Definition of a safe barrier for motorcyclists
The literature review was conducted by a team of experts; project manager Maria Nordqvist, SMC, Göran Fredriksson, SVBRF and Jan Wenäll VTI. Research, studies and statistics from around the world have been collected and studied. A joint meeting has been held. This is the result of a literature survey which is sent to the participants before the reference group meeting on February 20th 2015. We welcome comments on the collected material and tips on studies that are missing at the meeting.

Summary of conclusions
The best barrier for a motorcyclist is no barrier at all. If the barrier itself is more dangerous than what it is designed to protect, guard rail should be set up.

According to all tests carried out, barriers with Motorcycle Protection System, MPS, gives the lowest risk of injury, whether the rider slides into the barrier or is sitting on the motorcycle. We therefore choose the term MPS in the future since it gives positive effect in both sitting and gliding collisions.

Most studies show a lower risk of injury for collisions with concrete barriers compared to the w-beam and cable barriers, some displays of comparable severity. Guardrails with unprotected posts and protruding parts lead to the most serious injuries. Smooth barriers without unprotected posts, provide less risk of injury. Several studies have excluded accidents with cable barriers depending on the low number of accidents. The risk of injury in collisions with cable barriers was higher than all other barrier types in some studies, while the risk of injury corresponded to a collision with W-beam in a few studies.

We have chosen not to analyze discontinuous MPS, with protection around the poles, since they give very little reduction in risk of injury. There is also a risk that the rider slide between the posts and collide with the obstacles that the guardrail is intended to provide protection for.

The distance from the road is important for both avoidance of accidents and the risk of injuries.

The most common injuries in guardrail accidents are legs, head, chest and pelvis. All studies show a very high risk of being killed and seriously injured when motorcyclists collide with guardrails.

The technical specification EN1317-8 specifies a test method in which a dummy slid headfirst into a guardrail at an angle where few accidents happen. It is a method that should be simplified, without reducing the safety for motorcyclists. New Zealand and Australia has developed a new test method that should be explored.

It is easy to reduce the risk of injury to motorcyclists in terms of both the design of the guardrail and the installation. There is enough knowledge and experience to come to decisions that will increase the safety of motorcyclists in terms of design and installation.

Literature Study
Literature has been collected, mainly via Google Scholar and our global contacts. We have mainly looked for studies that highlighted three issues we have seen as important factors for the motorcycle safety.

1. Injuries or risk for injuries from different types of barriers
2. Injury risk depending on barrier design and type of barrier
3. Injury risk depending on installation of barriers

In addition, we compared data on Swedish motorcycle accidents against barriers with the rest of the world. Existing test methods has to some extent been analyzed, even if this part of our application for funding was rejected.

There is much research on the area and it grows as the number of killed and injured motorcyclists in barrier accidents increases. Most studies are done in Australia, New Zealand and the United States. Germany has conducted studies before and after MPS and other road safety measures were conducted.

Unfortunately this literature is only available in German. Studies have also been conducted in Sweden, Spain and Italy.

When it comes to concrete actions based on existing knowledge and experience, Norway has progressed furthest in Scandinavia. The Norwegian Public Roads Administration has a chapter in "Handbook for rekkverk (N101)" with clear requirements for the selection of barriers and where MPS should be installed. Spain and Portugal are the countries in Europe which have invested most in barrier protection for motorcyclists. Spain has developed a test method and set aside large sums for the retrofitting of MPS. Portugal has a regulatory framework since 2004 with demands for where MPS must be installed to increase motorcycle safety. Germany, as previously mentioned, also has a program for installation of MPS on popular motorcycle routes. Australia and New Zealand is aiming to install MPS, mainly black spots and popular motorcycle routes. In general however, we note that there is a lack of data on accidents before and after the installation of MPS in all countries.

Share of fatal motorcyclists in barrier accidents
Six motorcyclists were killed in collisions with barriers in Sweden 2014, out of a total of 29 killed in two-wheel motorcycle accidents. The share of motorcyclists killed in Sweden in barrier accidents varies between 10-20 percent per year. The corresponding share in the USA 5.5, Australia 5.4 and 8-16 percent in Europe. Thus, Sweden has an alarmingly high proportion of motorcyclists killed in barrier accidents (1).

57 motorcyclists have been killed in a barrier collision in Sweden from 2000 to 2014, or nearly four persons per year (Annex 2). 26 riders (45.6 percent) have been killed in barrier accidents on the TENT network (Trans-European transport network). Six accidents occurred on municipal streets and roads. The remaining 25 accidents (44 percent) occurred in the smaller state road. During the same period, 2000-2014, 72 persons in cars were killed in barrier accidents. The risk of a fatal crash with a barrier is significantly higher for those traveling on a motorcycle compared to those traveling in a car.

