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New motorcycle safety technology: an overview for South Australia

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ABSTRACT

The popularity of motorcycling in South Australia is rising and there have been increasing numbers in registrations and total distance travelled by riders. However, motorcyclists remain vulnerable road users and are at a higher risk of being involved in a serious crash. In 2012, motorcycle crashes were 17.5 times more likely to result in a fatality in SA relative to other vehicles, per distance travelled.

There have been considerable improvements to passenger vehicle safety over the last few decades but little has changed regarding safety for motorcycles. This report describes the relatively new technologies of anti-lock braking systems (ABS), combined braking systems (CBS) and traction control systems (TCS) for motorcycles, and the effectiveness of these systems in reducing motorcycle crashes. Mechanisms to encourage uptake of these technologies are also presented. ABS appears to be the most beneficial of these technologies and an analysis of ABS is included, estimating the potential benefit of the technology for South Australian motorcyclists.

KEYWORDS

Antilock braking systems, combined braking systems, traction control systems, motorcycle crashes

Summary

This report presents information about antilock braking systems (ABS), combined braking systems (CBS) and traction control systems (TCS) for motorcycles. The primary purpose of these technologies is to assist a motorcyclist in maintaining dynamic stability of a motorcycle in emergency braking situations or in adverse riding conditions. Any motorcyclist, regardless of skill level and experience, can have difficulty controlling a motorcycle in such situations.

A literature review was completed to identify the effectiveness of the systems, the acceptance and uptake of the systems, availability, cost and measures to encourage uptake. Many studies recognised ABS as the single most effective technology for motorcycles suggesting that this technology is likely to have the greatest influence in reducing the number of motorcycle crashes. Therefore, ABS is the primary focus of this report.

In a previous CASR report, Anderson et al. (2011) conducted a benefit-cost analysis for ABS on motorcycles based on NSW crash data for the period 1999-2008. They found that the likely effect of ABS, had it been available and fitted on all motorcycles that crashed in NSW in the period 1999-2008, was 280 fewer fatal motorcycle crashes and 8,262 fewer motorcycle crashes resulting in an injury, giving a benefit-cost ratio of 27.

When considering Australian crash data for 2006, ABS on motorcycles may potentially have resulted in 88 fewer motorcyclist fatalities and 8,618 fewer non-fatal motorcycle injuries. The monetised crash savings as a result of these crash reductions were estimated to be 795 million dollars (Anderson et al., 2011).

There are a number of effectiveness estimates for ABS in reducing fatal, serious and other injury crashes but all consistently indicate that ABS on motorcycles is likely to be an extremely effective road safety solution if adopted widely. Based on the estimates of Rizzi, Strandroth and Tingvall (2009), if ABS had been fitted on all motorcycles in South Australia in 2012, it would have resulted in seven fewer motorcycle fatalities and 57 fewer motorcycle serious injuries (at 48% effectiveness). Even using the minimum likely effectiveness of ABS for reducing motorcycle crashes (17%) according to Rizzi, Strandroth and Tingvall, 2009), there would have been three fewer motorcycle fatalities and 20 fewer motorcycle serious injuries in South Australia in 2012.

The literature review also identified that there is reluctance among some organisations to accept the benefits of ABS. This reluctance can be attributed to the belief that the evidence for ABS is overstated and the perception that having this technology on a motorcycle reduces rider skill and the level of control. Uptake of ABS systems was difficult to ascertain in the literature, predominantly because of a lack of consistency in data collection and analysis. Better monitoring of ABS uptake, similar to the monitoring of passenger vehicle technology uptake, would be useful.

Currently ABS is standard on 44% of the top selling road motorcycles. In most cases the technology is standard on the more expensive motorcycles, while it is generally only offered as an option (or not at all) on less expensive models. Cost was identified in the literature as a potential inhibiting factor, with optional ABS costing up to an additional 8% of the price of the motorcycle.

The literature review also considers some of the mechanisms that can be used to increase the uptake of ABS on new motorcycles, either by encouragement or regulation. These options include government incentives, such as taxation and subsidy schemes, regulation, education and promotion. Fleet purchasing schemes, publicity, lobbying and insurance schemes may also help to increase uptake rates.

The second section of the report examines the involvement of motorcycles in casualty crashes. Between 2003 and 2013, while passenger vehicle fatalities have been decreasing at an average of 4.6% per year, motorcycle fatalities have only been decreasing at a rate of 1.4% per year. Motorcycle registrations and distance travelled have both increased at a higher rate than for other vehicles, which would be contributing to the lower rate of decline. The average age of crashed motorcycles was 6.8 years and the median age was 4.2 years. A positive implication of this relatively low average age of crashing motorcycles is that the expected benefits of ABS (particularly in reducing fatalities and serious injuries) can be achieved reasonably quickly if ABS prevalence can be increased in a short timeframe.

In the final section of the report, levels of uptake of ABS into the vehicle fleet were estimated to determine benefits over time. The effectiveness estimates and estimated levels of uptake were combined to calculate the likely benefits over time, based on two possible scenarios:

- Scenario 1 : 100% of motorcycles sold from 2025 onward will have ABS fitted standard and correspondingly 68.1% of the crashing motorcycle population would have ABS by 2025. This scenario is likely to occur at the current estimated level of uptake of ABS in the new motorcycle fleet.
- Scenario 2 : 100% of motorcycles sold from 2020 onward will have ABS fitted standard and correspondingly 77.5% of the crashing motorcycle population would have ABS fitted by 2020. This scenario is likely to occur if a regulation was introduced and ABS was made mandatory on all new motorcycle sold from 2020 onwards.

