Flexible Barriers – Why we install wire-rope barriers on New Zealand roads

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Purpose of this report

This report has been prepared for the Minister of Transport, Hon Simon Bridges, by the Ministry of Transport (the Ministry) and the New Zealand Transport Agency (NZTA).

This report investigates the concerns and suggestions raised by a petition received from Change.org about the safety risk that wire-rope barriers (also referred to as flexible barriers) are thought to pose to motorcyclists. This report will inform the Minister's response to the petition, and the NZTA will use this document on their website as an informative public resource.

Executive summary

Road safety needs to be considered from the perspective of protecting all road users, and consequently, the question of barrier systems cannot be limited to motorcyclists. Our barrier systems are designed to maximise the safety of all New Zealanders by placing the safest, most suitable barriers, that are appropriate to the road conditions. Motorcycle crashes into roadside and median barriers are relatively infrequent, and are only a small proportion of both motorcycle safety and New Zealand's overall road safety.

The Change.org petition calls for stopping the installation of wire-rope median barriers on motorways, and instead to install semi-rigid barrier systems with motorcycle safety rails. However, there is a substantial body of evidence and research suggesting that flexible wire-rope barrier systems are the most forgiving barrier system, and have the lowest overall ratio of deaths and serious injuries from barrier collisions.

The MUARC Report, 'Motorcycles and Barriers' states, *"Given the demonstrated safety benefits of WRSB's* (wire-rope safety barriers) *to the majority of road users, and the fact that motorcyclists impacts into WRSB's have to date been extremely infrequent, the question of whether it is ethically responsible to deny the vast majority of vehicle-based road user groups the safety benefits of WRSB over other available barrier types must be raised"*.[i]

Whilst semi-rigid barriers with additional rub-rails may offer better protection for motorcyclists in some crash situations, these types of barriers are likely to have minimal effect on reducing motorcycle injuries overall. Research suggests that these barriers are only likely to be cost effective on high-risk motorcycle routes, such as the Coromandel Loop, where the pilot project for rub-rail barriers is being trialled. Motorways have the safest road conditions and alignments in New Zealand, and are not high-risk sites for motorcyclists to crash. Over the last 10 years, there have been only two motorcycle fatalities involving a barrier on a motorway.

The Ministry and the NZTA do not consider there is a case for replacing or discontinuing the existing flexible barrier systems, given the clear net safety benefits for all road users. The Ministry and the NZTA will continue to monitor international leading research and undertake investigations to continue to improve New Zealand's barrier systems. The NZTA will also

consider whether a wider motorcycle safety project is worthwhile, based on the outcomes of the Coromandel Loop pilot project.

The current situation requires a focus on rural road crashes

This report was commissioned by the Minister of Transport in response to the Change.org petition, which requests that the NZTA cease installing wire median barriers on New Zealand motorways. It suggests that the NZTA instead install semi-rigid steel guardrail barriers with additional safety rails to enhance road safety outcomes for motorcyclists.

Concerns from motorcyclists regarding the use of wire-rope median barriers relate primarily to rural, open road situations, as opposed to urban, low-speed environments. As such, this report focuses on these high-speed rural situations, classified as roads with speed limits over 70km/h. This classification also includes urban motorways with speed limits over 70km/h.

In accordance with New Zealand's *Safer Journeys Road Safety Strategy to 2020*, New Zealand has a focus on targeting efforts to these high-volume and high-risk roads to reduce the incidence and severity of these most common crash types. This includes programmes of installing median and roadside barriers, as these have been found to be the most successful treatment in preventing head-on and run-off-road crashes.

In New Zealand, the most common causes of rural road crashes and serious casualties involve loss of control leading to vehicles running off the road, head-on collisions, and intersection crashes. These three factors comprise 90%[ii] of rural road deaths and serious injuries, with run-off-road and head-on crashes totaling approximately 77% of these deaths and serious injuries. On the higher volume roads, the proportion of head-on crashes increase to a point that on roads carrying more than 5500-6000 vehicles per day, there are more deaths and serious injuries from head-on crashes than single vehicle run-off-road crashes[iii]. For every 100km stretch of high volume (>5000 vehicles per day), high speed (>70km/h), undivided sections of State highway, an average of 16 people are killed or seriously injured every year. Of these injuries and fatalities, six are from head-on collisions, four are from single vehicle run-off-road crashes, and four are at intersections (refer to Figure 1).