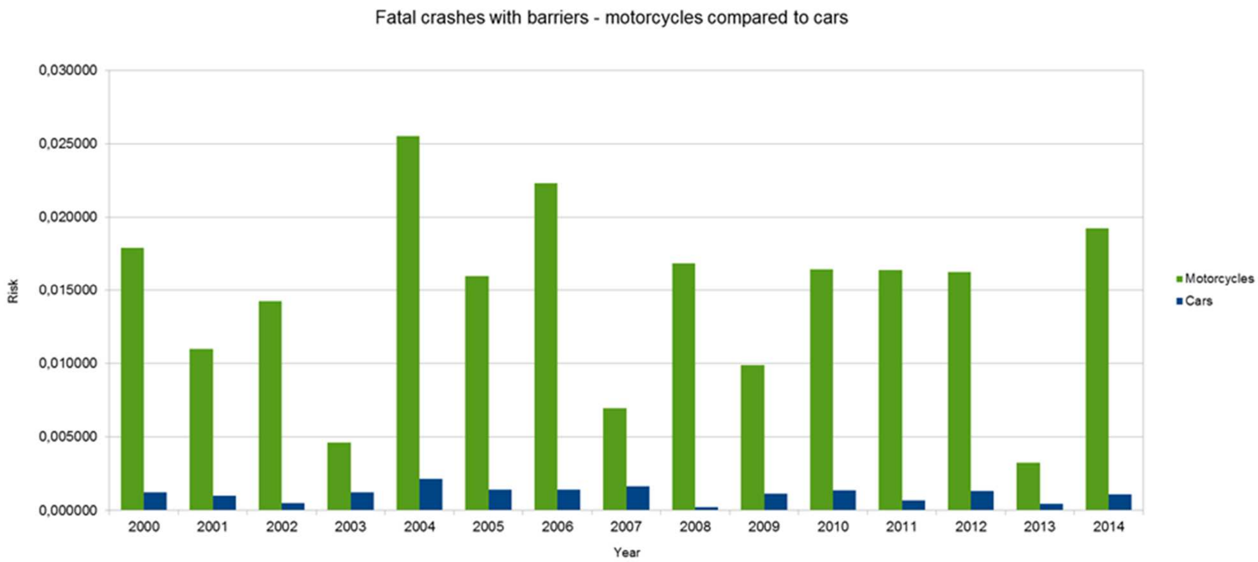

Figure 1. Risk per 1,000 vehicles of being killed in a barrier crash motorcycle/car 2000-2014.
Source: The in-depth studies of fatal accidents, the Swedish Transport Administration and vehicle fleet SCB June 30 each year.

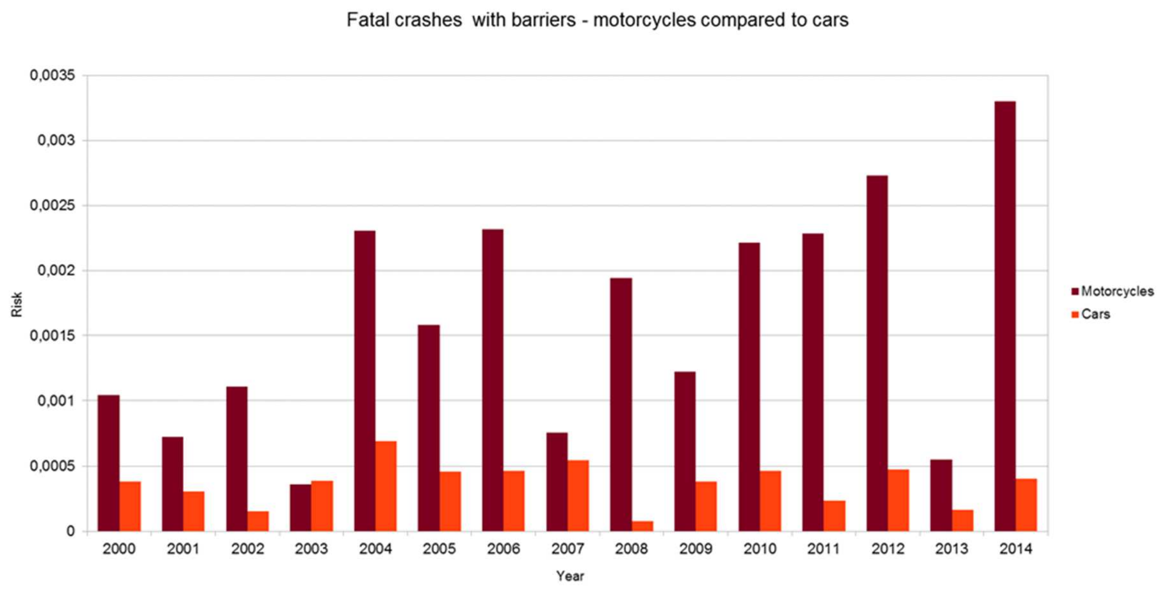

Figure 2: Risk per 1000 km of being killed in a barrier accident motorcycle/ car 2000-2014.
Source: Swedish Transport Administration in-depth studies of fatal accidents and annual mileage according to Trafikanalys. Mileage for a car estimated for 2014. Mileage MC estimated for 2013-2014.

Type of injuries and injury risk for different types of barriers

All studies suffer from that there are enough collisions with all types of barriers for them to be useful in the same survey. Therefore, different barrier types have been excluded in several studies in the absence of statistical evidence.

Myth or truth?

Many studies and presentations from a number of countries, including Sweden, states that it is a myth that cable barriers have a cutting or snagging effect and is usually dismissed as propaganda from motorcycle organizations. This is unfortunately no myth, neither in Sweden nor in other countries. We have taken note of injuries, both in fatal accidents from STRADA and reports from Rescue Services. There are a number of accidents involving motorcyclists who were divided into several parts when they crashed with a barrier (2-3). The same injures can also be found among the seriously injured.

The cutting and snagging effect applies not only to cable barriers but also guardrails of type W-beam and kohlswa. Wenäll noted in 2011 that autopsy reports described severed body parts, both from cable and steel guardrails (4). The common denominator with cable barriers are a large number of unprotected posts. An Italian study, conducted by two pathologists, contains nasty pictures of mutilated motorcyclist killed in collisions with W-beam guardrails. The authors believe that both motorcyclists could have survived if the posts were protected with MPS. The pathologists also adds that their unique knowledge of the injuries from traffic fatalities should be used to create safer roads (5).

Age

Motorcyclists are getting older, the Swedish motorcycle owner is on average 53 years (6) which increases the risk of serious injuries and fatalities in collisions with various obstacles on the side of the road (7).