The results of these scenarios indicate that under scenario 1 there is a potential to reduce motorcycle crashes by between 10.2% and 25.9% in 2025. Under scenario 2 the potential for motorcycle crash reduction is marginally higher at between 11.6 and 29.5% in 2025.

There is little doubt that ABS is a beneficial technology for improving the safety of motorcyclists, and this technology represents a potential means to significantly reduce the number of motorcycle injuries and fatalities in South Australia. It is important to use a range of mechanisms to encourage uptake of ABS so that the road safety benefits can be achieved sooner.

Contents

1 Introduction

It is acknowledged that the safety and crashworthiness of passenger vehicles has improved significantly over the last few decades. Newstead et al. (2013) reported that the greatest gains occurred in the 1970s, consistent with the introduction of Australian Design Rules aimed at occupant protection. Newstead et al. (2013) also reported steady gains between 1985 and 1995 and also since 2000, the latter presumably due to the improvements driven by the Australasian New Car Assessment Program. Many of these gains were achieved through the structural design of vehicles and passive safety devices such as advanced seat belts and airbags. These changes reduced crash risk by minimising occupant decelerations and preventing cabin intrusion.

The protection of motorcyclists in crashes is rather different, and is essentially limited to effective helmet protection (for preventing head injuries) and protective clothing that can assist with preventing abrasive injuries from the road surface (Baldock & Hutchinson, 2010). Hence, the bike itself is not usually considered as a source of crash injury prevention per se, although some bikes do offer some systems to assist the rider in head on collisions[1]. Compared to passenger vehicle occupants, motorcyclists and their passengers have little protection in impacts with other vehicles, the road or roadside furniture and are extremely vulnerable to injury, even in minor lower speed crashes (Andrea, 2006). Andrea (2006, p3) groups motorcyclists with pedestrians and pedal cyclists as 'vulnerable road users' and makes the claim that "[…] they cannot be adequately protected within the road system at [impact] speeds greater than about 40 km/h."

Of course, crash and injury risk depends upon more than the crashworthiness systems in vehicles. Anderson et al. (2009) discuss that the number of serious crashes (N) is the product of three components; risk of having a crash, risk that a given crash is serious and exposure.

N = (Risk of having a crash) x (Risk that a given crash is serious) x (Exposure)

Anderson et al. (2009) argue that to decrease the number of serious crashes of any type, measures that reduce any or all of these three components are required. The risk of having a crash is influenced by road user behaviour; any crash avoidance systems (e.g. effective braking systems) as well as road environmental factors (Anderson et al., 2009).

In the case of motorcycles, it is critical to focus on systems that can prevent crashes or, if they cannot prevent the crash, minimise the speed at which impacts will occur. This will result in reduced crash energies and subsequently reduced injury risk and injury severity. The most critical components of a motorcycle that can achieve this are in the braking system.

1.1 Motorcycle braking performance and stability

Vavryn and Winkelbauer (2004) report that while motorcycles have changed significantly since their initial market entrance, most of the changes have focused on weight reduction, improvement in engine performance and acceleration improvements. The authors discuss that while suspension, handling and braking systems and their performance have improved, the braking system controls have remained consistent: a hand controlled front brake paired with a foot controlled rear brake. For the majority of motorcycles that have a braking system configured in this manner, the successful, rapid deceleration of a motorcycle in an emergency situation rests solely on the ability of the rider in control of the motorcycle. This is inherently complicated, particularly when a rider is tasked with applying and

[1] Note: Honda offer airbags on their Gold Wing Model motorcycle.

distributing force to each brake control, and that considerably more deceleration can be achieved through the front brakes compared to the rear (Teoh, 2010).

Several studies indicate that a rider's ability to successfully brake a motorcycle in an emergency situation is sub-optimal. Ecker and Wassermann (2001) indicate that in emergency situations, the average rider under-utilises the braking capacity of their motorcycle by 44 per cent, particularly through inefficient use of the front brake. In emergency braking on a dry road, the rear brake on a motorcycle contributes relatively little to the overall deceleration because of the weight transfer during braking. While 10 m/s^2 deceleration is technically achievable on a modern motorcycle (Vavryn and Winkelbauer, 2004) the average deceleration in an emergency is only about 6 m/s^2 (Ecker and Wassermann, 2001).

Vavryn and Winkelbauer (2004) examined the braking performance of novice and experienced motorcycle riders. They found that there was variation between a rider's preference for brake use, be it a preference for using both brakes (58%), front brakes only (40%) or rear wheel brakes only (2%). Other literature indicates a tendency to overuse rear brakes by young riders (Baldock & Hutchinson, 2010).

While a motorcycle is in motion, provided there are no physical interruptions to that motion, it is kept stable by the gyroscopic effect of the wheels and the lateral grip of the tyres on the road. Any sudden interruption to the forward motion particularly by unbalanced braking or wheel lock-up due to emergency braking can severely influence the gyroscopic effect and lateral balance resulting in loss of control (Highway Loss Data Institute, 2009). Motorcycle riders may be reluctant to apply full force to brakes, because hard braking that causes wheel lock-up induces instability, which can result in sub-optimal deceleration and increased valuable braking distance (European Transport Safety Council, 2008).

