Km/h against a deformable element; and a side impact test, also at 50Km/h, in which a deformable barrier is driven into the side of the vehicle.

The Euro NCAP Road Map to 2020

Euro NCAP's road map sets out key priorities to 2020 and four domains for new activity (Euro NCAP, 2014). For each domain, key activities are set out with a time-line for deliverables in the Euro NCAP framework. The rationale for each domain is summarised briefly below:

Domain (i): Occupant protection in front and side accidents

Front and side accidents continue to dominate the number of road traffic fatalities and serious injuries. In frontal accidents, the focus will be on improved interaction between vehicles involved in an accident. Improved restraint system robustness for a diverse driver and occupant population means more attention to the elderly and the young of all sizes. Injuries sustained in far side accidents, mostly to head and thorax, can be mitigated by deployment of advanced restraint systems.

Domain (ii): Autonomous braking for cars and vulnerable road users (VRUs)

The present Euro NCAP specifications for AEB systems are focused on low speed and urban-type car crash scenarios. The next generation AEB systems will be able to address more complex accident scenarios, in which intervention is currently not possible, such as turning into oncoming traffic or crossing a junction. Human-machine interface and the driver warning strategy will require higher levels of standardisation within industry and warrants objective and cross-functional verification. With growing urbanization and the environmental concerns, it is expected that the number of two-wheelers, with or without power, will increase. Increased attention to vulnerable road users, pedestrians and (motor) cyclists, in terms of vehicle design measures and especially accident avoidance technologies are also expected.

Domain (iii): Lateral assist systems

The increasing adoption of lane support systems is an essential part of the drive towards autonomous vehicles. Many current lane departure warning, lane-keeping assist and blind spot support systems, designed to help keep the car on the road and prevent accidents, don't seem to deliver on their promise due to poor levels of consumer acceptance. More intuitive, intelligent and integrated systems are expected to emerge in the coming years that will be able to avoid

unintended road departures, critical lane change manoeuvres as well as (narrow off-set) head-on collisions.

Domain (iv): Speed and impaired driving

More than ninety percent of road accidents are caused by human mistakes. In general two kinds of mistakes can be observed: violations, of which speeding and driving under the influence of alcohol or drugs are most common; and human errors, in which the driver state - inattentiveness, fatigue, distraction - and inexperience play an important role. Already, driver advisory systems such as Speed Assistance systems and Attention Assist, target the human element in accidents by alerting the driver in critical situations and, ultimately, by supporting the driver to improve his behaviour. In addition, adapting intervention criteria to individual drivers and driver state may provide a significant potential for earlier interventions in the future. Semi-automated vehicles will become more widely available, in particular those that offer Level 1 (Combined function automation) and Level 2 (Limited self-driving) functionality according to NHTSAs proposed Levels of Automation 1.

An ETSC report (ETSC, 2016) looking at the market take up of Euro NCAP rated cars reported that out of 151 models tested by Euro NCAP over the study period, 109 were granted 5 stars, 27 reached 4 stars, and 12 reached 3 stars. Some 60% of new cars sold in 2013 were granted 5 stars in Finland, Norway and Ireland while in Romania, Israel, Italy and Greece, the share of 5-star cars among new cars sold did not exceed 48%. On average, 52,5% of all new cars sold in the EU in 2013 were awarded 5 stars by Euro NCAP, 4,5% were awarded 4 stars, 3% were awarded 3 stars and 0,5% 2 stars.

Euro NCAP goes far beyond the legal requirements set in the EU's General Safety Regulation when testing new cars. A car that meets no more than the minimum EU legal requirements would not be eligible for any stars. Improvements in pedestrian protection by car manufacturers have been slower compared to achievements in adult and child occupant protection and the take up of new safety technologies (ETSC, 2016).

Details of the Euro NCAP safety rating system, test protocols and other key information can be found at www.euroncap.org. For a full assessment of the penetration of different Euro NCAP star ratings into the vehicle fleet in EU countries, see ETSC 2016.

5.1.2 Retrospective vehicle safety ratings

Retrospective safety ratings can be of particular help in assisting buyers of used cars, which have the lion share of the car sales market (ETSC, 1995). In retrospective systems, safety ratings are based on the actual performance of cars in real accidents. Here, the frequency and severity of injury to car occupants in individual model cars are determined by examination of police accident statistics and/or insurance injury claim data. The earliest ratings to back to 1975 to those published based on insurance claims data by the Highway Loss Data institute (HLDI, 1994). In general, they have been in use over the last 25 years.

While the general approach is the same for all systems, there are many differences in the exact methodology, such as the types of accidents included in the analyses, whether seat belt usage is accounted for, how the effects of exposure are controlled and whether or not the rating also takes into account the effects on other road users outside the vehicle. Aspects of the different methodologies and the adjustments made for exposure have been summarized by ETSC (1995)

and Cameron et al (2001). The more these potentially confounding factors are controlled, the better the rating system (ETSC, 1995).

Folksam Car Safety Rating System (Sweden)

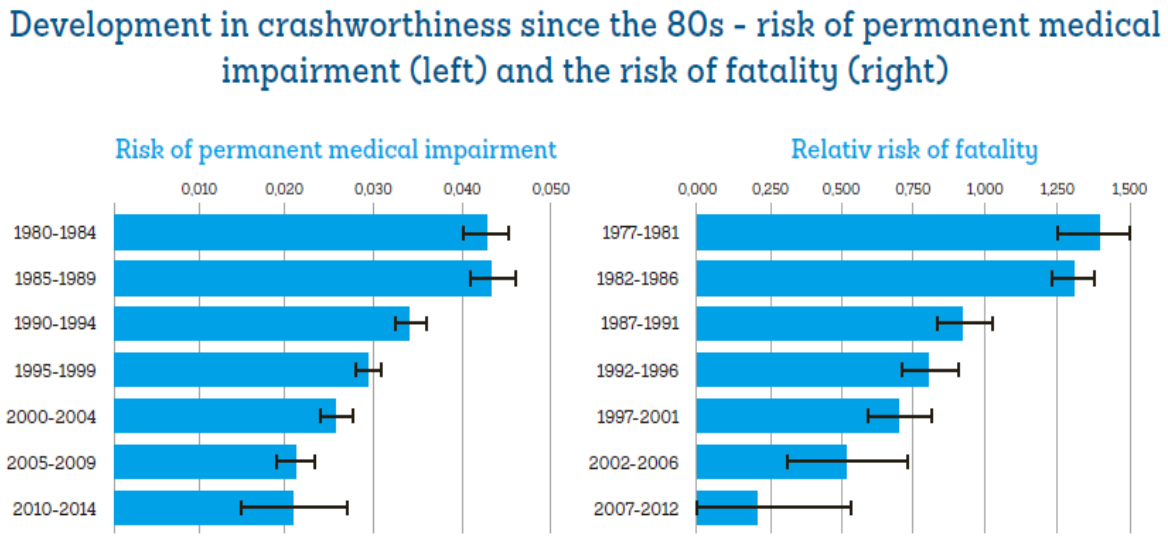
The Folksam ratings comprise the main retrospective ratings in use in Europe. Since the 1980s, the Folksam insurance company publishes injury risk ratings based on statistical analysis of real-world accidents using police and insurance databases. Folksam annually updates their assessment of the safety of cars sold in Sweden, according to both their involvement in injury collisions in Sweden if any and/or their performance in Euro NCAP tests. Folksam concludes that the safest cars are the ones that show good performance in both collisions and Euro NCAP crash tests.

The paired comparison method using 2-car accidents is used to control for impact speed and the mass differences between cars of different weights is normalized. The injury outcome in both vehicles is considered. For every car insurance policy issued by Folksam, the customer pays 5 Swedish kronor towards research. The latest rating was published in 2015 and the rating composition is shown in Figure 2 (Folksam, 2015).