Studies from different countries

Sweden

Two Swedish studies have looked at injuries to motorcyclists who collided with a motorcyclist. The first studied about 20 typical accidents against various barrier types. In almost all accidents, the rider was sitting on the motorcycle at the collision. Most common were injuries on legs and feet. In the fatal accidents dominated head, neck, chest and pelvis injuries. In the most severe accidents, limbs were torn off. In all the accidents where the motorcyclist died, he/she got caught in the barrier (4).

Another Swedish study has analyzed all police-reported motorcycle accidents with guardrails and made a number of in-depth interviews. Accidents on cable barriers, W-beam and kolswa have been studied (73 percent of all accidents), while accidents with concrete, pipes and unknown types were removed. The study covers 116 police-reported accidents and 55 interviews.

FSI ratio (Fatal Serious Injury) showed no difference in injury outcomes of motorcyclist collisions with any of the investigated barrier types: cable, w-beam and kohlswa. Meanwhile, the FSI ratio is high, 50 percent or more, in a crash between a motorcyclist and the three investigated barrier types. The FSI ratio is about 35 percent in general motorcycle accidents in Sweden.

The analysis also shows a clear association with risk of injury based on if the motorcyclist was sitting on the motorcycle at the collision or slid into the barrier. Motorcyclists who slipped into the barrier was injured considerably more serious than those who sat on the motorcycle in the collision. The predominant injuries were legs, especially among those who sat on the motorcycle in the collision. The author says that the risk of medical disability and severe outcome can be reduced (8).

Australia / New Zealand

In Australia / New Zealand, a number of studies have been made of 78 fatal accidents on three barrier types: cable, w-beam and concrete. The injuries that occurred was similar, regardless of barrier. Most injuries occurred to the chest, followed by head injuries. More injuries occurred to the chest and pelvis when the motorcyclist slid along the barrier. All riders who collided with cable barrier (seven accidents) had thoracic injuries which was the highest rate (1). A previous study by the authors show that collisions with concrete barriers resulted in fewer serious injuries (9).

A study was presented in December 2014, based on the 78 accidents in Australia and New Zealand by the authors of the studies above. It constitutes the completion of seven years of research with the aim to clarify which barriers are safer for motorcyclists, where they should be installed and also proposes a new test method. The study concludes that smooth barriers (steel guardrails with MPS and concrete barriers) provides a significantly lower risk of injury to motorcyclists. The best effect is a guardrail with MPS which is envisaged to prevent serious head, neck and chest injuries in collisions at 15 degree angles at speeds up to 100 km/h. Concrete barriers are expected to prevent serious injuries in collisions at speeds below 80 km/h when the collision occurs at a 15 degree angle(10).

Germany

A German study 2005 compared the crash tests with both a seated dummy on motorcycle (60 km/h) as a sliding dummy against concrete, W-beam and guardrails with MPS. Measurements were made of the collision, both with the barrier and with the ground. This was compared with computer simulations of the seated dummy, which collided with cable barriers at Monash University in Australia. It is the only crash test between a motorcycle and cable barriers that the authors found. No country or manufacturer has conducted crash tests with motorcycles and cable barriers in reality.

When the motorcycle and seated dummy collided with the w-beam barrier, serious but not life-threatening injuries when the dummy got stuck and injured by protruding parts. Most injuries occurred on chest, shoulder and pelvis. A corresponding test with concrete barrier gave less damage, but the dummy was thrown over the barrier. The crash tests against w-beam barrier where the dummy and motorcycle slid into the barrier showed very serious injuries over the limit for survival when the dummy collided with a pole after five meters. In the horizontal test against the concrete barrier the dummy slid dummy longer compared to the w-beam. This test also showed injuries that could cause serious or fatal head injuries while injuries to the thorax and pelvis were lower compared with the W-beam barrier.

The German tests provided a basis for a computer simulation in MADYMO model against cable barriers and concrete barrier where the rider drives into the barrier seated at two different speeds and angles. The simulations with concrete barrier showed severe injury to the head and chest, within the limit of survival. The simulations with cable barriers showed very serious injuries, regardless of the speed and angle. In all simulations, the rider got stuck in cable barrier which caught the front wheel in the post and threw the rider forward with the head first. Since the rider got his leg stuck in the cable, the head and chest was hit in the rotating motorcycle. In all simulations the rider was thrown over the barrier with the head first, which meant head injuries that are impossible to survive. Although the risk of getting caught and getting leg snagged was severe in the cable barrier tests, the authors considered that the biggest risk is that the cable led the motorcycle into the posts where the front wheel got stuck and the rider was thrown from the vehicle. No simulations were made when the motorcyclist slid on the ground into the cable barrier.

The study showed that the lowest risk of injuries, in both sitting and lying collisions, was with guardrails with MPS. The MPS made it impossible for body parts to get stuck in the barrier at the seated test. The dummy however, fell over the barrier at the end of the test. The only barrier where a sliding dummy were measured to survivable injuries was in the test with MPS railing (11).

USA

Several researchers in USA have analyzed in-depth studies of fatal accidents on motorcycles. We have not found any study that describes injuries associated with barrier collisions, but a number that describes the risk of injury due to barrier types and other obstacles.

Gabler has studied fatal accidents on motorcycles in several reports 2007-2013 in the United States and 2000-2008. He concluded the one of eight motorcyclists who collided with a railing died. It gives a mortality risk that is 80 times higher compared to those traveling in a car. All studies show a comparable level of risk based on two compared barrier types: steel guardrails, w-beam, and concrete barriers. All collisions with fixed objects leads to higher risk of death compared with the risk of colliding with another vehicle or a fall to the ground. The risk of being killed in collision with w-beam barrier is 12 percent, while the risk of being killed in collision with concrete barrier is 8 percent. Gabler concludes that the risk of serious injury is 1.4 times higher in crash with w-profile compared with concrete railing. The study found no significant difference in collision with a cable barrier compared to the w-beam barrier. Gabler has also found that the risk of death is higher in collision with both concrete and w-profile rail compared to cars where the risk is 4.8 per cent (12, 13, 14).