Emergency braking resulting in front wheel lock, while producing high braking forces, can cause shifts in weight resulting in severe pitching (or nosedives) or unstable motorcycle body movement resulting in a motorcycle falling (Tsuchida et al., 2002; Teoh, 2010). Rear wheel lock, while more controllable, can also result in loss of control if there is simultaneous steering (Teoh, 2010). Renewed road-tyre traction that occurs through a corrective brake release (following a rear wheel lock) can result in the motorcycle rolling "high side[2]" in the direction of the skid, and rider ejection (European Transport Safety Council, 2008).

Inefficient or incorrect brake use has been found to be a significant contributing factor in many motorcycle crashes. McLean et al. (1979) found that in South Australia 23% of motorcycle crashes in their in-depth study involved motorcyclists who failed to respond appropriately in an emergency situation, particularly relating to the manner in which the emergency braking occurred. For the crashes investigated in which the rider applied brakes before the collision, usage of combined front and rear braking or rear braking only were similar (20% and 18% respectively) with front only braking occurring in six per cent of cases (4 out of 69). McLean et al. (1979) found that the main reasons for lack of front brake use was concern with instability that might result. They also found that failure to make full use of braking performance was equally likely for both inexperienced and experienced riders alike.

Hurt (1981) found results consistent with McLean et al. (1979): in a sample of US motorcycle crashes investigated (N=900), rear brakes alone were used in 18.5% of crashes, combined rear and front brakes were used in 17% of the crashes (and often were not used effectively), and combined rear brake and swerving in 11.7% of crashes. Front braking alone occurred in only 0.8% of motorcycle

[2] High Side - a motorcycle sidewards upset involving an extreme rolling and capsizing motion, where the upper part of the vehicle rolls toward the direction of travel (European Association of Motorcycle Manufacturers, 2009,, p. 133)

crashes. Hurt (1981) suggested that correct use of front brakes had the potential to reduce the severity of many collisions or prevent collisions altogether.

The European Association of Motorcycle Manufacturers (2009) found that the most frequently utilised collision avoidance response was braking, either in isolation or in combination with another avoidance response. Braking was undertaken 49.3% of the time to avoid a collision in the sample of crashes they studied (664 braking responses within 1346 total collision avoidance responses out of 921 crashes). In most other cases there was no collision avoidance response (26.9% due to no opportunity or failure to respond) and swerving to avoid a crash was undertaken in 16.2% of collision avoidance responses.

The European Association of Motorcycle Manufacturers (2009) found loss of motorcycle control occurred in 31.9% of all crashes examined. In 41% of the loss of control crashes (13.1% of all crashes), the loss of control was predominantly the result of the rider's braking response having a negative effect on the dynamics of the motorcycle.

In summary, braking performance by motorcyclists is critical in emergency situations. Experimental studies indicate that the braking performance of motorcyclists is often inefficient and correct brake use is often not practised. Crash studies have also consistently reported that inefficient or incorrect brake use has been found to be a significant contributing factor in many motorcycle crashes.

1.2 RiderSafe (SA) – braking fundamentals

In South Australia beginner riders are taught riding and braking fundamentals[3] in the compulsory "RiderSafe program". Much of the safety component of the RiderSafe program is to encourage riders to have responsibility for their own safety and riders are encouraged to constantly be aware of the traffic environment, good hazard perception, allowing adequate space to anticipate other road user behaviour (and errors) as well as being able to maintain self-control and not exceeding thresholds for safe riding. While emergency braking is not taught directly or practiced per se, traction theory and braking is taught through the lesson guide. (D. Roe, personal communication, August 11, 2014).

A two-stage braking technique is taught: (1) initially brakes should be set-up by applying light pressure on the brake levers and pausing, followed by (2) progressively applying the necessary braking pressure. This reduces the likelihood of skidding and helps with maintaining control during required deceleration (Department of Transport, Planning and Infrastructure, 2012).

Field training techniques focus on "quick stops" with an emphasis on correct braking technique so that it becomes automatic. The training for practical braking begins with slow stops in first gear, and as gear changes are learned, braking from higher speeds is also practiced, although the field riding speed is limited to 30 km/h. (D. Roe, personal communication, August 11, 2014).

The encouraged method for emergency situations is to: "use both brakes simultaneously applying a firm progressive squeeze on the front brake lever (approximately 70% of total brake force distribution) while applying light to lighter pressure to the rear brake pedal" (while squeezing the clutch to prevent engine stall). This method results in the weight of the rider and motorcycle being transferred forward resulting in increased weight distribution towards the front of the motorcycle (increased front traction) and decreasing load on the rear wheels (decreased rear traction). Maintaining this braking

[3] In addition to and as well as basic motorcycle control skills including riding in a straight line, cornering, gear shifting, bike control theory, interaction with other bikes on a riding range, advanced bike control theory and traffic skills (see RiderSafe 2012 for more info).

technique without locking any wheels, remaining upright and in a straight line maximises braking capacity of a motorcycle. (Government of South Australia, 2008-2014).