In the 2015 report (Folksam, 2015) results for 254 car models based on 178.000 real-world accidents between 1994 and 2015 are presented. The injury outcome for 50.000 front seat car occupants is identified and the risk of sustaining an injury leading to fatality or permanent medical impairment is calculated. For a further 380 car models, Euro NCAP crash test results are presented to inform consumers about the predicted safety level of cars. Results are presented for the same car categories as used by Euro NCAP: superminis, small family cars, large family cars, executive, small MPVs, large MPVs, small SUVs and large SUVs. For all cars an average crash safety rating is calculated.

Early Folksam ratings indicated that if all cars were designed to be equal to the best current car in each class, 50% of all fatal and disabling injuries could be avoided (Hägg et al, 1992). An analysis of Folksam data on car to car accidents in Sweden between 1994 and 1996 showed a decrease of 35% in the relative risk of fatal and severe injury associated with 'new' car designs compared with 'old' designs (Larsson et al., 1996). Good correspondence has been found between Euro NCAP and Folksam real-world accident and injury ratings (Kullgren et al, 2010). Folksam's 2015 analysis shows that the risk of permanent medical impairment has been halved when comparing car models introduced in the early 80s with models introduced the last 5 years, while the risk of fatality has dropped by 85% during the same time period.

Figure 2: Development in crashworthiness since the 80s



Source: Folksam, 2015

Used Car Safety Ratings (UCSR) (Australia)

The UCSR were developed by Monash University´s Accident Research Centre MUARC based on records of over 2,8 million accidents on Australasian roads. The UCSR rates cars according to their on-road crash performance and how well they protect drivers in an accident. Also rated is the risk each vehicle presents to other drivers involved in an accident with that particular model. The ratings are presented in governmental websites e.g. VicRoads Used Car Safety Ratings (Australia), the Transport Accident Commission and Land Transport New Zealand as well on websites of the Australasian motoring organisations.

Other rating systems which have been developed in the past include the University of Oulu Passive Safety Ratings (Finland) and the Car and Driver: Injury Accident and Casualty Rates publication (UK). Since 1987, the Traffic Safety Committee of Insurance Companies (VALT) in Finland has regularly published ratings compiled by the University of Oulu. These analyses compare the crash performance of passenger cars in two-car collisions on Finnish roads. Ratings conducted in the mid-1990s concluded that if the crash protection of all the car models in the same weight class matched the best then 27% fewer drivers would be injured in urban car to car collisions (Tapio et al, 1995). In 1991 in the UK the first edition of "Car and Driver: Injury Accident and Casualty Rates" was published giving information on comparative accident involvement and injury risks of popular makes and models of car (DoT, 1991). The rating, based on the risk of driver-only injury in car-to-car injury accidents reported to the police showed that if the safety of all models were improved to the level achieved or exceeded by the safest twentieth of models then the number of drivers injured in car to car accidents would fall by 12% and the number killed or seriously injured by 22%.

Retrospective ratings: SARAC conclusions

The EU Safety Rating Advisory Committee (SARAC) project brought together an international forum initiated by the German insurance organisation GDV and the European Comité Europeén des Assurances (CEA) of experts from the accident research community, government agencies, universities and automobile manufacturers. Research was undertaken in the SARAC 1 and SARAC II projects between 1999-2006 funded by the European Commission and the Comité Europeén des Assurances (CEA). In SARACII, safety ratings from around the world were examined to identify

and develop advanced methods to assess crashworthiness and aggressivity and other aspects of statistical reliability, presentation of results and areas requiring further research.

SARACII indicated that an ideal retrospective rating should have:

- A measure of impact severity
- A range of variables that provide good proxies for impact severity if no measure is available
- Good data on non-vehicle variables that affect injury outcomes and differ from vehicle to vehicle
- Full reporting of injury and non-injury accidents

None of the existing data sets on which rating systems are based meet these requirements in full. No existing rating has a measure of impact severity and it is not clear how well the available proxy measures represent impact severity. In addition to the need for action on assessing and recording impact severity, SARAC also highlights the need for action on the recording of vehicle annual kilometrage/mileage, the Vehicle Identification Number (as required in the US) and the availability of Event Data Recorders all of which would improve the retrospective rating data sets.

5.2 Road network safety ratings

Road assessment programmes have been developed in recent years to monitor the safety quality of the road network, to draw attention to the need for improvements and to help inform road network safety policies and programmes. See also ERSO web text on Roads.

Road assessment programmes are based on the expectation that the design of the road infrastructure should minimize the risk of predictable mistakes resulting in serious and fatal accidents, and should offer sufficient protection such that accidents do not result in death or permanent disability.

Road assessment programmes can comprise predictive safety ratings which look at the protective quality of various elements of a road network as well as retrospective safety ratings which involve risk-mapping and performance tracking according to specific protocols.

Road assessment programmes address the main accident types identified by research as resulting in the vast majority of deaths and serious injuries on the road network. These are:

- single vehicles leaving the road,
- impacts at junctions,
- head-on impacts with opposing vehicles
- impacts involving vulnerable road users (OECD, 1999; Lynam et al., 2003)

The proportion within each of the four groups varies between countries depending on the characteristics of the road network and traffic flow levels. The proportion also varies between road types and at different flow levels (Lynam & Lawson, 2005).

Road Assessment Programmes (RAP) were first developed in 2001 with the launch of the EuroRAP programme and are in use in more than 70 countries throughout Europe, Asia Pacific, North, Central and South America, the Phillipines and Africa. iRAP is the umbrella organisation for EuroRAP, AusRAP, KiwiRAP. usRAP and MyRAP (Malaysia) and others.

5.2.1 Predictive safety rating protocols – Road Protection Scores

Road protection scores (RPS) and star ratings are based on road inspection data and provide a simple and objective measure of the level of safety (comprising either crash protection or accident avoidance features or both depending on the specific road assessment programme, as shown below), which is 'built-in' to the road for different types of road users.

RPS provides information that is not readily available through accident histories. Accidents are always random and accident rates subject to statistical fluctuation. Over time as accident numbers decrease, identification of higher risk sites through variations in observed accident numbers will become more difficult. The RPS aims to provide a consistent assessment of the potential long-term risk of a given road design.

Road protection scores are used in low, middle and high-income countries and are of especial value in providing network safety information where quality accident injury data are not available for use by road designers. As a critical tool for a Safe System approach, road protection scoring uses vehicle speed and its role in the injury outcome of both vehicle-vehicle impacts and vehicle infrastructure impacts, as a key factor in the assessment. In Sweden, a new speed limit classification is being developed using the principles underlying road protection scores to ensure that the protective qualities of the road and roadside are aligned to allowable posted speed limits.

Using specially equipped vehicles and software, teams undertake detailed road inspections. All road assessment models use measures of risk that can be collected from a drive-through inspection or can be augmented by retrospective coding of a video recording towards a star rating.

The Road Assessment Programme ethos is one of continuous improvement and several RPS (Road Protection Score) versions have been developed or tested over recent years (EuroRAP, 2011).

- EuroRAP RPS1.0 is the original EuroRAP RPS launched in 2001. Only crash protection items (secondary safety elements) relating to car occupants are included. Section lengths can be based upon start and end points at which the character of the road changes or divided every 100m, the latter analysed using an online calculator developed in 2010. Data collection can be completed whilst travelling the road and recorded via a touch-sensitive pad. Star rating = 1-4 stars.
- EuroRAP RPS2.0 includes accident likelihood factors. It uses the car elements from the iRAP model and a multiplicative model, rating roads every 100m. Typically, data for RPS2.0 can be taken partly from a drive-through inspection and partly (or wholly) by retrospective assessment of the videos of the inspection route. Star rating = 1-5 stars.
- iRAP RPS this includes assessments for four separate modes (car, motorcycle, pedal cycle and pedestrian), and requires some or all of the data to be obtained retrospectively by rating the inspection videos. Data have been collected in more than 20 countries using versions 2.1 and 2.2 of this model. Star rating = 1-5 stars.
- The Australian and New Zealand models (AusRAP and KiwiRAP) have most of the same core factors of the iRAP version but incorporate several variations.