Malaysia

Computer simulations were carried out at different speeds, different angles and with different distances between the posts. It contained only simulations against w-beam barriers which are the most common barrier type on the particular motorcycle roads in the country. The study concludes that W-beam barriers are not safe for motorcyclists and the risk of serious injury increases with higher speed, higher impact and the shorter the distance between the posts (15).

Accident Sequence

Regardless of the study and the country in which research is conducted, the results show that in about half of the accidents the motorcyclist was sitting on the motorcycle at the collision, in half the motorcyclist was sliding into the barrier. When the motorcyclist is sitting on the motorcycle, the risk that the driver is thrown over the barrier is relatively high. The risk of being thrown over the barrier seems to be similar for w-beam and concrete barriers. Simulation studies made with collisions against cable barriers showed that the rider always was thrown over the barrier (11). The majority of the investigated accidents in all countries takes place at angles less than 15 degrees, while the European technical specification EN 1317-8 uses 30 degrees at the test.

Sweden
The Swedish study of 160 accidents showed that the impact angle was 1-20 degrees in 50 percent of accidents. 29 percent of all riders slid into the barrier, 23 percent were sitting on the motorcycle and fell over the barrier, 36 percent were sitting on the bike and did not fall over the barrier, and in 13 percent, the circumstances of the accident is unknown. An analysis of the fatalities in the Swedish study showed that 43 percent slipped into the barrier, 32 percent were sitting on the motorcycle and fell over the barrier and 25 percent were sitting on the motorcycle without falling over over (16).

Australia / NZ
Of the 78 surveyed fatalities in Australia, the average angle was 15.4 degrees and the average speed was 100.8 km/h. The distance from impact to stop was 28.9 meters for a seated motorcyclist, 26.3 meters when the motorcyclist scraped, rolled or slid along the railing top and 12.7 meters for the motorcyclist who slid along the ground (1).

Germany / Netherlands / France / UK / Finland
The project APROSYS analyzed motorcycle accidents in four databases. It notes that most accidents occur at low angles at a speed of 50 km/h. It is more common that the motorcyclist is sitting on the motorcycle at the collision than the rider/passenger sliding into the barrier or other obstacles in the side area (17).

Where do the accidents occur?

Sweden
A review of 57 Swedish fatalities among motorcyclists and motorcyclist from 2000 to 2014 shows that 26 of the accidents occurred on the TENT-network (18). 53 percent of all barrier accidents in STRADA 2003-2010 took place on collision-free roads without oncoming traffic. Two thirds of the accidents occurred on a curve, the rest on a straight road. 39 percent of the accidents occurred on roads with a maximum speed of 90 km/h hour or more, while 48 percent took place on 50 and 70 routes.

The Swedish study of 160 accidents conducted by Vectura and the Swedish Transport Administration identifies two types of rail accidents in Sweden:

1. Accidents on busy roads with high standards and high speed limit. No significant differences in risk of injuries between different W-beam rail and cable barriers were found.

2. Accidents on smaller roads with low standard. 20% higher risk of injury in a collision with barriers compared to other single vehicle accidents where rider went off the road (16).

Australia / New Zealand
Accident analysis of all barrier accidents in New Zealand shows that twelve of the 20 accidents occurred on State highways with 100 as a speed limit. Fifteen of the fatalities occurred in the curve. Of accidents with non-fatal outcome, 83 percent occurred in a curve. Countries with guidelines for installation of MPS has demands for MPS in curves with a given radius and at slip roads. A brand new study from Australia/NZ notes that it is economically viable to install MPS along roads with a lot of motorcycle traffic (10). Germany has implemented similar initiatives resulting fewer fatalities in motorcycle against barriers (19).

The installation of barriers
The Swedish study of a number of typical motorcycle accidents against different types of barriers drew attention to the importance of a recovery zone. It allows the rider to take evasive action if something unexpected happens on the road. It is obvious that increased barrier expansion close to the roadway gives more barrier collisions for all types of vehicles (4).

Research is also available in this area which shows that increasing the distance of both barriers and other fixed obstacles in the road environment provides improved security. Several studies describe that higher demands on the roadway and roadside width increase safety. IRAP has presented a number of guidelines regarding the installation of obstacles in the road lane areas. The guidelines are based on iRAPs methodology to identify safe routes. ARRB Group has also evaluated iRAPs risk parameters. ARRB say that a very important factor for determining the risk of collision is road width, including paved shoulders. The risk decreases by increasing both the road and the coated roadside width. Several studies describe how the accident risk decreases by increasing the roadside width of 1.5-2.5 meters (20). Norwegian Trafikksikkerhetshåndboken points to the same accident reduction with increased width of the shoulder (21).

iRAPs guideline "Roadside Severity Distance" concludes that most collisions with obstacles in the road environment occurs in 5-20 degrees. The relatively low angle means that recovery zones up to five meters or less can have an effect on the outcome of the accident. A number of studies are analyzed and all clearly show that an increased security zone from one to five meters would increase safety substantially, both for those who travel in cars and on motorcycles (22). The same results are reported in the Norwegian Trafikksikkerhetshåndboken (21).

Conclusions

All studies point in the same direction regarding accident sequence, injury risk and injuries. Based on accident data and simulations, we have based our definition of a safe barrier for motorcyclists. First, some certainties that are important to point out regarding barriers.

- If the barrier itself is more dangerous than what the barrier is designed to protect from - no barrier should be installed.

- The more barriers that are installed, the more motorcyclists will be killed and seriously injured in barrier accidents.

- The risk of injury to a motorcyclist in a collision with a barrier is very high compared to those traveling in the car.