The knee jerk reaction to an emergency situation to 'hit the rear brakes' is strongly discouraged, as is harsh and excessive braking. The intention is that in a correct emergency braking manoeuvre, brakes are applied in the manner described above to prevent wheels locking and skidding and hence minimising the likelihood of loss of motorcycle control.

Too much front braking pressure to the point where the front brake locks and the tyre skids, can result in a loss of control. It is recommended that if front wheel lock occurs, that the front brake be quickly released and reapplied with progressive pressure (Department of Transport, Planning and Infrastructure, 2012).

In a situation where too much rear brake pressure is applied, and the rear wheel begins to skid (limiting the riders' control) two methods are recommended that the rider keeps the rear wheel locked until fully stopped (provided the braking occurs in a straight line, on a flat road with good pavement surface) or alternatively releasing the rear wheel brakes and gently reapplying (on a poor road surface such as a gravel road) (Department of Transport, Planning and Infrastructure, 2012; Government of South Australia, 2008-2014).

Issues arise when skidding occurs on poor pavement surfaces, in road curves or during motorcycle lean manoeuvres and hence the expectation that a motorcyclist might be able to regain or maintain control of a motorcycle in an emergency may diminish.

Training and education is important for fundamental riding and braking skills, however, real world riding, exposure and experience allow a rider to further develop riding and braking skills. Under normal riding conditions where the task of guiding, navigating and controlling a motorcycle is not exceeded a rider can be expected to remain safe and brake effectively provided they have adequate riding ability and experience. However in emergency situations correct braking education and training may not always translate to the appropriate emergency braking response, hence the likelihood of skidding and loss of control is increased. In these situations even the most experienced riders cannot always optimise braking, prevent skidding and prevent loss of motorcycle control that may lead to a crash. Technologies that can assist motorcyclists in these situations offer the best opportunity for reducing likelihood of crashes requiring emergency braking.

2 Motorcycle safety technologies

It is apparent from the literature that in emergency situations, motorcycle riders may have difficulties in independently controlling front and rear brakes effectively. Technological solutions exist that can assist with overcoming these difficulties.

Three such safety technologies for motorcycles are described in detail below. Following this is a discussion of their potential effectiveness and methods of encouraging greater uptake in the motorcycle fleet.

2.1 Description of technologies

Three motorcycle safety technologies are described below: combined braking systems, antilock braking systems and traction control systems.

2.1.1 Combined Braking Systems

In Combined Braking Systems (CBS) the application of one brake control will actuate both the front and rear brakes (European Transport Safety Council, 2008). The two objectives of CBS are firstly to obtain higher decelerations than are achievable by motorcyclists using traditional independent braking systems and secondly to reduce front pitching (nosediving) due to excessive front wheel braking or locking (Tsuchida et al., 2002).

In traditional braking systems a foot pedal (or left hand lever on some scooters) actuates the rear brakes, on single combined braking systems this would activate both front and rear brakes through this single actuator.

Tsuchida et al., (2002) describe the Honda single CBS and dual CBS systems:

- *Single CBS on small scooters:* a left front lever (that normally actuates the rear brakes alone) simultaneously activates front and rear brakes through a cable linked to a mechanical brake equaliser when brake lever force is high. When brake lever force is small, the system apportions braking only to the rear wheels. The right front lever still allows activation of the front brake only.
- *Single CBS for large scooters, medium sized touring bikes and cruisers with hydraulic brakes:* application of the foot pedal (or left front lever for large scooters) simultaneously applies hydraulic pressure initially to the rear brakes and then the front brakes (via a delay valve) when the brake pedal or lever force is high. When the brake pedal or lever force is low, the CBS distributes more braking capacity to the rear compared to the front. Again, the right front lever still allows activation of the front brake only.
- *Dual CBS for larger motorcycles*: these motorcycles have both a front right hand lever and a foot pedal and application of either brake actuators results in distributed braking on both the front and rear wheels, with a slight brake bias to the front brake with the hand lever and rear brake bias for the foot pedal. While both brake actuators distribute braking effectively, resulting in good deceleration with hard braking, slightly better decelerations can be achieved by actuating both the hand and foot brakes simultaneously, and certainly better than traditional braking systems (Tsuchida et al., 2002). Honda (2014) claim that motorcycles with CBS can achieve decelerations 1.7 times higher compared to a brake pedal alone (around 0.7 g compared to 0.4 g).

BMW have similar combined braking systems and refer to them as "integral brake systems". Partial integral systems actuate both rear and front brakes when the hand lever is applied, however when the foot pedal is applied, only the rear brakes are actuated. Full integral systems actuate both the rear and front brakes regardless of whether the hand lever or foot pedal is applied (BMW, n.d.).

The primary benefits of CBS relate to preventing stability issues due to biased front or rear braking (as described earlier). It is most useful for motorcyclists who under use, or do not use, front wheel brakes fearing front wheel lock and problems with forward pitching (Teoh, 2010). An additional benefit of CBS is shorter stopping distances through improved deceleration. However, CBS cannot resolve issues of instability once a motorcycle is skidding, nor can it help with any potential traction stability issues if braking is relieved.