5.2.2 Retrospective safety rating protocols – Risk Mapping

Risk Mapping provides a means of measuring and mapping the number of accidents on individual road sections and is used in several Road Assessment Programmes globally. In regions where detailed accident data is available, iRAP produces Risk Maps that indicate the distribution of road fatalities and where accident risks are greatest. The maps capture the combined risk arising from the interaction of road users, vehicles and the road environment.

EuroRAP also maps accident density and is able to show both where the risks are high to individual drivers and where collective risk is high due to high traffic volumes. This allows an assessment to be made of the investment required to bring risk down to defined levels on different road types (Lynam and Lawson, 2005; Lynam, 2006; Castle et al, 2007a). See EuroRAP section below for further information.

5.2.3 International Road Assessment Programme (iRAP)

iRAP is a registered charity and is financially supported by the FIA Foundation for the Automobile and Society and Road Safety Fund. Projects receive support from the World Bank's Global Road Safety Facility, automobile associations, regional development banks and donors.

iRAP is being used as a major tool in diagnosing road safety engineering needs in low and middle-income countries in which almost half of those killed are vulnerable road users motorcyclists, bicyclists and pedestrians.

iRAP's vision is 'a world free of high-risk roads'. iRAP's objectives and processes which build on the methodologies of EuroRAP and AusRAP are set out in Box 2 and Figure 3.

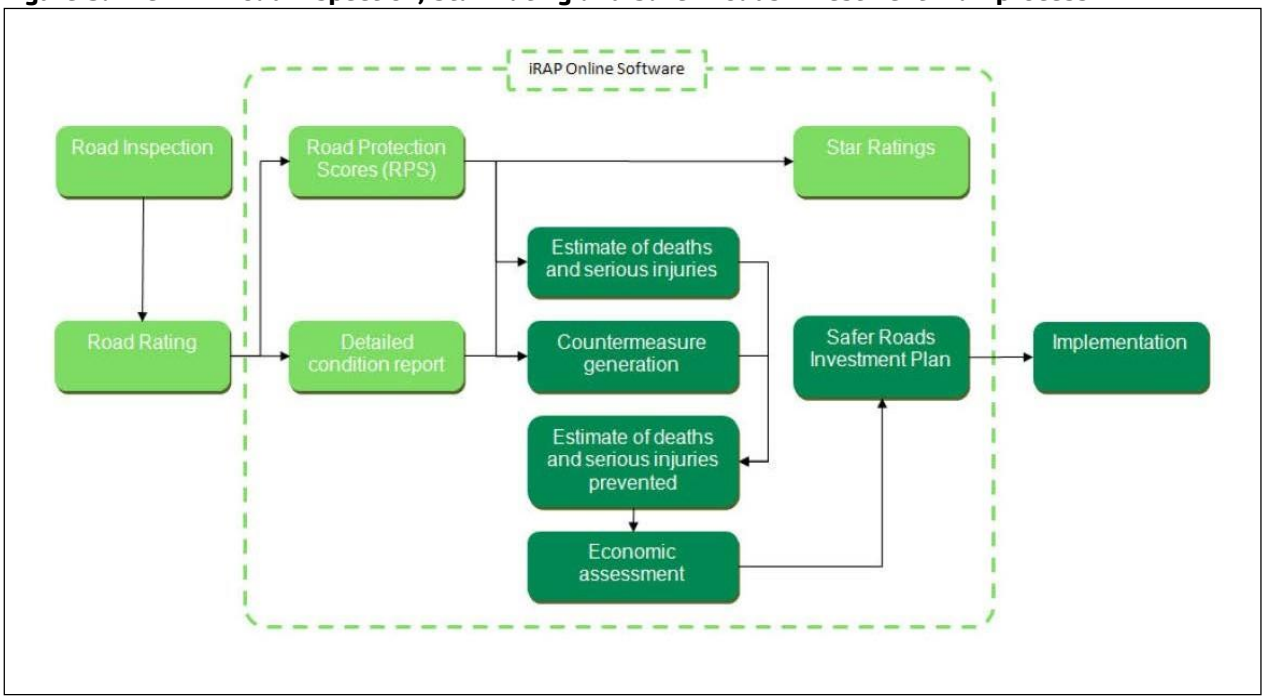
Box 2: iRAP's objectives

iRAP

- works in partnership with government and non-government organisations to: inspect high-risk roads and develop Star Ratings and Safer Roads Investment Plans
- provide training, technology and support that will build and sustain national, regional and local capability
- track road safety performance so that funding agencies can assess the benefits of their investments.

Source: www.irap.net

Figure 3: The iRAP road inspection, Star Rating and Safer Roads Investment Plan process



Source: iRAP

See iRAP library for technical publication list.

iRAP Star Ratings

iRAP Star Ratings provide a simple and objective measure of the level of safety which is 'built-in' to the road for car occupants, motorcyclists, bicyclists and pedestrians. A road's Star Rating is based on an inspection of infrastructure elements that are known from extensive research to influence the likelihood of accidents occurring and the severity of those accidents that do occur. Star Ratings can be completed without reference to detailed accident data, which are often unavailable in low-income and middle-income countries.

Methodology: iRAP Star Ratings are based on a detailed visual inspection of a road's infrastructure elements. iRAP currently uses two types of road inspections: drive-through and video-based. The type of inspection conducted depends on the availability of technology, the complexity of the road network and the degree to which a project is focused on building the capacity of road safety stakeholder organisations.

Drive-through inspections involve at least two people: one driving a vehicle and a passenger recording road infrastructure elements as they travel using a RAP Inspection Device (RAPID). This type of inspection is technical and requires inspectors to hold iRAP accreditation RAPID inspections are often used in situations where the road network is not overly complex or it is difficult or time-consuming to import a vehicle that is equipped for video-based inspections. The RAPID inspection equipment includes a video camera, touch-sensitive laptop (see Figure 3) and Global Positioning System (GPS) antenna. Although road infrastructure elements are primarily recorded during the drive-through inspection, the video is also later used as a means of quality checking and assurance.

Video-based inspections differ from drive-through inspections because data is first collected by video and this is later used by raters to record road infrastructure elements. The videos are recorded with a specially equipped survey vehicle that records images of a road at intervals of 5–10m using an array of cameras aligned to pick up panoramic views (such as forward, side-left, side-right, and often, rear). The main forward view is calibrated to later allow measurements of key road infrastructure elements. The vehicle is also equipped with GPS that enables the video images to be correlated to precise locations on the road network. The vehicles can drive along the road at legal speeds while collecting this information. After the video data is collected, raters undertake desktop inspections of road infrastructure elements by conducting a virtual drive-through of the network. The raters use specialised software to make accurate measurements of elements such as lane widths, shoulder widths and distance between the road edge and fixed hazards, such as trees and large poles.

Although the drive-through inspections involve a continuous record of road infrastructure elements, and the video-based inspection records video images at 5-10m intervals, the Star Ratings are based on 100m long sections of road. At the completion of each type of inspection, it is possible to produce a detailed condition report that summarizes many roadway characteristics for the inspected network. The report contains information such as the proportion of the network that has paved shoulders and number of locations that have adequate pedestrian crossings. These data form the basis of Star Ratings.

These inspections focus on more than 75 different design features known to influence the likelihood of accidents as well as their severity. These features include intersection design, road cross-sections and markings, roadside hazards, footpaths and bicycle lanes.