- The main task for the median barriers is to reduce the risk of collisions, which will benefit all road user groups. But the median barriers must also include a minimal risk of injury for those who collide with them, also vulnerable road users like motorcyclists.

- A flat slope or a ditch without a fixed obstacle means significantly reduced risk of injury to a motorcyclist compared to a side barrier.

- Barrier types with unprotected poles; w-beam, kohlswa- and cable barriers have the highest risk of injury to motorcyclists.

- Barrier types with MPS have the lowest risk of injury to motorcyclists, regardless of how the collision occurs.

- Most Swedish fatal accidents on motorcycles occurs in curves, also among the barrier accidents. The risk of being injured and killed in rail accidents is very high on TENT roads.

- A wider recovery zone, between barriers and road reduces both the risk of accidents and the risk of injuries.

- Guardrails where body parts may get stuck is worse than barriers where body parts can slide along the barrier.

- An motorcycle-friendly barrier shall not impair the safety of those traveling in cars or other types of vehicles.

- The road authorities can reduce the risk of injury to motorcyclists in the selection of the roadside measurements, the choice of barrier and the distance between barrier and roadway.

A safe barrier for motorcyclists is
- a barrier where you cannot be thrown over in a collision,
- a barrier without protruding parts where parts of the body and/or the motorcycle can get caught
- a barrier without openings, vertical or horizontal, where parts of the body and/or the motorcycle can become trapped,
- a barrier with a smooth upper surface,
- a barrier without unprotected posts in both the ground level as the top side,
- a barrier with energy-absorbing MPS
- a barrier that is not fitted with bodywork which involve a higher risk of injury and
- a barrier which is located at a distance from the road surface allowing a fescue space

Classification of barriers, based on collision-friendly features

Based on the literature review, we have made a proposal for a classification of barriers, based on collision-friendly features when a motorcyclist, sitting or sliding, collides with a barrier. The classification is done from -1 to +5. For each type of barrier protection, positive barrier properties have been specified by the characters **, each of which reduces the risk of injury. In each class there are specified examples of typical barriers in the class. Pictures of each railing is available in Appendix 3.

Class	Positive barrier properties	Examples of typical barriers
5 **	** Smooth side with energy-absorbing MPS, smooth top, overrun protection fitted	NA
4	overrun possible ** smooth barrier profile, energy absorbing MPS smooth top	Euskirchen Plus
3	Uneven top, overrun possible, ** smooth barrier profile, energy-absorbing MPS	W-beam with MPS according to 1317-8
2	Uneven peak, driving over possible ** smooth barrier profile, MPS function is, however, not energy-absorbing	Concrete barriers
1	Accessible balusters cc <4 m, sharp edges, large openings in horizontal and vertical directions, overrun possible ** smooth barrier profile with smooth / covered upper side arbitration Railing (roof rack) with smooth steel profile both side and top	Roof rack with smooth profile on both side and top
0	Accessible balusters cc <4 m, sharp edges, large openings in horizontal and vertical directions, uneven top, driving over possible ** smooth barrier profile	W-beam, kohlswa
-1	Protruding parts on the barrier side and top, accessible balusters cc <4 m, sharp edges, large openings in horizontal and vertical directions, odd page, uneven top, overrun possible	Cable barriers with hanging hooks

Definitions:
- Sharp edges implies a radius less than 40 mm (pipe barriers typical diameter of about 90 mm)
- Protruding parts may be hanging devices for rope, screw heads, steel edges and pole tops sticking out above the barrier
- Large openings are those in which a body part can enter or part of the motorcycle get caught
- Uneven side constitutes that part of the barrier that serves as railing (capture/hold back the vehicle) is not smooth. In addition to an increased risk of injury when sliding along the barrier, the wheel on the motorcycle can get stuck and also body parts.
- Uneven top means that the pole tops are accessible, ends flush with or below 50 mm below the top edge of the railing, alternatively railing design is uneven for other reasons, such as joints between elements.

Remarks:

- The possibility of retrofitting and adding MPS to existing guardrails to make the barrier more MC-friendly is a positive quality that is not valued above.
- The distance from the roadside/outer coating and barriers are not taken into account since this is a factor that is assumed to limit the risk of collision, the greater the distance is. The table above instead assumes that a collision occurs and how to minimize the injury risk when it happens.

Discussion and suggestions for action

Safer barriers

An increased use of barriers in Class 3-4-5 above instead of -1 and 0 would reduce the risk of injury among motorcyclists significantly. Road authorities should endeavor to always choose barriers where the retrofitting of MPS protection can be used to increase motorcycle safety. Test railings with MPS, new class designation, eg Nm Hmm, Lm?

It should be possible to do the w-profile barriers safer by using the crossmember on the railing but not on the MPS. This will avoid that the foot peg and legs to collide with the MPS protection in a collision. It should also give greater possibility that the motorcyclist will not fall over the barrier. However, at the same time there is a greater risk of hitting the pole tops (25). We believe that this is an appropriate area to conduct tests and therefore recommended that this is done.

It should be possible to introduce similar regulation in Sweden as in Norway for where MPS should be installed on the road network. Most motorcycle accidents occur in curves and the Norwegian rules are based on crash tests with barriers based on the Vision Zero collision curves (23). We recommend that the Swedish Transport Administration, the Swedish Transport Agency and SKL introduce these rules promptly in all legislation concerning barriers.

The above proposal does not solve the problem of barrier accidents on the TEN-T road network where there are only requirement of using MPS on side barriers at the exits. Most barrier accidents on TENT-tract occurs on the straight roads. A first measure is to increase the distance between the roadway and the median and side barriers. In addition to this, the barriers on the TENT-roads with high speed limits must be chosen with great care. There are existing requirements to use barriers that are safe for unprotected road users (including motorcyclists) at the initial investment and replacement of barriers (24). Although it is desirable that all barriers are fitted with MPS, it is unclear whether this is economically viable.