2.1.2 Antilock Braking Systems

Further enhancement of a motorcycle braking system can occur when CBS is paired with an Antilock Braking System (ABS) (Tsuchida et al., 2002). This is commonly referred to as 'enhanced ABS' or an advanced braking system. Honda (2014) claim that motorcycles with CBS combined with ABS can achieve decelerations 2.3 times higher compared to using a brake pedal alone (around 0.9 g compared to 0.4 g), or compared to a brake pedal with ABS.

ABS uses sensors that continually monitor wheel speeds and wheel deceleration when a motorcycle is undergoing emergency braking (Teoh, 2010). The system is programmed and tuned to the specific characteristics of the motorcycle it is fitted on, including tyre size and calliper elasticity (Jackman, 2014). During emergency braking, the ABS continually calculates and compares the front and rear wheel speeds, throttle position, and other dynamic characteristics [brake slip[4] values] of the motorcycle (Jackman, 2014).

When skidding is detected (by brake slip exceeding 15-30%), the ABS quickly and continually modulates the braking pressure by reducing or limiting the pressure (to return to the stable range of 10-30% brake slip) (WABCO Vehicle Control Systems, 2011). Hence, the ABS control system regulates the braking pressure (when brake lock is imminent) to ensure that maximum braking can be achieved and maintained without allowing the motorcycle brakes to lock (Teoh, 2010).

The benefits of such a system include improved stopping distance and increased stability, steering ability, and control of a motorcycle particularly on poor friction surfaces such as wet pavements or pavements with debris.

Vavryn and Winkelbauer (2004) found that both novice and experienced motorcycle riders could improve their emergency braking deceleration with ABS and correct instruction of brake use. Mean deceleration of experienced motorcyclists on their own motorcycles (without ABS) increased from 6.6 m/s^2 to 7.8 m/s^2 when using motorcycles fitted with ABS. Novice riders improved their mean braking deceleration from 5.7 m/s^2 to 7.7 m/s^2.

Green (2006) evaluated the straight-line braking performance of various riders on motorcycles without ABS, with ABS and with ABS combined with CBS. These brake tests examined stopping distances using both brakes, front brakes only and rear brakes only. Comparing the best stopping distances achieved without ABS to the average stopping distances achieved with ABS combinations, Green (2006) found that on dry pavement ABS alone provided an overall average reduction in stopping

[4] Braking slip is the ratio of wheel speed to the vehicle speed, and optimal braking force occurs when the braking wheel speed is around 85 to 90% of the vehicle speed. Optimal braking is achieved at 10 – 15% slip and at 100% slip the motorcycle wheels will lock (Rosenbluth, 2001).

distance of 5%. Improved stopping distance reductions occurred with heavier[5] loaded motorcycles (average reduction of 7%) and the most significant reductions with ABS occurred (17% average) when rear brakes were used to stop a motorcycle from 128 km/h.

On wet surfaces Green (2006) found similar results; ABS provided an overall average reduction in stopping distance of 5%; improved stopping distance was achieved when both brakes were applied (10.8% average stopping distance reduction) and this increased to 15.5% with a heavier loaded motorcycle.

2.1.3 Traction Control Systems

Traction Control Systems (TCS) are designed to prevent a motorcycle from losing traction when accelerating on a road surface with a poor or varying friction coefficient. This is particularly relevant when a motorcycle is accelerating through a corner or bend and the road surface is wet or icy or there is debris on the road that may cause the rear wheel to slip or spin.

A TCS monitors signals from the rear wheel speed sensor (generally as part of the antilock braking system), and by assessing the relative difference in rotational speed of the rear wheel compared to the front wheel can detect wheel spin/slip. When wheel slip is detected, the TCS via the engine management system reduces the throttle input and/or momentarily cuts power to the engine to reduce the wheel slip and restore rear wheel traction, preventing a possible loss of motorcycle control (Anderson et al., 2011).

Waheed (2008) details an ‘after-market’ TCS that attaches to a motorcycle’s wiring harness. This device examines a motorcycle’s throttle position, rpm and gear-position to achieve the same goal. This system also allows adjustments to the TCS as well as a quick shifting gear system and appears to be aimed more at improving motorcycle performance.

Some systems are limited to functioning when the motorcycle is accelerating in a straight line (motorcycle upright) (Anderson et al., 2011) but newer systems incorporate inclination angle sensors and integrate this information within the engine management protocols (BMW, n.d).

Bosch have developed a lean-angle sensor (Bosch, n.d.a), and this combined with the ABS sensors can achieve improvements in motorcycle intervention functions such as ABS in bends, traction control, inclination-dependent brake force distribution and various other functions. Increasingly, all aspects of emergency intervention control in motorcycles fall within the technology of “motorcycle stability control (MSC)”, combining all sensor information in emergency situations and applying the optimal corrective action (Bosch, n.d.b). For example, these MSC systems can optimise ABS in all braking situations (straightline and curved), enable traction control and optimal combined braking, in addition to controlling rear-wheel lift and address other critical incidents that can initiate motorcycle loss of control (Bosch, n.d.b.).

Bosch (n.d.b) quote: “For motorcyclists, the Bosch MSC can be a lifesaver. However, just like ABS, it cannot suspend the laws of physics. In particular, extreme misjudgement of the riding situation and major errors on the part of the biker can still lead to an accident. Nonetheless, the system supports bikers in borderline situations, helping them get more out of their motorcycles, while keeping them much safer at the same time.”