The rating. In the iRAP rating, five-star roads are the safest while one-star roads are the least safe. The safest roads (4- and 5-star) have road safety features that are appropriate for the prevailing traffic speeds. Road infrastructure elements on a safe road might include separation of opposing traffic by a wide median or barrier, good line-marking and intersection design, wide lanes and sealed (paved) shoulders, roadsides free of unprotected hazards such as poles, and good provision for bicyclists and pedestrians such as dedicated paths and crossings.

The least safe roads (1- and 2-star) lack safety features that are appropriate for the prevailing traffic speeds or safely accommodate mixed road use between slow and faster moving traffic or motorized and non-motorized users. iRAP analyses show that these are often single-carriageway roads with relatively high posted speed limits, with frequent curves and intersections, narrow lanes, unsealed shoulders, poor line markings, hidden intersections and unprotected roadside hazards such as trees, poles and steep embankments close to the side of the road.

See also Star rating roads for safety: the iRAP methodology.

iRAP Risk mapping

In regions where detailed accident data is available, iRAP produces Risk Maps that indicate the distribution of road fatalities and where accident risks are greatest. The maps capture the combined risk arising from the interaction of road users, vehicles and the road environment. See Star rating roads for safety: the iRAP methodology.

5.2.4 European Road Assessment Programme (EuroRAP)

Developed as a partner programme to Euro NCAP, the EuroRAP programme was piloted in 2001 in four countries and has been rolled out widely to provide risk mapping, performance tracking and protection score star ratings for major rural roads in many European countries. EuroRAP's objectives are shown in Box 3.

Box 3: EuroRAP's objectives

- To reduce death and serious injury on European roads rapidly through a programme of systematic testing of risk that identifies major safety shortcomings which can be addressed by practical road improvement measures;
- To ensure assessment of risk lies at the heart of strategic decisions on route improvements, crash protection and standards of route management;
- To forge partnerships between those responsible for a safe roads system - motoring organisations, vehicle manufacturers and road authorities.

Source: www.eurorap.org

Death rates on European regional single carriageway roads typically average 5-10 times higher than those seen on motorways in the same country - even though motorway operating speeds may be 30-40km/h higher (EuroRAP/Euro NCAP 2011). EuroRAP thus focuses on covering a network of inter-urban roads on which at least 30% of national fatalities occurred. Route lengths within the EuroRAP networks typically average around 20kms, but many of the links are much shorter. Comparisons are made between roads of similar types, both within and between countries.

Three main predictive and retrospective rating protocols shown in Box 4 have been developed by EuroRAP. EuroRAP analyses aim to contribute at three levels – providing a systematic audit of the road network, understanding the sources of risk, and indicating the priorities for network improvement (Lynam et al., 2007).

Box 4: EuroRAP's protocols and outputs

Risk Rate Mapping: the numbers of killed and seriously injured road users per billion vehicles are shown on a colour-coded road map.

Performance Tracking: Identifies whether fewer people are being killed or seriously injured on road over time and identifies the countermeasures that are most effective.

Road Protection Scores (RPS): assess how much or how little protection a road environment will provide for the occupants of a car in the event of a crash. On the basis of this score, each road is given a star rating varying from 1 to 4, with 4-star (EuroRAP RPS1.0) or 1-5 stars (EuroRAP RPS2.0) representing a road which is engineered to minimise the likelihood of a crash resulting in a fatal injury to car occupants.

Source: www.eurorap.org

EuroRAP's Star Rating:

EuroRAP's Star Rating is a scale showing how well a road protects the user from death or serious injury once an accident occurs. The aim of the assessment is to evaluate the safety that is 'built in' to the road through design, in combination with the way traffic is managed on it. Data on road design and the standard of a road's safety features is collected by drive-through inspections

in specially equipped vehicles. Large scale inspection has taken place in Sweden and Germany. Trained inspectors assess and score each road's safety features and hazards, either in real time (as the road is driven), or later from video images captured along the route. This standard inspection formula can be used on a variety of road types and allows roads across Europe to be assessed and compared on the same basis. EuroRAP's Star Rating differs from normal road safety audits in that the aim is to assess the general safety standard of a route not to identify individual high-risk sites. The scoring system is based on the road design elements that correspond to each of the four main accident types on Europe's roads shown in Box 5.

Box 5: The elements of EuroRAP's Safety Rating scoring system

Head-on Crashes: measures of how well traffic lanes are separated
Run-off Crashes: checks for roadside protection (for example, safety fencing protecting rigid poles, lampposts and trees)
Junction Crashes: checks for junction layout and frequency
Pedestrians and Cyclists: checks for facilities and separation from vehicles where vulnerable road-users are present.

Source: www.eurorap.org

The protection scoring system is closely linked to vehicle speed, and demonstrates that an appropriate balance between speed and road design is needed to produce high levels of protection on most road types. The initial focus on scoring the passive safety of the road allows a direct link to be made with vehicle safety assessment by considering injury severity in both cases as a function of the biomechanical forces involved in the impact. To make this link, minimum relative risks for the Road Protection Score rating are based on the speeds at which car occupants can be expected to survive an impact in a car rated highly in Euro NCAP -70km/h or below for head on crash protection, 50km/h for intersection accidents and run off accidents (although here occupant protection will depend on the nature of the obstacle hit) and 30 km/h for impacts with pedestrians. Pedestrian and vehicle movements need to be segregated on any roads with higher speed limits, in order to gain maximum Road Protection Score ratings for this accident type. Findings of a EuroRAP Road Protection Scores review in 2004 are shown in Box 6.

Box 6: EuroRAP Road Protection Scores (RPS) Review (2004)

The review indicated that:

- on many roads there is substantial scope to improve the potential for injury prevention and crashes involving fatal injury.
- on average, single carriageway RPS scores are lower than divided (dual carriageway) roads. Single carriageways show more variability in their design and associated injury protection.
- many roads score poorly for run-off protection, reflecting that fatal injuries are likely to occur unless barriers or very wide safety zones can be provided. There is considerable variability in run-off protection along individual routes.
- The lowest scoring roads score poorly for head-ons, single-vehicle runoffs and those at junctions.
- most of the assessed divided roads do not score the full four stars available, even though they are the safer roads in all highway networks. Scope remains to reduce serious injuries from crashes at uncontrolled junctions and from vehicle run-offs.
- On ordinary 2-lane roads, despite the lower speeds adopted, protection is often limited by narrow safety zones, poor access provision and by the lack of measures to limit the interaction of opposing traffic streams. Some good examples of median treatment of these roads can be seen in Sweden, the Netherlands and Ireland.

Source: Lynam et al., 2004.

European results

Within Europe, EuroRAP ratings have been carried out in 23 countries - See European road safety atlas. Risk-mapping has been carried out in 20 countries covering 180.000Km of network and star rating has been carried out to some extent in 16 countries covering 60.000Km. In the EU, road inspections have been extensively used in Sweden (See Box 7) and Germany, and trialed in Britain, Ireland and Northern Ireland, the Netherland and Spain (Box 8).

Box 7: Road Protection Star Rating in Sweden

Sweden was the first to begin and publish a programme of Star Rating based on the first EuroRAP RPS protocol. Using a specially equipped Toyota Hiace loaned to the programme from Toyota Sweden, inspections started in October 2003 and covered 1000km of the national road network, concentrating on two main roads between Stockholm and Gothenburg. Pilot results were launched in February 2004, and generated great interest amongst media, professionals and the public.

Inspections continued in 2004 with the addition of data for a further 7090km. Results for 3780km in the south of the country were launched in December of that year, whilst 3310km in the north were launched in February 2005. See EuroRAP results for Sweden.

EuroRAP star ratings have been used in the review of speed limits in Sweden, matching speed limits to the level of crash protection provided by the road.

Of particular significance in the Swedish programme has been the finding that a correlation exists between the number and location of fatal crashes and the Star Rating awarded to particular road sections. Sections with a high number of fatalities generally received a poor Star Rating.