This is an area where the Swedish Transport Administration could initiate and fund innovative work to find a barrier type that reduces the risk of injury for motorcycle riders while maintaining or even increase the protection for other vehicles. A slightly increased barrier height, about 100 mm W-profile barrier in the capacity class N2 provides better vehicle restraining effect and allows the installation of many existing MPS system. The MPS are often too high to fit between the existing W-profile and ground with the old standard height of 550 mm to the center of the railing. Median and side barriers with smooth and wider railings than what's on the existing railings is desirable. Existing concrete railings could be used to a much greater extent than today since they present a lower risk of injuries to motorcyclists compared to a cable-, w-beam- and kohlswa barriers. However, without initiative, requirements and wishes of road management, there will be no development in this area.

Safer road sides

It is not difficult to improve safety for motorcyclists regarding roadsides. A first response is to never install side barriers on the roadsides if they can be cleared of obstructions. An increased width of the paved shoulder and a longer distance to the side barrier will also reduce the injury risk. This calls for clear requirements in all regulations that govern the roads and street design and maintenance.

Reduce fall over the barriers

A first measure is to demand higher barriers compared to today, for both median and side barriers. Another possible measure to reduce falls over median and side barriers is to trap the motorcyclist safely before the motorcycle and rider reaches the barrier. This could be accomplished by creating sand pens between roadside and road barrier in the same way as in the motorcycle sport.

Tests
Today's test method in which an MPS protection is tested by a lying dummy which slides with the head first against a barrier is too complicated. This method is costly when the dummy breaks in collisions of 60 km/h. Thus, one cannot measure the outcome of the collision. The collision occurs at an angle where few accidents happen, 30 degrees.

Barriers should be tested in a much simpler way. Computer simulation has proved to be useful in many contexts. Australia and New Zealand have conducted simulations and compared with results from tests according to EN 1317-8. Computer simulations will, if we understood the study correct, be included in the barrier standard which is revised right now to include motorcycle safety (10). Important in this context is that the demands on the quality of the simulation is established.

We recommend that the authorities proceed according to our initial request from Skyltfonden with the development of alternative tests that are more realistic, cost efficient and full-scale experiments based on what this literature study has given in the form of conclusions.

Maintenance
The Swedish Transport Administration has installed MPS protection in 2012 in order to determine their resistance to damage during winter. After two winter seasons, it has not recorded any injury outcomes that would be a hindrance, in terms of longevity and maintenance, installation of this type of protection. There is an accumulation of debris, gravel and leaves on the ground against the side of the road, however, which is an effect that requires some increased maintenance compared with barriers without MPS. The trials will be completed and evaluated after this winter season, becoming the third.

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Appendix 1. Studies and research in the field and method

Sweden

Motorcycle Safety - a literature review and meta-analysis, Pål Ulleberg 2003. Method: literature review.

VTI notat 38-2002, Motorcycles and crash barriers, Göran Nilsson. Method: Literature study and review of motorcycle accidents against barriers.

VTI notat 43-2005, Crash barriers and hazards to motorcyclists in collisions with a small angle, Håkan Andersson 2005. Method: Literature study of collisions with low collision angle to the road barrier, less than 20 °.

Motorcyclists colliding with crash barriers, Study of a number type accidents, Jan Wenäll 2011. Method: By calling for accidents from the Police, SMC and the Swedish Transport Administration examine the typical personal injury as a motorcyclist hit by the collision with a crash barrier, with a hope to be able to link the injuries to specific technical details and, if possible, identify possible improvements in barriers.

Motorcycle Crashes into Road Barriers: The Role of Stability and Different Types of Barriers for Injury Outcome, Rizzi others. Method: an analysis of police-reported accidents and in-depth interviews with a number of motorcyclists who collided with railings. Both analyzes compared the motorcyclists injuries.

Improved road design for future maintenance - Analysis of Road Barrier Repair costs. Hawzheen Karim 2011. Method: Treatise on the rack-life costs, including social costs, as well as injury rate per edge protection based on the cost of railing repairs and accidents in STRADA.

Motorcycle accidents with barriers, Vectura/the Swedish Transport Administration 2011, presentation. Analysis of 160 rail accidents and 55 in-depth interviews.

Norway

Trafikksikkerhetshåndboken, Alena Høye, Rune Elvik, Michael WJ Sørensen, Truls Vaa, Institute of Transport Economics in 2012. Methods: A comprehensive literature review concludes with suggestions. Describes, among other things, risks of side barriers compared with forgiving roadside areas and how the road's width and increased recovery zone can reduce the risk of accidents.

Rekkverk och vegens sidoområder, Public Roads Administration in 2014. Chapter 3.98 describes requirements on the railings outside the MC safety, and in which curves, based on speed and radius, railing protection to be installed.

Crash tests Nordic Test Center AS 2009, dummy against barrier with MPS protection (STAR MC Hallingplast AS). Objective: The approval of the MPS for the Norwegian market.

Italy

Massive Lesions Owing to Motorcyclist Impact Against Guard Rail Posts: Analysis of Two Cases and Safety Considerations, Brandi Marti multi 2011. Methodology: autopsy of two killed MC drivers against the railing with W-beam.

Germany

Schutzeinrichtungen am Fahrbahnrand kritischer Streckenabschnitte für Motorradfahrer, Jürgen Gerlach and Kai Oderwald, Heft 152 BAST 2007. Methodology: analysis of accidents in Rhineland-Pfalz. Analysis of road conditions where accidents occurred which were compared with distances without accidents. The booklet presents suggestions on where planners should consider measures MPS to reduce the risk of injury to motorcyclists.

Pruefung von Fahrzeug-Rückhaltesystemen an Straßen durch Anprallversuche Gemäß DIN EN 131, Heft 157, Ralf Klöckner and Jürgen Fleisch, BAST 2007. Method: The study deals with barriers and MPS that reduce the risk of injury for both heavy traffic and motorcyclists. The results will be used to develop a barrier standard.