[5] Heavier refers to when a motorcycle was loaded to the maximum manufacturer design weight.

Similarly, BMW (n.d) state "Although the traction control DTC [dynamic traction control] provides invaluable support to the rider and therefore an enormous boost to acceleration safety, it cannot – like ABS – redefine to any degree the constraints posed by the laws of physics. Bad judgement or poor riding can still exceed these constraints, and, in extreme cases, the rider can fall off his machine."

2.2 Effectiveness in reducing crashes

Most of the research regarding motorcycle safety technologies focuses on advanced braking systems and predominantly ABS, although enhanced ABS (ABS and CBS) would appear to have additional benefits to ABS alone. Rizzi, Strandroth and Tingvall (2009) examined the potential effect of ABS on reducing motorcycle crashes in Sweden. Based on 164 fatal motorcycle crashes between 2005 - 2008 in Sweden, they found that 14% of fatal crashes could definitely have been avoided with ABS and 16% of fatal crashes would have been definitely influenced by ABS. Therefore, 30% of all fatal crashes could have been potentially avoided with ABS.

ABS was found to have had the greatest effect on reducing fatalities at intersections, where 31% of crashes would have been avoided, and 21% of crashes would have been definitely influenced by ABS. ABS had no significant influence in 57% of head-on collisions and 51% of single vehicle collisions, but probably could have influenced 14% of head-on collisions and 31% of single vehicle collisions (Rizzi, Strandroth and Tingvall, 2009).

Rizzi, Strandroth and Tingvall (2009) also conducted an induced exposure case-control study based on police reported crash data involving some sort of injury. They identified 187 case motorcycles (with ABS) and 985 control motorcycles (no-ABS) and found that the case and control groups had similar crash type distributions. For all crash types excluding head-on crashes (the crash type they found to be non-sensitive to ABS from the fatal crash analysis) they estimated that crash involvement reduction due to ABS was 41% (95% confidence interval of 12% - 70%) for all crashes and 43% (95% confidence interval of 11% - 75%) for intersection crashes.

ABS was even more effective for severe and fatal crashes. Rizzi, Strandroth and Tingvall (2009) estimated that the overall reduction in severe and fatal crashes due to ABS (excluding head-on crashes) was 54% (95% confidence interval of 19% - 89%) and the reduction at intersections was 71% (95% confidence interval of 42% - 100%). Overall, including head-on collisions, ABS was found to have an effectiveness in reducing all casualty crashes by 38% (95% confidence interval of 11% - 65%) and all severe and fatal crashes by 48% (95% confidence interval of 17% - 79%).

The Highway Loss Data Institute (2012) also found reductions in motorcycle crashes resulting from fitting ABS. They compared collision insurance claims for motorcycles fitted with ABS with those collision claims for motorcycles without ABS, and found that motorcycles with ABS were 30% less likely to have a collision claim within the initial three months of an insurance policy, and then 19% less likely between three months and two years of holding a policy (Highway Loss Data Institute, 2012).

Using a larger sample of crashes, the Highway Loss Data Institute (2013) also found that motorcycles with ABS were 20.1% less likely to have a collision claim, compared to those without ABS, but also found that motorcycles with ABS combined with CBS were 31.3% less likely to have a collision compared with motorcycles that did not have an advanced braking system. The Highway Loss Data Institute (2013) also found a 28% reduction in motorcycle injury medical payment claims, and a 22% reduction in claims for injury caused to other people from an at-fault motorcycle rider for motorcycles with ABS compared with those without.

The effect of ABS on fatal crashes in the US has also been examined. Comparing fatal crash rates per motorcycle registration for motorcycles with and without ABS during 2003 to 2008, Teoh (2010) found that fatalities per 10,000 registered vehicle years was 37% lower for motorcycles with ABS compared to those without. Teoh (2010) found fatality rates per 10,000 registered vehicle years was 4.1 for motorcycles with ABS (47 fatalities in 115,156 registered vehicle years) compared to 6.4 (274 fatalities in 430,103 registered vehicle years) for those motorcycles without.

Teoh (2013) extended the 2010 analysis to include fatal crash data up to 2011 and found that fatalities per 10,000 registered vehicle years across all motorcycles in the study was 31% lower for motorcycles with ABS compared to those without. The fatality rate per 10,000 registered vehicle years was 3.8 for motorcycles with ABS (87 fatalities in 230,659 registered vehicle years) compared to 5.2 (441 fatalities in 841,614 registered vehicle years) for those without.

Recently Rizzi et al., (2014) extended their 2009 analysis to include data from Italy (N=13,695, crash year 2009) and Spain (N=57,160, crash years 2006-2009) as well as expanded Swedish data (N=8,720, crash years 2003-2012). The authors noted differences in motorcycle usage in each of the countries. In Italy 63% of the crash sample involved scooters and 72% of all motorcycle crashes occurred in urban areas. Similarly, a high proportion (66%) of motorcycle crashes in Spain also occurred in urban areas and scooters accounted for 42% of motorcycle crashes. In Sweden scooters only accounted for 4% of motorcycle crashes and similar numbers of crashes occurred in both rural and urban areas.