Source: www. eurorap.org

Monitoring in general shows that even among the EU road safety leaders, there is significant potential for improving infrastructure safety performance. For example, in Britain where most road deaths are concentrated on just 10% of the road network (motorways and 'A' roads outside

major urban areas) 14% of the network surveyed has unacceptably high risk. The risk of death and serious injury to road users is 7 times greater on an average single carriageway road than a motorway, with certain roads representing more than 20 times the motorway risk. Motorways and A roads in Britain via a capital investment of £8,2 billion over 20 years, could save 600 lives annually, equivalent to £34 billion over a 20-year life of measures implemented.

EuroRAP has recently launched a campaign for '3 stars or better' on Europe's roads. A new report provides key statistics and cost-benefit analyses to make the economic case for improving road infrastructure in order to help reduce deaths on Europe's roads by 2020 to less than 50% of their 2010 total of 31.500. It features case studies and national 3-star policy targets and sets out recommended policy goals (Euro RAP 2016).

EuroRAP Risk Mapping

Under EuroRAP's Risk Mapping protocols, safety indicators based on the road network, accident numbers and traffic flow are used to produce four maps charting:

- Risk per kilometre
- Risk per vehicle kilometre travelled
- Risk in relation to roads with similar flow levels
- Economic potential for accident reduction

Risk is divided into five coloured bands from high-risk (black) to low risk (green). EuroRAP maps give various insights into risk and are designed to support messages aimed at the differing needs and levels of expertise of the target audiences, ranging from the public through to road engineers and policymakers. For example, EuroRAP explains that the maps directed to policymakers and roads authorities comprise:

Accident density - showing accident rates per kilometre of road, illustrating where highest and lowest numbers of accidents occur within a network.

Accident rate in relation to similar roads - comparing the accident rate of similar roads with similar traffic flows, illustrating which road sections have a higher rate. Separate road groups are considered - for example, motorways, main roads with traffic flows below 10,000 vehicles per day, main roads with daily traffic flow between 10,000 and 20,000 vehicles per day, and main roads with daily traffic flow greater than 20,000 vehicles per day.

Potential for accident reduction - providing information on the number of accidents that might be saved if accident rates of road sections, with risk above the average roads of a similar flow, were reduced to the average or to an alternative defined standard risk. This information can be used for considering investment decisions, providing authorities and policymakers with a valuable tool for estimating the total number of accidents that could potentially be avoided if safety on a road were improved. Used with cost information, this map can indicate locations where the largest return on investment can be expected.

Results to date indicate that there are large differences in fatality rate between groups of countries for similar road types. For EuroRAP results on risk mapping in several European countries, see Risk Mapping results and EU Road Safety Atlas.

The EU Trans-European Road Network has also been mapped. Euro RAP monitoring (2011) of 50% of the TEN-T network against a *Safe System* assessment model recorded some 30,000 fatal and serious road accidents. Some 55% of these were on motorways, 20% on dual carriageways and 25% on single carriageways. Large differences in risk on TEN-T roads in different Member States are found. Sweden's network is assessed as low-risk for 85% of its TEN-T sections whereas in Poland, only 4% of its TEN-T network is assessed as being low-risk.

EuroRAP currently estimates that approximately 25% of the TEN-T within the EU is below 3-star at either the 1-star or 2-star level. This network is largely in newer EU countries but flaws are common across many national networks. French auto routes have been cited by EuroRAP as achieving the most consistent and high star ratings. In the Greek TEN-T network on 3.600Km surveyed in a recent study, 54% was rated 1- or 2-star, and 45% achieved 3 Stars (Bellos et al, 2015).

Box 8: EuroRAP Risk Mapping in Spain

Spanish Risk Mapping began in 2002 with the production of a pilot risk map for Catalonia - the first time that such information had been made publicly available.

The Spanish EuroRAP programme has been extended progressively to cover the complete road network, including over 20,600km of the national system.

In 2003 the first map illustrating risk on the Spanish RCE (Carreteras del Estado) was published. The most dangerous region was found to be Galicia, with 52% of road sections in the area categorised as high (black) or medium-high (red) risk. Examination of results by province showed Pontevedra, Lugo, Asturias and Burgos to have the highest risk overall.

In 2004, further developments were made with the publication of both a crash density map and updated risk map - the first time national EuroRAP results had been launched using both forms of information. The meaning of risk was not well understood by the Spanish public and density maps were used to explain how road administrations set priorities for action and the connection between high traffic flows and high accident numbers. Mapping is being extended to other regions.

Source: www.eurorap.prg

EuroRAP Performance Tracking

Performance tracking provides a means of monitoring the number of accidents occurring on individual road sections over time - which are getting safer, which are getting worse, and which are staying the same. The EuroRAP process of tracking the performance of road sections over time has several stages: data is initially analysed to identify road sections which have shown a reduction in the number of collisions over time and those where there has been little or no change; data for individual years is then checked to assess consistency of the patterns; and finally, highway authorities are asked for information on remedial, enforcement or education measures that have been implemented that might explain the reduction in accidents. For EuroRAP results of performance tracking in several European countries, see Performance Tracking results. For case studies showing how safe road design and the in-built safety of roads contributes to minimising the likelihood of an accident and, in the event of an accident, and protect from death or serious injury see Road Safety Foundation (2015).

5.2.5 Examples of other national road assessment programmes

Australian Road Assessment Programme (AusRAP)

AusRAP aims to provide a safety rating for the national highway network across Australia and estimates that 47% of road fatalities could be prevented by improved roads. The aim is to generate consumer information for the public and give road engineers and planners vital benchmarking information to show them how well, or badly, their roads are performing compared with others, both in their own and other countries. AusRAP is an initiative of the Australian Automobile Association (AAA). AAA is the national association of Australia's State and Territory motoring clubs and its first report was published in 2005.

AusRAP's objectives are:

- To reduce deaths and injuries on Australia's roads by systematically assessing risk and identifying safety shortcomings that can be addressed with practical road-improvement measures
- To put risk assessment at the heart of strategic decisions on road improvements, crash protection and standards of road management.

AusRAP uses two protocols:

- Risk Mapping, based on a road's history of casualty accidents and traffic flow. Previous AusRAP reports, released in 2004 and 2005, used risk-maps to provide a measure of the safety performance of the AusLink National Network. Road accident fatalities on this network typically account for around 15% of annual road deaths in Australia.
- Star Ratings which include the influence of accident likelihood as well as injury severity, involve an inspection of a number of design elements such as lane and shoulder width as well as, for example, the presence of safety barriers. Between 1 and 5-stars are awarded to road links depending on the level of safety which is 'built-in' to the road. The star ratings do not take into account a road's accident history.

KiwiRAP

The New Zealand Road Assessment Programme, KiwiRAP, is a road safety partnership between the Automobile Association and New Zealand government agencies: NZ Transport Agency, Ministry of Transport, Accident Compensation Corporation, and New Zealand Police. The objectives of KiwiRAP are:

- to reduce deaths and injuries on New Zealand's roads by systematically assessing risk and identifying safety shortcomings that can be addressed with practical road improvement measures
- to have risk assessment as a key factor in strategic decisions on road improvements, crash protection and standards of road management
- to provide meaningful information on where the greatest levels of risk are faced, and in turn to influence behaviour.

Like AusRAP, KiwiRAP carries out risk-mapping and star ratings. In January 2008 KiwiRAP published the first set of risk maps for New Zealand. These were followed with the publication of Star Ratings in June 2010. See KiwiRAP reports.

The Star Rating approach focuses on the elements influencing the three most common and which contribute over 80% of all fatal and serious accidents and severe types of accidents on New Zealand's rural state highways.

- Run-off road accidents (which account for over 50% of all accidents)
- Head-on accidents
- Accidents at intersections

The Star Rating system includes some additional elements to those included in iRAP or EuroRAP rating schemes and uses a combination of video rating and high-speed geometry data for 100m road sections.