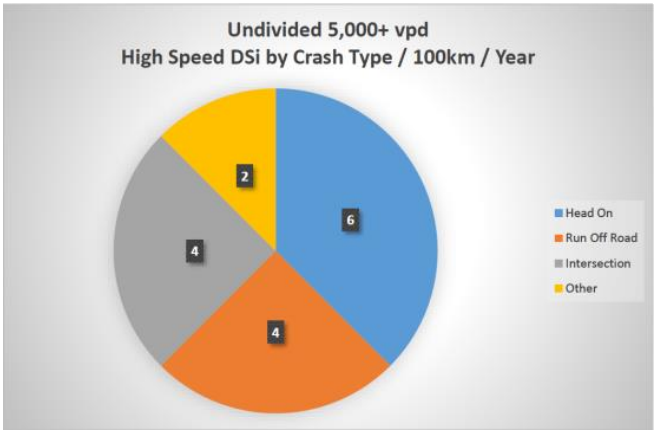

Figure 1: Number of persons killed or seriously injured per annum per 100km undivided high volume rural State highways

New Zealand's historical approach to lane departure crashes

The clear-zone approach

Historically, New Zealand's approach to addressing the primary crash types of run-off-road and head-on crashes, was based around the North American clear-zone approach.[iv] This strategy aimed to create a wide, clear space, typically between nine and 12 metres in width, beside the road carriageway. The clear-zone is intended to be completely free of any hazards, and should be between opposing carriageways on high-speed roads. This resulted in a wide road footprint, which was difficult and expensive to accommodate and maintain in New Zealand's challenging geography. Our historical standard one chain (20.2 metres) road reserve width also posed challenges to finding this amount of space for New Zealand roads. The only place this amount of space could be found was on new motorways and expressways.

Recent research has indicated that this clear-zone approach is not a cost-effective method of preventing run-off-road or head-on casualties, as vehicles can still cross these wide areas and collide with objects at the boundary or cross into opposing traffic lanes. The research by Woolley and Doecke in 2015 found in practice, the desired clear-zone width is rarely achieved, and clear-zone surfaces are rarely free of imperfections that provide rollover trip hazards. As the vehicle departure angle increases, the likelihood of vehicles rolling over increases (refer to Figure 2).

Figure 2: A used clear-zone on the roadside

Furthermore, the clear-zones in the research were rarely free of hazards. Sign posts and lighting poles are frequently located within them, and although they designed to shear off if hit by a car, they can still be very hazardous to motorcyclists. The likelihood of fatalities with vehicle side impacts into narrow objects rises rapidly beyond impact speeds of 40km/h. For motorcyclists, survivable impact speeds are far lower. The research found that roadside barriers as close as practicable to the edge of road are likely to result in better safety outcomes than clear-zones.

In another study,[v] lane departures from French southern motorways were examined. The researchers found that from 11 years of crash data, a longitudinal barrier halved the injury risk, although casualties from concrete barriers were often very serious. A similar study of run-off-road crashes on Italian motorways near Naples[vi] showed that crashes with walls, ditches, fore-slopes, and back-slopes were more severe than crashes with barriers. Median concrete barriers showed greater crash severity and a higher proportion of rollovers compared to other barrier types.

The NZTA's research report RR 517, written by Jamieson et al. 2013, "Use of roadside barriers versus clear-zones",[vii] found that it is more cost effective to provide flexible barriers on rural roads than clear-zones. Furthermore, it found that flexible barriers should be considered for use before other barrier types.

Based upon this and similar international research and findings, New Zealand's approach to reducing the incidence and severity of run-off-road and head-on crashes has been modified over recent years to prefer installing roadside and median barriers.

New Zealand's modern approach to lane departure crashes

Internationally, there are three different categories of roadside and median barriers: rigid, semi-rigid, and flexible.

Rigid barriers

Rigid barriers are most commonly concrete barriers. This type of barrier is often installed on high-volume motorways, where semi-rigid and flexible barriers would be difficult and costly to maintain; where there is insufficient space to allow barriers to deflect; or where a higher level of protection is required. Rigid barriers can be the most expensive to install ($500-800 per metre for a median barrier), but have the advantage that they can withstand most impacts without deformation damage, and therefore have the lowest maintenance cost of the three barrier types. Rigid barriers result in more severe impact forces and casualties than semi-rigid or flexible barriers for most road users than other barrier types. This is because rigid barriers do not allow for the absorption of impact forces, and can result in vehicles either rebounding into the traffic stream or rolling over the barrier. Rebounding or rolling often results in secondary collisions with other vehicles.[viii] Rigid barriers are typically used on straight and easy curves, as high-angle impacts into them would be severe.