Anprallversuche an motorradfahrerfreundlichen Schutzeinrichtungen, Heft 193, Ralf Klöckner, BAST 2010. Describes how the MPS developed to railings will be safer for both those who travel in cars and on motorcycles. A new railing protection, "EDSP-Motorrad" was designed based on research and experiences from the Federal Highway Research Institute.

Merkblatt zur Verbesserung der Verkherssichrheit auf Motorradstrecken, 2007 . An MC-working group of the "Gesellschaft für Forschung und Straßen- Verkehrswesen" has studied motorcycle accidents, implemented measures and then presented a paper on how popular motorcycle roads can be made safer.

Germany / Australia

Motorcycle impacts to roadside barriers - real world accident studies, crash tests and simulations carried out in Germany and Australia. Berg & Grzebieta 2005. Method: Step 1 in Germany: Analysis of 57 motorcycle accidents leading to two different test scenarios (seated 12 ° / sliding 25 °) in 60 km / h on W-beam and concrete railings. Although tests against railing with MPS. Step 2 at Monash University, Australia. The German performance against the concrete railing was used for computer simulation for motorcycle drivers who collide with railing sitting on motorbike. The model has been used for different speeds in the 25 ° angle with the cable barrier.

Spain

Improving motorcyclists' safety in Spain by Enhanced Crash Test Procedures and Implementation Guidelines, Garcia and others 2009. Methodology: evaluation and development of Spanish test method UNE 135900-2008.

Innovative Concepts for Smart Road Restraint Systems (RRS) to Provide Greater Safety for motorcyclists, Juan Albla multi 2014. Methodology: a part of the project Smart RSS, which includes testing of the railing with sensors that function as e-call.

Technical bases for the development of a test standard for impacts of powered two-wheelers on roadside barriers, Steffen Peldschus et al 2007. Metho: 1000 analyzed in depth studies in various European databases and investigated the railing collisions. Also investigated methods of testing in Spain and Germany.

USA

Probabilistic models of motorcyclists' injury severities in single- and multi-vehicle crashes, Savlolainen, Mannering 2006. Method: Investigated all police-reported motorcycle accidents in Indiana 2003-2005.

Death by Motorcycle: Background, Behavioral and Situational Correlates of Fatal Motorcycle Collisions, Samuel Nunn 2011. Method: Analysis of 601 police-reported fatalities from 2003 to 2008 on the motorcycle in Indiana, USA. Order to identify the causes of death and the factors that increase the risk of being killed.

The risk of fatality in motorcycle crashes with roadside barriers, Paper 07-0474, Hampton C. Gabler 2007. Method: Analysis of several different reporting of accidents and vehicles.

The Fatal and Serious Injury Risk of Motorcycle Collisions with Traffic Barriers, Hampton Clay Gabler, 2014. Presentation at the International Road Federation-Asia Conference Designing Safer Road Side.

The emerging risk of fatal motorcycle crashes with guardrails, Hampton Gabler 2007. Methodology: Comparative analysis of rail accidents in the US for motorcycle and car.

Fatality risk in motorcycle collisions with roadside objects in the United States, Allison Daniello, Hampton C. Gabler, 2010. Methodology: analysis of two databases Motorcycle accidents from 2004 to 2008. The aim is to clarify the risk of being killed in a collision with different object.

Malaysia
Roadside barrier and passive safety for motorcyclists, Ibitoye, Radin, Hamouda 2007 Method: Simulations MADYMO W-beam. Different angles (15,30,45) different speeds (32, 48, 60) and the varying distance between the poles (2 and 4 meters).

Australia / New Zealand
Motorcycle crashes into roadside barriers, Stage 4: Protecting motorcyclists in collisions with roadside barriers, Bambach & Grzebieta, 2014. Method: A fourth and final step in the research on collisions MC railings with a view to provide knowledge about how railings can made safer for motorcyclists without increasing the risk to other road users. Analysis of 78 fatalities in Australia / New Zealand and a number of simulations. Motorcyclist impact into roadside barriers, Grzebieta, Bambach, McIntosh, 2013. Method: Has studied 78 fatal accidents motorcyclist-railing (2001-2006) in Australia / NZ on cable barriers, W -balk and concrete.

Motorcyclist Impacts Into Roadside Barriers- Is the European Crash Test Standard Comprehensive Enough? Raphael Grzebieta, Mike Bambach, and Andrew McIntosh 2013. Method: Have compared the European technical specification EN 1317-8 for motorcyclists who collide with railings and relevance for Australian fatal accidents where the motorcyclist collided with railings.

The Protective Effect of roadside barriers for motorcyclists, Bambach, Mitchell, Grzebieta, 2012. Method: Analyzed police reports and hospital data in 1364 cases from 2000 to 2009 and compared railing collisions with obstacles. Seven collisions with cable barriers were removed from the study, because of the low number.

Injury Typology of fatal motorcycle collisions with roadside barriers in Australia and New Zealand in 2011, Bambach, Grzebieta, McIntosh. Method: Analyzed autopsy reports of all fatal accidents MC In Australia and New Zealand, of 1348 were 78 fatal accidents against the railings.

Characteristics of fatal motorcycle crashes into roadside safety barriers in Australia and New Zealand, Jama Hussein, H. 2010. Method: Based on autopsy reports in Australia and New Zealand 2001-2006.

Singapore
An Analysis of Motorcycle Injury and Vehicle Damage Severity using Ordered Probit Models, MA Quddus, 2001. Methodology: Analysis of all motorcycle accidents in Singapore from 1992 to 2000.