5.3 Protective equipment safety ratings

Manufacturing standards for safety equipment, in particular, child restraints and safety helmets are in place in a wide variety of jurisdictions and are supported internationally by dedicated ISO standards. However, variations in performance identified by research have given rise to evaluation systems designed to be more user-friendly to consumers and which draw on state of the art knowledge to maintain pressure on manufacturers to produce equipment that performs well in advance of national and international standards.

5.3.1 Child restraint safety rating

Euro NCAP testing

In Europe, child restraint safety rating is carried out as part of whole car testing and safety rating within EuroNCAP, given the shared responsibility of car manufacturers and child restraint manufacturers for the safe design and installation of child restraints in cars. In the frontal and side impact barrier tests, dummies representing 1½ and 3 year-old children are placed in the rear of the car in the type of child restraint, recommended by the car manufacturer. The score depends on the child seat dynamic performance in front and side impact tests but also on the fitting instructions for the child restraints, airbag warning labels, and the car's ability to accommodate the child restraints safely. See Euro NCAP's child protection protocol.

UK TRL Child Seat Rating Scheme

An additional scheme launched in 2009 operates in the UK which rates the performance of child restraint systems from 1-5 stars and aims to provide consumers with performance ratings for all child restraint systems. The star rating is based on a suite of tests to assess the front and side impact performance and the usability of the product. Performance information for each of these is available for added clarity. All child restraint systems tested will have already achieved Regulatory Approval to R44 - a minimum mandatory requirement for sale in Europe. However, R44 offers no differentiation of product quality or effectiveness to the consumer. Additionally, within R44 there is no assessment of side impact performance which is considered to be of great importance. TRL's rating scheme requirements are laid out in Transport Research Specification, TRS1002:2009, which calls up a bespoke suite of tests and assessments based largely on the NPACS (New Programme for the Assessment of Child Restraint Systems) protocols, published by TRL for the Department for Transport.

UK Consumers Association Which? rating

The UK Consumers Association also publishes a child restraint Best Buy and Don't Buy rating based on the Euro NCAP test results and expert inspection but requires a membership fee to access results online.

Australian Child Restraint Evaluation Programme (CREP)

In Australia the Child Restraint Evaluation Programme (CREP) has been created as a stand- alone safety rating system but one involving whole car testing. In 1992, the Roads and Traffic Authority of New South Wales (RTA), the National Roads and Motorists Association (NRMA) and the Australian Consumers' Association (ACA) came together to create a child restraint evaluation program in order to provide consumers with better information and to maintain pressure on manufacturers. After some early problems with working methods and the addition of support from other motoring organisations and the federal Traffic Accident Commission, a review of the programme was undertaken in 2005 which defines current protocols, methodology and results (Brown et al, 2005).

The current CREP Stage 4 Series recognises eight types of restraint equipment which are shown in Box 9.

Box 9: Types of restraint tested in CREP

ASC	Anti-submarining clip
A1	Rearward-facing restraint for babies up to six months*
A1/B	Convertible forward-facing restraint for babies up to six months* in rearward-facing mode then or toddlers up to 4 years* in forward-facing mode
A2	Rearward-facing restraint for babies up to 12 months*
A2/B	Convertible forward-facing restraint for babies up to 12 months* in rearward-facing mode then for toddlers up to 4 years* in forward-facing mode
B	Forward-facing restraint
B/E	Convertible booster seat
E	Booster seat

*Approximate guide

Source: CREP website

Each of the above categories is subjected to three simulated crash tests, frontal, side and oblique impacts and given a star rating from 1-5. A rating of 1 represents acceptability under AUS/NZ standards and 2 signifies the average performance. A further star rating with the same registration is given for ease of correct use. Here, an expert assessor examines five aspects of use: packaging, instructions, labeling, ease of securing/releasing the child and ease of securing/releasing the restraint. A sample of assessments is reviewed by a second assessor and a panel of experts then provides final moderation if needed. Traditionally CREP periodically publishes its findings in a brochure which is widely distributed and is now available to download as a PDF file from a number of websites. The current edition is Child Restraint Safety Ratings – Your guide to buying child restraints (CREP), February 2011.

5.3.2 UK Safety Helmet Assessment and Rating Programme (SHARP)

Head injuries cause some three-quarters of all fatalities to motorcyclists, while about one quarter of all injured riders suffer a head injury and about 20% of fatal and serious head injuries could be reduced by a recommended and achievable improvement in crash helmet performance (COST, 2001).

In its Motorcycling Strategy published in 2005, the UK Department for Transport (DfT) stated its intention to devise a safety rating scheme for motorcycle helmets and the SHARP helmet test/rider information initiative was developed and launched in 2007. UK research had estimated that as many as 50 lives a year in the UK could be saved if motorcyclists wore the safest helmets available to them. See also (DFT, 2008).

SHARP's method is to purchase helmets anonymously at ordinary retail outlets and to test them rigorously in a battery of thirty-two tests that reflect 'real world' accident conditions.
Helmets are initially laser calibrated to ensure proper comparison and then subject to impacts against flat and kerb type surfaces at varying speeds in a range from above to below those specified in regulatory standards. The results of the tests are then analysed to give a star rating between 1 and 5. 5-star helmets offer good levels of protection in impacts all around the helmet. All helmets in the UK are required to meet at least one regulatory standard but this only ensures a minimum level of protection. Testing has identified a variation of up to 70% in performance between high and low scoring helmets.

Consumers access SHARP's data through an 'easy to use' website that can be searched using variables such as make, model and type if an assessment of an individual helmet is sought and by price and star rating if a more general search is required. The site emphasises the importance of helmet fit and provides an animated guide to helmet fitting. It is possible to individuals to subscribe to a newsletter and for traders to register.

For most recent results (July 2016) see also: sharp.direct.gov.uk/news/1-july-2016-publication-new-helmet-ratings.

5.4 Other safety ratings

5.4.1 Star rating school walking routes

A model for star rating the safety of school walking routes was devised by Monash University Accident Research Center. The model was based on the determinants of pedestrian accident and injury risk at specified pedestrian road crossings. These include:

- The speed limit applicable to drivers and riders at the crossing point during the periods when children walk to and from school;
- The average number of vehicles per hour at the crossing point during the periods when children walk to and from school;
- The width of road to be traversed to complete an individual crossing movement;
- The number of directions of conflicting traffic that must be assessed by a pedestrian crossing at the crossing point; and
- Whether there is a formal crossing facility provided (such as traffic signals, a school crossing, a zebra crossing, etc) to facilitate the crossing manoeuvre.

Then based on established relationships and expert consensus, these are mathematically combined to obtain a star rating between zero and five at each crossing point along the route The model demonstrated that it is feasible to objectively rate the safety of individual crossing points as well as to provide overall indications of route safety (Corben, 2008)

The model was subsequently piloted within realistic settings (Liu et al., 2010). The main findings from the data analyses revealed that:

- Participants who took part in the trial were largely supportive of the Star-Rating concept such that the availability of such information would have the potential to influence their decision regarding their children walking to and from school; and
- An approximate two-star difference was established between objective and subjective ratings.

The pilot concluded that future research should aim to address additional trialing of the tool in a greater variety of settings, as well as population groups, with the results used to help further develop and enhance the Star-Rating tool's reliability.

5.4.2 Q3 - Work-related safety ratings in Sweden

Swedish trade unions in cooperation with environmental and road safety organisations have developed a ranking system for heavy goods transport. This ranking system is called Q3 and is based on working environment, environmental and road safety requirements (See http://www.q3.se/ for details). The system is becoming well accepted and is considered a worthwhile initiative.