Figure 3: A rigid concrete barrier

Semi-rigid barriers

Semi-rigid barriers are most commonly steel rail and hard post barriers, often known as W-beam barriers. These are the most common barrier type in New Zealand, and are installed in more challenging road environments where other barrier forms cannot be, such as tight corners and where there is minimal room for deflection.

Semi-rigid barriers are typically less expensive to install than rigid barriers ($110-$220 per metre for a median barrier), but are more expensive to maintain. Semi-rigid can withstand some impacts with minimal damage. They are more forgiving than rigid barriers, as they allow for some deflection and energy absorption. They have a lower rate of deaths and serious injury outcomes from collisions than rigid barriers, although rebounds back into the traffic stream are problematic. Furthermore, with their relatively low height, they have an increased incidence of vehicles with a high centre of gravity such as SUV's tipping or launching over them than other barrier systems.

Figure 4: A semi-rigid W-beam barrier

Flexible barriers

The most common type of flexible barriers are wire-rope barriers, made up of three or four tensioned wire cables supported by steel posts. They are known as flexible barriers because they stretch to absorb the force of the crash. The barriers use a dual mechanism to slow down and divert excessive force away the people inside the vehicles. The ropes deflect and absorb the energy and the posts collapse, slowing down and redirecting the vehicle away from the hazard with very little rebound. Flexible barriers are the least expensive to install ($75-$150 per metre), and have the narrowest area footprint. Practically, they require a greater space for deflection behind the barriers, although they have still proven to be very effective in narrow spaces as, for example, on the Centennial Highway north of Wellington (refer to Figure 5). Flexible barriers are the most expensive to maintain however, as even low impact force crashes result in damage to the barrier. In emergencies, flexible barriers can be pulled out of the road quickly and easily to allow access for emergency service vehicles and clean-up operations. They are the most forgiving type of barrier with the lowest overall ratio of deaths and serious injuries from barrier collisions.

Figure 5: A flexible wire-rope barrier on Centennial Highway

Relative safety performance of the barrier types

The best barriers for all road users

To date, the design of barriers has been based on passenger occupant safety data, as these figures constitute the greatest number of roadside and median crash fatalities and serious injuries.[ix] There has been a lot of research undertaken in comparing the advantages and disadvantages, and the safety performance of the different barrier systems. A recently published report “An evaluation of the effectiveness of flexible and non-flexible road safety barriers in Western Australia”[x] found that road safety barriers were generally successful in reducing the rate of death and serious injury crashes, especially in rural regions. Both flexible wire-rope barriers and semi-rigid W-beam barriers resulted in significant reductions in deaths and serious injuries, ranging between 52 to 84% for single vehicle and run-off-road crashes. The evaluation found that concrete barriers were not successful in reducing the rate of death and serious injury crashes. Flexible wire-rope barriers were found to be the most successful in reducing single-vehicle death and serious injury crashes.

Research conducted by MONASH University Accident Research Centre (MUARC) shows that flexible barriers are superior compared with concrete and semi-rigid steel W-beam barriers. This is because of the way they dissipate the energy of the crash away from people in the cars, their deflection ability, and the way they contain the vehicle. Wire-rope barriers along centre lines are now specifically used for, and are effective at, preventing head-on crashes when a vehicle crosses the median strip into oncoming cars.

Figure 6: A flexible wire rope barrier system on the State Highway 1 near Rangiriri, Waikato

MUARC's research evaluated 100km of wire-rope barriers across Victoria, and their findings suggest the flexible barriers are responsible for significantly reducing the risk of death and serious injuries in crashes. Their results are consistent with other studies conducted overseas, and estimate all crashes have been reduced including run-off-road and head-on crashes by 75% or more. On the Hume Highway and Eastern Freeway in Australia, the estimate is even greater, with up to 87% and 83% respectively.