Despite the differences in motorcycle usage and crash patterns, Rizzi et al., (2014) found ABS reduced injury crashes as well as reducing severe and fatal crashes. Reductions in injury crashes due to ABS on all motorcycles were 24%, 29% and 34% for Spain, Italy[6] and Sweden respectively. For serious and fatal crashes the reductions were more significant, with 34% in Spain and 42% in Sweden. Rizzi et al., (2014) also analysed scooter crashes separately. In Italy, a 27% reduction of injury crashes can be attributed to ABS. In Spain, ABS reduced injury crashes by 22% and for serious and fatal crashes there was a 31% reduction. There were too few scooters in the Swedish data to examine the effectiveness of ABS on scooters.

Anderson et al. (2011) conducted a benefit-cost analysis for ABS on motorcycles based on NSW crash data for the period 1999 to 2008 using ABS effectiveness estimates from Rizzi, Strandroth and Tingvall (2009). In their calculations, Anderson et al. (2011) used the 525 fatal crashes (of 650 total fatal motorcycle crashes) and 20,152 injury crashes (of 20,928 total injury motorcycle crashes) in the NSW crash data that were considered by Rizzi, Strandroth and Tingvall, (2009) to be most sensitive to ABS: non head-on type motorcycle crashes. The likely effect of ABS, had it been available and fitted on all motorcycles that crashed in NSW in the period 1999 to 2008, was 280 fewer fatal motorcycle crashes and 8,262 fewer motorcycle crashes resulting in an injury.

Assuming a unit cost for ABS of $500, an 11-year benefit period with a 5.5% discount rate, annualised crash costs for 1999 to 2008 crashes in NSW and using the number of registered vehicles in NSW in 2006, Anderson et al. (2011) calculated a break even cost of $13,700 and a benefit-cost ratio of 27. When considering Australian crash data for 2006, ABS on motorcycles potentially may have resulted in 88 fewer motorcyclist fatalities (a 6% reduction in all Australian road crash fatalities) and 8,618 fewer non-fatal injuries. The monetised crash savings as a result of these crash reductions were estimated to be 795 million dollars (Anderson et al., 2011).

[6] Only injury crashes in general could be analysed in Italy as the authors could not distinguish from the Italian database whether riders were slightly injured or seriously injured (Rizzi et al., 2014)

There are a number of effectiveness estimates for ABS in reducing fatal, serious and other injury crashes but all consistently indicate that ABS on motorcycles is likely to be an extremely effective road safety solution if adopted widely. Based on the estimates of Rizzi, Strandroth and Tingvall (2009), ABS being available on all motorcycles in South Australia in 2012 would have resulted in seven fewer motorcycle fatalities and 57 fewer motorcycle serious injuries (at 48% effectiveness). Even using the minimum likely effectiveness of ABS for reducing motorcycle crashes (17%) according to Rizzi, Strandroth and Tingvall, 2009), there would have been three fewer motorcycle fatalities and 20 fewer motorcycle serious injuries in South Australia in 2012.

There appears to be very little information on the effectiveness of TCS, however, an analysis of German motorcycle crashes showed that a subset of 4% to 8% of fatal crashes might have been preventable through additional stability technology (Seiniger et al., 2008). The remainder might have been affected by the use of ABS or TCS or not at all (because the rider was unable to react to the imminent collision, Anderson et al., 2011).

2.3 Acceptance by motorcycle riders and organisations

While the research literature indicates the considerable benefits of safety technologies on motorcycles (particularly with advanced braking systems) there appears to be reluctance among some motorcyclists and organisations to embrace these systems. As a result, deployment (or supply) of systems on motorcycles based on consumer demand may delay the prevalence of these systems in the wider motorcycle fleet. Some (e.g., Griffith, 2013) are reluctant to accept the claims and evidence about the potential benefits of ABS, citing that perhaps some of the research draws unrealistic conclusions about the benefits of ABS. Despite this reluctance, the Federal Chamber of Automotive Industries (FCAI, 2013, p7) “supports the continued development, introduction, and promotion of better technology for safer motorcycles”. However, the FCAI suggest that regulation is unnecessary stating that “the introduction of ABS on new motorcycles was an industry safety initiative which has been naturally taken up by consumers without the need for regulation” (Federal Chamber of Automotive Industries, 2013, p7).

Cairney and Ritzinger (2008) assessed the acceptability of various motorcycling technologies among experts and riders in Australia, and found that experts and some riders agreed about the benefits of advanced braking systems in emergency braking situations. However, some riders believed that these systems could “… undermine the development of braking skills and leave riders worse off“ (Cairney and Ritzinger, 2008, p350). There was acknowledgement by experts and riders that even skilled motorcyclists have issues with effectively controlling a motorcycle in an emergency situation and in some situations it was thought that a skilled rider could brake more effectively without an advanced braking system (although most riders would not attain this level of skill). Most riders had not ridden motorcycles with these systems, so their opinion was not based on actual experience. Riders also believed that such systems would disrupt a rider’s braking routine if it operated in a manner a rider did not expect (Cairney and Ritzinger, 2008). This concern is common with most dormant primary and secondary vehicle safety systems: a driver/rider may never actually require the intervention of a safety device or feature during their lifetime and hence will never experience how it performs if it is required in an emergency situation.