EuroRAP
Barriers to Change - Designing safe roads for motorcyclists, EuroRAP 2007. Methodology: a panel of exports from various countries analyzed statistics and research, pointing to the proposed measures.

FEMA
Crash Barrier Report, Eric Thiollier FEMA 2000. Method: A review of existing test methods, railing protection and infrastructure safety railings in Europe. Concludes with proposals for action.

The road to success - reporting of ongoing measures to increase motorcycle safety with respect to the railings in Europe in 2005.

New Standard for Road Restraint Systems - Designing Safer road-side for motorcyclists, 2012. The document is written a FEMA under the project Riderscan where research, statistics and measures from all over Europe were compiled and analyzed.

IRAP
Review of IRAP risk parameter, Turner and others ARRB Group, 2009.
Road Attribute risk factors; Media Type, 2013. Method: iRAPs toolkit and literature studies
IRAP road attriute risk factors; Roadside severity-object, 2013. Method: Literature study iRAPs + toolkit.
IRAP Road Attribute risk factors; Roadside severity-distance, 2013 Method: iRAPs toolkit and literature studies.

Appendix 2. Fatal motorcycle- barrier accidents Sweden 2000-2014 R= rider P= passenger E=transeuropean network roads

Month	Day	County	Place	Road	Road	Age R/P
2014						
4	23	Uppsala	Enköping	Trafikverket	E18	54 /R
5	30	Skåne	Åstorp	Trafikverket	E4	42/R
7	5	Ö-götland	Söderköping	Trafikverket	LV799	34 /R
7	16	Y	Örnsköldsvik	Trafikverket	E4	49/R
7	24	X	Sandviken	Trafikverket	E16	43 /R
8	23	Sörmland	Nyköping	Trafikverket	E4	34 /P
2013						
5	26	O	Strömstad	Trafikverket	Lv1027	21/R
5	26	T	Askersund	Trafikverket	LV205	30/R
6	24	K	Ronneby	Trafikverket	E22	27/R
7	27	H	Oskarshamn	Trafikverket	LV771	38/R
9	21	O	Partille	Trafikverket	E20	44/R
2012						
7	12	X	Gävle	Trafikverket	E4	63/R
2011						
4	24	AB	Nacka	Local	Street	44/R
5	20	AB	Sollentuna	Trafikverket	E4	39/R
5	21	LM	Ängelholm	Trafikverket	E6	20/R
6	26	AC	Umeå	Trafikverket	E4	38/R
7	30	AB	Vallentuna	Trafikverket	LV280	65/R
2010						
7	10	Y	Sundsvall	Trafikverket	E4	43/R
8	7	D	Nyköping	Trafikverket	E4	56/R
9	8	AB	Stockholm	Trafikverket	E4	18/R
9	10	O	Göteborg	Trafikverket	E45	30/R
9	27	LM	Örkelljunga	Trafikverket	A ALLM VÄG	21/R
2009						
6	15		Göteborg	Local		33/R
7	30		Älvsbyn	Trafikverket	LV 555	58/R
8	20		Kungälv	Trafikverket	E 6 MV	45/R
2008						
6	6	O	GÖTEBORG	Trafikverket	A ALLM V	21/R
6	21	LM	HELSINGBORG		Local	25/R
8	2	O	GÖTEBORG	Trafikverket	E6/RV 45	42/R
8	6	F	JÖNKÖPING	Trafikverket	E4	48/R
8	24	X	GÄVLE	Trafikverket	RV 80	42/R
2007						
6	4	BD	LULEÅ	Trafikverket	E4 MV	59/R
8	23	BD	LULEÅ	Local	Street	29/R

2006						
6	21	K	RONNEBY	Trafikverket	RV 27	23/R
6	8	S	KARLSTAD	Trafikverket	E18	29/R
6	14	AC	UMEÅ	Trafikverket	E4 MV	40/R
8	1	H	VÄSTERVIK	Trafikverket	LV786	42/R
4	23	AC	ROBERTSFORS	Trafikverket	LV 670	52/R
6	15	K	OLOFSTRÖM	Trafikverket	LV 538	56/R
2005						
10	1	D	TROSA	Trafikverket	LV 219	20/R
6	3	F	JÖNKÖPING	Trafikverket	RV 40	23/R
8	1	T	KUMLA	Trafikverket	LV 529	25/R
7	27	T	KARLSKOGA	Trafikverket	E 18	58/R
2004						
4	15	O	ALE	Trafikverket	RV 45	25/R
5	22	U	KÖPING	Trafikverket	E 18	40/R
5	27	AB	STOCKHOLM	Local	Street	27/R
6	24	LM	VELLINGE	Trafikverket	E 6	32/R
8	14	LM	HELSINGBORG	Trafikverket	E4 MV	22/R
9	18	LM	LUND	Trafikverket	LV 945	16/P
2003						
8	20	W	LEKSAND	Trafikverket	LV 919	24/R
2002						
4	12	T	KUMLA	Local	Street	22/R
7	28	U	VÄSTERÅS	Trafikverket	E18	24/R
8	24	W	HEDEMORA	Trafikverket	LV270	45/R
2001						
8	19	AB	VAXHOLM	Trafikverket	LV274	21/R
7	28	T	LJUSN-BERG	Trafikverket	LV792	33/R
2000						
7	28	AB	VAXHOLM	Trafikverket	LV1002	28/R
8	1	D	KATRINEHOLM	Trafikverket	LV216	30/R
7	9	N	KUNGSBACKA	Trafikverket	E6	45/R

Average age: 36 years. Two women, one passenger, one rider. Two passengers, 55 riders. Most fatal barrier accidents on the following roads:

E4	13
E6	5
E18	4

E16, E22, E20 and E45= one fatal accident on each road. In total 6 fatal accidents on the TENT roads which means 45,6 percent. Six fatal accidents on local authority roads/streets, 51 on the state owned roads.