In a Swedish example where high-speed roads that were converted to alternating two lanes in one direction with a central median cable barrier (commonly referred to as the Swedish 2+1 system), fatalities were reduced by 76% for all road users, compared to the normal outcome for these road types without barriers installed.[xi]

New Zealand also has examples where the installation of wire-rope barriers have resulted in substantial reductions in severe road crashes. These include the Rangiriri section of State Highway 1 north of Huntly, where the installation of a wire-rope median barrier and side barriers over a 9.2km length of road resulted in a 65% reduction in serious casualties overall, and a 100% reduction in head-on casualties.[xii]

The installation of a wire-rope median barrier on State Highway 1 on the Centennial Highway north of Wellington has so far resulted in an elimination of head-on fatalities.[xiii]

Wire-rope barriers installed on some of the new Roads of National Significance have already been hit, potentially saving lives and serious injuries. Figure 7 shows a collision with the wire-rope median barrier on the recently completed Tauranga Eastern Link, which likely stopped a head-on collision and resulted in no injuries.

Figure 7: A collision with the wire rope median barrier on Tauranga Eastern Link

Austroads report AP-R437-14 “Improving Roadside Safety: Summary Report”[xiv] states crash outcomes with flexible barrier systems come the closest to eliminating the likelihood of deaths and serious injuries. This makes flexible barriers the closest to the Safe System safety standard, which is the basis of our *Safer Journeys* road safety strategy. This report supports the ongoing use of wire-rope barriers in the centre of the road to reduce head-on crashes.

The best barriers for motorcyclists

All roadside objects including barriers, and opposing vehicles, pose a threat to all road users should they crash. Nevertheless, as discussed above, the flexible barrier system is the most forgiving and has the lowest severity ratio. Motorcyclists are more vulnerable to injury in all crashes, due to the limited protection their bodies have, which is similar to that of a pedestrian compared to someone in a vehicle.[xv]

Having a wide roadside completely free of roadside objects including fence posts and road signs, is arguably the best for motorcycle safety. However, this is rarely practical to achieve in New Zealand’s geographic environment, and is not as effective as barriers in most situations.

Over the last 10 years (2006 to 2015), there have been 28 reported deaths and 114 serious injuries from motorcyclists colliding with barriers. This compares to 119 motorcyclist deaths and 716 serious injuries from collisions with other roadside objects, and 129 motorcyclist deaths and 342 serious injuries from collisions with opposing vehicles (refer to Figure 8 below). Of the barrier collisions, two fatalities occurred on motorways.

Over the same 10-year period, there were a total of 448 motorcycle deaths and 4,152 serious injuries. These figures mean that barrier collisions of any type make up 3% of deaths and serious injuries suffered by motorcyclists (refer to Figure 9 below), and 0.50% of the 26,599 deaths and serious injuries to all road users. Motorcyclist collisions with barriers are relatively infrequent, and represent a small proportion of the safety problem for motorcyclists and all road users.

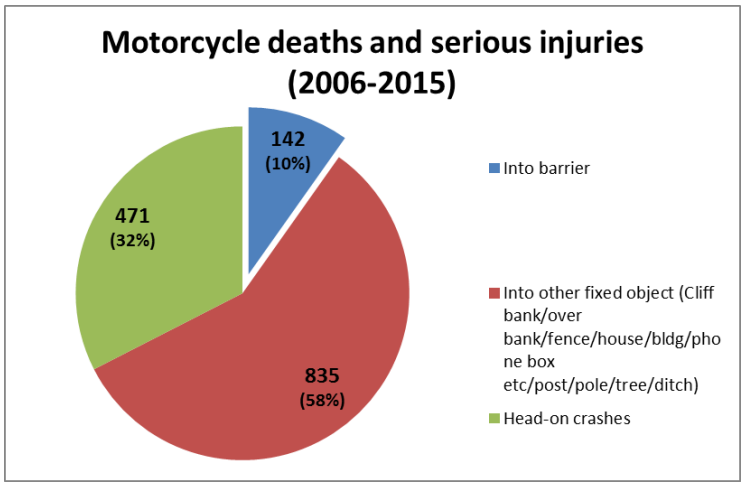

Figure 8: Motorcycle deaths and serious injuries involving objects including opposing vehicles

A University of New South Wales study[xvi] of New Zealand motorcycle-barrier crash data from January 2001 to July 2013 found that of the 20 motorcycle fatalities sustained because of riders hitting a roadside or median barrier, three involved flexible barriers. Eleven involved semi-rigid steel barriers, two involved wooden rails, two involved bridge rails or a bridge, and two were undetermined.