5.4.3 ETSC Performance Index

The ETSC's Road Safety Performance (PIN) Index is a new policy instrument to help EU Member States to improve road safety. Started in June 2006, the Index covers several areas of road safety including road user behaviour, infrastructure and vehicles, as well as road safety policymaking more generally. National research organisations and independent researchers from 30 countries participating in the programme ensure that any assessment carried out within the programme is based on scientific evidence and is effectively communicated to European road safety policymakers.

To facilitate the collection of accurate data from all 27 EU Member States, as well as Norway, Switzerland and Israel, ETSC has set up a the PIN Panel of national focal points comprising 30 high level national experts from ETSC's network of member organisations and other organisations.

Eight individuals, who are particularly committed to ETSC and road safety policy, form the PIN Steering Committee providing guidance to the PIN Programme Secretariat.

PIN to date has concentrated on final outcomes – the fall or otherwise in road deaths - as well as intermediate outcomes for speed, seatbelt wearing, drink driving, car safety quality. For key findings to date, see PIN publications at www.etsc.eu.

Box 10: The ETSC PIN programme comprises:

- PIN Flashes – profile-raising quarterly overviews of specific road safety topics
- PIN Reports – wider-ranging annual reviews of a range road safety performance indices
- PIN International events – to launch the annual PIN Reports
- PIN Talks - National events in each Member State to encourage that country's road safety effort

Source: www.etsc.eu

Box 11: EU country performance towards the EU 2010 road safety target

Monitoring of EU country progress against the EU target carried out by the ETSC PIN Project showed that Latvia, Estonia, Lithuania, Spain, Luxembourg, Sweden, France and Slovenia all reached the EU 2010 target. Portugal very nearly reached it with a reduction of 49,4%. Ireland, Germany, the UK, Italy, Slovakia and Belgium achieved reductions above the EU average, while the other countries progressed to a lesser extent (ETSC, 2010).

ETSC estimates that had road deaths remained at the same level as in 2001, there would have been 102.000 more deaths in the EU. The total value to society of the reductions in road deaths in EU27 over the years 2002-2010 compared with 2001 is estimated as 176 billion euro.

Source ETSC PIN Report 5

6 Effectiveness of safety rating systems

A prerequisite for effective rating systems is high quality information. Rating systems are of value when the tests used in them are realistic and evidence-based; when the tests and analysis take account of possible factors which might bias the results; where the publication or website explains clearly what the particular rating means and where the results are disseminated very widely while, at the same time, being targeted at specific users.

6.1 Changing design, upgrading standards and reducing risks

Whilst evidence-based legislation can ensure a uniform minimum level of safety across the product range, predictive and retrospective safety ratings can create a demand for safety products and outcomes which can produce more rapid responses in individual product design.

6.1.1 In-car safety

New Car Assessment Programmes around the world are playing a key role in encouraging improvements in in-car safety. Since the US NCAP Programme started, the NHTSA report there has been around a one-third reduction in the probability of a life-threatening injury in NCAP passenger cars as measured by controlled crash test results. In recent years NCAP light vehicle performance has led to about a 25 per cent reduction in the calculated probability of AIS 4 or above injured (Hackney & Quarles, 1982; Hackney, Kahane and Chan 1996). In Australia, research has also indicated a good correlation between ANCAP testing and the retrospective accident data in terms of injury risk and injury severity (Newstead and Cameron, 1999).

Euro NCAP

Monitoring has shown that together with key legislative provisions, Euro NCAP has had a significant influence on the way that cars are designed (Fails and Minton, 2001). Only three years after its introduction, Euro NCAP research reported that cars with three or four stars were approximately 30% safer, compared to two star cars or cars without an Euro NCAP score, in car to car collisions (Lie & Tingvall, 2000). In the last decade, accident data has confirmed that a 50% reduction in the risk of serious injury has been achieved in new car models (SARAC II). The European Commission stated in 2000 that Euro NCAP had become the single most important mechanism for achieving advances in vehicle safety (CEC, 2000).

Recent research shows that this effect is being sustained. A Swedish study compared Euro NCAP safety ratings of cars with those published by the Folksam real-world injury ratings; and

compared injury risk measures between Euro NCAP 2 and 5 Star cars with real-world injury and disability outcomes using police and insurance injury data. It concluded that a good correlation exists between Euro NCAP test results and real-world injury outcomes. In addition, 5-star rated Euro NCAP cars were found to have a 68% lower risk of fatal injury and a 23% lower risk of serious injury compared to 2-star rated cars (Kullgren et al, 2010).

While car manufacturers were initially hostile to the development of Euro NCAP, standards have increased to the extent that cars typically achieve this rating and manufacturers see 5 stars as the goal for all their new models Euro NCAP, 2007. Today only a 5-star rating is truly acceptable (EuroRAP/Euro NCAP, 2011) and the car industry has achieved significant improvements in in-car safety.

"Not only Euro NCAP has been instrumental in bringing forward concrete safety advances, but it has also managed to instill a consideration for safety in the minds of consumers and to effectively change their patterns. The European Automobile Manufacturers are proud to be associated with this initiative, and we warmly congratulate all involved in Euro NCAP for their good work, for their dedication, for their achievements".

Statement by Chief Executive of Fiat, Euro NCAP's 10th Anniversary, Brussels, 2005

Frontal impact protection: Euro NCAP testing has encouraged car manufactures to work to improve crash protection in frontal impacts:

- to prevent intrusion such that the chances of the occupant impacting the car's interior is minimised with space remaining for the restraint system to operate effectively and thus reduce the risk of serious and fatal injury.
- to adopt seat belt pre-tensioners, load limiters and dual stage airbags, to help attenuate the forces transmitted to the occupant. It has also helped to avoid situations where the chest is directly loaded by the steering wheel.
- to remove hazardous structures from the areas that the knees can impact with the aim of avoiding serious and disabling leg injury.
- To reduce intrusion of the footwell and secure greater control of foot pedals displacement in order to minimise injury.

Side impact protection: Through the programme, Euro NCAP has seen large improvements in side impact performance. The provision of side impact airbags has helped. It is now typical for the cars tested by Euro NCAP to be fitted with side impact airbags.

Child protection: As a consequence of the child protection rating, Euro NCAP has seen improved designs, where the child is less likely to strike the car's interior, whilst at the same time experiencing reduced forces from the restraint system.

Electronic stability control: Fitment is steadily increasing and by 2012 Euro NCAP will only reward equipment which is fitted as standard across the whole of the model range.

6.1.2 Pedestrian protection

The car industry's response to improving pedestrian protection in vehicle design has been much less responsive, although some progress has been reported. During the first two years of Euro NCAP, the typical pedestrian rating (which was then separate from the overall rating) was one

or two stars; in 1997 30% of the tested cars were given one star and 70% two stars. However, in 2007 the distribution of stars was 13% one star, 65% two stars and 19% three stars (Euro NCAP, 2008). In 2009 the new overall rating system was introduced and the average score was 16,8 points and in 2010 19,1 points (Strandroth et al, 2011). New EU legislation comes into force for all new type approvals in 2015 and for new registrations in 2019. Euro NCAP's requirement from that a five-star rating will require at least 60% of the pedestrian tests requirements to be met (i.e. 21 points) should encourage faster progress. From 2016 onwards, the pedestrian protection score also includes points for Autonomous Emergency Braking (AEB) systems able to detect pedestrians and from 2018 for AEB systems that can detect cyclists.

A Swedish study (Strandroth et al, 2011) found significant correlation between Euro NCAP pedestrian score and injury outcome in real-life car to pedestrian accidents. The results showed a significant reduction of injury severity for cars with better pedestrian scoring, although cars with a high score could not be studied, due to lack of cases. The reduction of risk of serious consequences for average performing cars in comparison with low performing cars, in urban areas with speed limits up to 50Km/h, was 17%, 26% and 38% for 1%, 5% and 10% of medical impairment, respectively. No significant reduction was found in higher speed zones. While Brake Assist (BA) was found to contribute to a small injury reduction of about 5%, the results were non-significant. It was also found that the combined effect of BA and higher pedestrian scoring was greater than the two effects separately.