Research has shown approximately 50% of motorcyclists-barrier collisions involve motorcyclists in an upright position, while the other 50% of motorcyclists slide into the barrier.[xvii] Other research suggests the best types of barrier systems for motorcyclist safety are continuous barriers, such as concrete barriers.[xviii] These provide lower injury potential than semi-rigid and flexible barriers, since the motorcyclist does not collide with any barrier posts. One study has found concrete barriers have a fatality rate of 7.9% compared to W-beam types of barriers at 12.4%,[xix] though other studies have found varying fatality and injury rates, or insufficient amounts of data to draw meaningful conclusions.[xx] However, even these continuous barrier systems do not protect the upright motorcyclists from being thrown over the top of the barrier and into a roadside hazard, or opposing traffic.

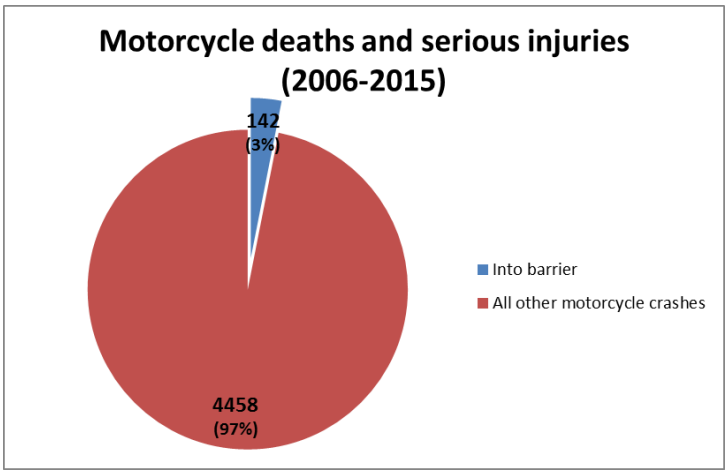

Figure 9: Motorcyclist deaths and serious injuries involving barriers

The safety risk motorcyclists experience with non-continuous barrier systems, such as flexible barriers and semi-rigid barriers, is with the posts. The posts present an increased risk to head and thorax regions of the body.[xxi] Several methods for protecting motorcyclists in collisions with road safety barriers were assessed in the University of New South Wales study, referenced above.[xxii] These include installation of rub-rails (continuous motorcyclist protection system, refer to Figure 10) or post padding (discontinuous motorcyclist protection system). The rub-rail systems which cost around $15-30 per metre to install were found to reduce the severity of motorcycle casualties, whilst post padding systems which cost around $100-$150 per post (equates to about $50 per metre) were found to only have minimal effect. Both protection systems are now available in New Zealand, although the rub-rail system is only available for one semi-rigid system, cannot be fitted to wire-rope barrier systems, and has only been tested at 70km/h. The post padding system has only been tested at 30km/h.

Due to the low incidence of motorcycle-barrier collisions generally, research suggests that the retrofitting of barriers with under-run, rub-rail type systems is unlikely to be cost-effective, except in very high-risk locations,[xxiii] and these systems would have a minimal effect on reducing motorcycle fatalities and injuries overall.[xxiv]

Figure 10: Rub-rails installed at the Coromandel Loop

However, for routes used heavily by motorcyclists, particularly with tight curves, barrier systems without exposed posts (such as semi-rigid steel barriers attached with motorcycle rub-rails attached) are potentially safer for motorcycles, particularly if hit at lower speeds. As such, motorcycle rub-rails have been installed on existing roadside safety barriers along a 130km State Highway route called the Coromandel Southern Loop, which passes through Kopu, Whangamata, Waihi, and Paeroa.

The choice of which barrier to install in any situation needs to consider the:

- level of protection required from the roadside and oncoming hazards
- safety performance of the barrier itself
- traffic volumes and types of vehicles using the road
- footprint of the barrier and deflection space available
- ease and accessibility for maintenance of the barrier
- whole-of-life installation and maintenance costs
- road alignment
- aesthetic effects.

There is no one-size-fits-all approach, but from the perspective of reducing deaths and serious injuries, the flexible wire-rope barrier is the preferred barrier type for New Zealand roads wherever possible.