A study by BASt (Pastor, 2013) showed that for each additional point in the Euro NCAP pedestrian protection score, the probability of pedestrian death in the event of a car-to-pedestrian accident is reduced by 2,5% and the probability of serious injury by 1%. It was also found that a vehicle scoring 22 points is related to a reduction in pedestrian death risk by 35% and in serious injury risk by 16% compared to a vehicle scoring 5 points.

6.1.3 Road network safety

Several years of annual reporting of risk mapping results in Britain and Spain has generated substantial media interest in the variation in risk between roads, and the roads where risk is reducing or remaining high. Many safety engineers in Britain are beginning to use the Euro RAP risk data alongside their more traditional accident analysis techniques.

Performance tracking of risk over the period 1999 to 2004 has identified reductions of about half in the length of roads in the highest risk band in Spain, Britain and Sweden (Lynam et al, 2007).

An assessment of 1.200Kms of motorway in Germany (ADAC Press Release, July 2006) comparing the Euro RAP star rating system with relevant accident data showed that motorways rated with four stars produced 50% fewer severe run-off accidents than three star routes.

Studies in Sweden and Britain (Castle et al, 2007) comparing average fatal and serious accident rates for roads with different star ratings have shown differences in rating of one star to be associated with 25-33% reduction in accidents. More detailed comparisons of ratings and accident rates for individual accident types show the correlation to hold for run-off and head-on accidents, but suggested at one stage of development that the junction assessment methodology needed to be improved.

A recent Euro RAP review found some evidence of a link between average accident rates or accident costs associated with increasing star rating and vice versa in different models that include elements of both crash protection and accident likelihood and from the model with only crash protection elements While there was some variation between studies, the review reported that the more robust studies showed an accident rate reduction in the region of a third to a half when moving from a 2-star to 3-star rating. The reduction was often found to be less when moving between higher Star Ratings. On-going evaluation will be useful to explore these issues further.

6.1.4 Communicating results

There are several issues regarding presentation of results. It is important that:

- Given that safety rating systems need to be built on objective safety data, the 'messenger' i.e. the safety rating partnership is actually independent as well as seen to independent of national governmental and industry concerns. Most rating systems have achieved this with broad international consortiums of motoring and consumer organisations, governments from several countries and independent experts (See the EuroRAP and Euro NCAP partnerships for examples).
- Given the variety of safety rating systems which exist, each publication explains clearly what the particular safety rating in question means and draws attention to any limitations;
- Given the wide audience for results, that these are disseminated widely but targeted at the same time at the road using public, car and infrastructure providers, fleet buyers and decision makers in general.

Euro NCAP

With online information and results available in several languages, Euro NCAP has successfully communicated its findings both to road safety professionals, the car industry and the media. As Bernard Gauvin, the French delegate to Europe NCAP stated at Euro NCAP's 10th Anniversary, the rating system was delivered "in a proper way and using very simple and easy-to-use information. It was non-controversial information both in scientific and commercial aspects and so it was accepted by everybody including consumer associations, media and manufacturers".

Governmental lead agencies for road safety have also been key to successful promotion of new car assessment programmes. In Europe, the Swedish Road Administration (now STA) has created a demand for a high star rated vehicles through its in-house travel and procurement policies and uses higher Euro NCAP ratings as a performance target and performance indicator in its national strategy.

A recent review (ETSC, 2016) indicated that strong governmental promotion was consistent with a high proportion of 5-star rated fleet in Ireland. It noted that 63% of all new cars sold in Ireland received 5 stars - the second largest proportion in the EU. Action six of the Government's Road Safety Strategy 2013 to 2020 consists of a campaign promoting Euro NCAP ratings. The purpose of the campaign was to assist the public when purchasing a car, by informing them on which safety features are available on each model.

"The Irish Road Safety Authority has implemented a national and local information campaign targeting the public through national press, digital and online marketing. The campaign is activated twice a year in the run up to the two dual registration periods at the start and middle of each year." Sharon Heffernan, Road Safety Authority (RSA), Ireland"

Mandatory stickers of Euro NCAP ratings on car windscreens in car show rooms have been promoted by safety organisations. However, this activity has not had the same level of promotion in Europe as the Stars on Cars initiatives in some of the Australian States, following the example of Western Australia, which involve promotion by the road safety lead agencies and others of take up of Australasian NCAP.

A SARAC survey of Euro NCAP ratings in Spain and Sweden concluded that Euro NCAP needed to be promoted more widely and effectively so it plays a higher role in fleet purchasing decisions and encourages fleet managers to develop fleet purchase policies to include specific safety criteria. The postal and telephone survey also concluded that both members of the public and fleet purchases needed be educated about sources of information about vehicle safety. Price and reliability seem to be more important than safety in the purchasing decisions of fleet management SARAC II.

Euro NCAP's strategy 2010-2015 recognizes the importance of a strong communication strategy and timely and accessible communication. It states its intention to support and better coordinate its activities with its member organisations and other stakeholders as part of a 'consumer' targeted dissemination strategy. To provide further focus for Euro NCAP's communication activity, the organisation also intends to carry out clear target-setting, periodic monitoring of key indicators and the demonstration of return on investment (Euro NCAP 2009).

EuroRAP

The value of identifying risk distributions across the major inter-urban road network, and showing roads which have been improved substantially and those that continue to show persistent safety problems, is now well established through the regular publication of EuroRAP results in many countries.

EuroRAP has focused on multi-agency working in its research and dissemination and in popularising topics in the messages it provides. This has commanded widespread media attention. EuroRAP has also provided a full programme of launches/conferences, and a website which attracts many visitors.

According to EuroRAP, awareness of the road safety maps amongst drivers is steadily increasing, although it varies between countries. Website publicity is the most effective way of reaching drivers, although television and motoring magazines are also important sources of information. Over 60% of drivers perceive, correctly, that single carriageway roads are the most dangerous, and more than three quarters of drivers are now influenced by safety concerns when planning their journey.

The campaign in Spain has been particularly successful, with over 40% of Spanish drivers being aware of the maps, but countries which have produced their maps more recently, such as Poland, have also demonstrated rapid progress and show what can be achieved. More than one third of Polish drivers know about the maps and over half report that they frequently choose their route for safety reasons.

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Notes

1. Country abbreviations

	Belgium	BE		Italy	IT		Romania	RO
	Bulgaria	BG		Cyprus	CY		Slovenia	SI
	Czech Republic	CZ		Latvia	LV		Slovakia	SK
	Denmark	DK		Lithuania	LT		Finland	FI
	Germany	DE		Luxembourg	LU		Sweden	SE
	Estonia	EE		Hungary	HU		United Kingdom	UK
	Ireland	IE		Malta	MT			
	Greece	EL		Netherlands	NL		Iceland	IS
	Spain	ES		Austria	AT		Liechtenstein	LI
	France	FR		Poland	PL		Norway	NO
	Croatia	HR		Portugal	PT		Switzerland	CH

2. This 2016 edition of Traffic Safety Synthesis on Safety Ratings updates the previous versions produced within the EU co-funded research projects SafetyNet (2008) and DaCoTA (2012). This Synthesis on Safety Ratings was originally written in 2008 and then updated in 2012 and in 2016 by Jeanne Breen, Jeanne Breen Consulting.

3. All Traffic Safety Syntheses of the European Road Safety Observatory have been peer reviewed by the Scientific Editorial Board composed by: George Yannis, NTUA (chair), Robert Bauer, KFV, Christophe Nicodème, ERF, Klaus Machata, KFV, Eleonora Papadimitriou, NTUA, Pete Thomas, Un.Loughborough.

4. Disclaimer

5. Please refer to this Report as follows:
European Commission, Safety Ratings, European Commission, Directorate General for Transport, October 2016.

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