Dispelling the "cheese-cutter" myth[xxv]

The term 'cheese cutter' originated in New Zealand after 21-year-old Daniel Evans was fatally injured in 2007 after colliding with a roadside wire-rope barrier. News reports at the time suggested the wire-rope barriers presented a danger to motorcyclists. The investigation and coroner's report into Daniel's death found that speed was a major factor. It was calculated Daniel was travelling between 148 – 190km/h when he left the road, which resulted in an impact speed the equivalent of jumping off a 13-storey building. Similar cases involving extreme impact speeds have been found in Australia.

While all barriers are designed to protect people from hazards, either on the side of the road or from oncoming traffic, they still pose a risk. Experts acknowledge this.[xxvi] Additionally, motorcyclists are more vulnerable to sustaining injuries from crashes into barriers because of their limited protection.[xxvii]

Flexible barriers pose a risk to motorcyclists because of their steel posts, rather than the wire-rope as commonly thought. Semi-rigid barriers also have this risk. The posts are designed to bend for vehicles, but not people. Generally, motorcyclists will come off their bike and slide underneath the wire, or into a post. Professor Raphael Grzebieta, the professor of Road Safety at the Transport and Road Safety (TARS) Research Unit at the University of New South Wales, has undertaken extensive research on wire-rope barriers and motorcycle crashes.[xxviii] In the coroner's report into Daniel's death, he is quoted as saying:

"There is no evidence to date... of motorcycle riders travelling at or below the posted speed limit, and who has crashed into a wire-rope barrier, being cut by the wire-rope in a manner similar to how cheese is cut with wire…"[xxix]

In Sweden, a survey of more than 600km of flexible barriers on their roads had no record of motorcycles being 'sliced' by the barriers.[xxx] Sweden has seen a 40-50% reduction in risk in motorcyclists killed since introducing flexible wire-rope safety barriers with their 2+1 system.[xxxi]

Figure 11: A wire rope barrier separating lanes on a 2+1 road in Sweden

Are flexible barriers banned overseas due to concerns about dangers to motorcyclists?

There is a common misconception that flexible barriers are banned in some places in Europe because of the danger they pose to motorcyclists. This is not the case. In countries such as Denmark and Norway, governments have ceased installation of the barriers because of political pressure from lobby groups. As mentioned in the previous section, Swedish studies have shown there is a 40-50% reduction in the risk of motorcyclists being killed by wire-rope safety barriers.[xxxii] Flexible barriers are being installed worldwide by countries seeking to reduce trauma on their roads, including Sweden, the USA, New Zealand, and Australia.

The SWOV Institute for Road Safety Research in the Netherlands has advised that since 2006, the policy of the Dutch Ministry of Transport and the National Road Authority (Rijkswaterstaat) is not to advocate, or use cable barriers along any national road. This does not constitute a ban however, and does not prevent local road authorities from using cable barriers if they prefer. The policy was the result of lobbying by a motorcycling interest group, despite scientific evidence showing it to be a safe and effective barrier system.

Figure 12: An impacted flexible wire rope barrier in Australia, where the vehicle and occupants drove away unharmed because of the flexible barrier system (Source: Towards Zero website)

The UK, Sweden, South Africa, and Australia all make extensive use of flexible barrier systems, and are reporting positive results.

New Zealand is engaging in ongoing work for motorcycling safety

Research

New Zealand is continuing to monitor and fund comprehensive, leading research on motorcycle safety. The NZTA, ACC, and the Motorcycle Advisory Council in New Zealand have all contributed to funding all four stages of the University of New South Wales report "Motorcycle crashes into roadside barriers", since before 2010.[xxxiii] The NZTA and ACC are presently considering funding further research into fitting continuous-rail systems for wire-rope barriers.

The Ministry and the NZTA are not ruling out further investigations and trials, and will continue to monitor international best practice and undertake leading research.

Improvements and trials

The Change.org petition suggests installing motorcycle-friendly safety rails on semi-rigid barrier systems, instead of using the flexible barrier systems. These safety rails have been installed on existing roadside safety barriers along the Coromandel Loop, as mentioned earlier in this report. The installation of this type of barrier in this area is a result of this route being identified as a high-risk motorcycle route, and the outcomes for motorcyclists in this area are being monitored.

The Coromandel Loop barriers were funded in conjunction with the Motorcycle Safety Advisory Council with the ACC motorcycle levy fund. This pilot project may provide further information as to whether a wider joint motorcycle safety project could be effective in other high-risk areas for motorcyclists.

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