Other points highlighted by Cairney and Ritzinger (2008):

- A significant barrier to uptake was the belief that experienced riders could brake as effectively as advanced braking systems (although few riders had actually experienced ABS on motorcycles).
- It was believed that inexperienced riders would gain more benefit from the technology, although there was concern that reliance on it could diminish or inhibit basic skill development.
- The technology was generally more acceptable on higher cost motorcycles rather than lower cost models, i.e. when the cost of the system was a small proportion of the value of the motorcycle.

Beanland and Lenne (2013) assessed the acceptability of motorcycle safety technologies internationally (including Australia) by surveying frequent motorcycle riders. Awareness of ABS was very high among Australian riders with 98.4% being aware of ABS. Beanland and Lenne (2013) asked riders to rank the importance of various systems for improving the safety for motorcyclists - on a scale of one (not important) to five (very important). The highest rated system overall was night vision with an overall mean acceptability rating of 3.79, followed by advanced lighting (3.62) and ABS (3.6) respectively. TCS (3.12) was slightly more highly rated than CBS (3.07) and systems considered important in four-wheeled vehicles such as collision warning devices and airbags had mean acceptability ratings below three (2.52 and 2.61 respectively). For Australian riders specifically, the highest rated system was also night vision with an overall mean acceptability rating of 4.32. This was followed by ABS (4.09) and advanced front lighting (4.02). TCS (3.75) was slightly more highly rated than CBS (3.35).

Other points highlighted by Beanland and Lenne (2013):

- Systems with high levels of intervention had the lowest levels of acceptability across all countries.
- Systems that had higher levels of acceptability were those that were informative (such as night vision and GPS) or systems that only intervened in emergency situations such as advanced braking systems and traction control.
- Australian riders who reported low acceptability of assistive systems were part of two distinct rider groups:
    - Those who were more likely to engage in risky behaviours and hence were more likely to be dismissive of systems that interfere with their riding tasks or their 'fun': this would include many recreational riders.
    - Riders who are less likely to engage in risky behaviours (such as commuters) who believe that assistive systems are unnecessary, particularly when the cost of the system is a large proportion of the value of the motorcycle (consistent with Cairney and Ritzinger, 2008).

Finally, the Victorian Motorcycle Council (VMC) (2014) reported scepticism toward optimistic claims about the benefits of ABS on motorcycles. In a response to the *Victorian Road Safety Strategy 2013-2022: Motorcycling*, the VMC agree that there are benefits with ABS in assisting to prevent loss of control by regulating emergency braking but claim the research by the Insurance Institute for Highway Safety (Teoh, 2010) is flawed. The VMC agree that ABS may cause some reduction in fatalities but not to the extent determined by the Insurance Institute for Highway Safety (Teoh, 2010). The VMC highlight that conservative riders may be more likely to choose ABS by nature, ride more conservatively and crash less. The VMC were particularly concerned about ABS not being able to replace good braking skills and that it may encourage riders to stop practising, become complacent (lazy) about braking and subsequently increase stopping distances.

2.4 Uptake of ABS

ABS was first introduced on production motorcycles in 1988 (Bosch, n.d.c; BMW Motorrad, 2012), ten years after it was introduced on passenger vehicles (Bosch, n.d.c). Prevalence of ABS as standard on Australian (and South Australian) passenger cars is 99% on new cars sold (Polk, 2014).

There is difficulty in determining prevalence of ABS on motorcycles. It has been reported that 80% of motorcycles on sale in Australia (by Federal Chamber of Automotive Industries members) have ABS standard or available as an option (Federal Chamber of Automotive Industries, 2013). In the Victorian Road Safety Committee Inquiry into Motorcycle Safety, VicRoads estimated that 'around seven per cent of new motorcycles are equipped with ABS'. (Parliament of Victoria, 2012, p156). Unpublished data from Victoria (C. Jones, personal communication, June 6, 2014) indicated that ABS prevalence on new motorcycles sold in Australia in the 2010/2011 period was around 15%. If the trend in uptake was consistent with uptake of ESC and curtain airbags in cars, then it was estimated that ABS prevalence on new motorcycles sold might be 35% by 2013 (C. Jones, personal communication, July 17, 2014).

Hincliffe (2011) indicated that for BMW, where ABS and ASC (traction control) was optional, take up was as high as 85%, whereas the take up rate of Honda motorcycles offered with ABS was only 15%.

According to Bosch (2013) worldwide production of powered two-wheelers is approximately 51 million units, worldwide ABS installation rates are approximately 1%. The highest rates of ABS are in the US (46%) followed by Japan and Europe with 26%, Brazil 1% and China and India 0% (Bosch, 2013). However, Bosch (2013b) indicate that ABS installation rates for motorcycles with an engine size greater that 250 cc in Europe increased from 26% to 36% between 2007 and 2010. This is compared to <1% to 3% between 2007 and 2010 for motorcycles with an engines size less than 250 cc, and overall ABS fitment in Europe has increased from 9% to 16% between 2007 and 2010.

This is contrary to information provided by Department for Transport (2011), who received information from ACEM [European Association of Motorcycle Manufacturers] that in 2008, 35% of new motorcycle registrations in Europe were fitted with ABS. However, other sources indicated that fitment rates in the UK may be lower, with only 5% of new vehicles having ABS fitted as standard and a further 10% having ABS as an option[7] (Department for Transport, 2011).

The current levels of ABS uptake within the new and registered motorcycle fleet are not clear. There is a lack of consistency in the data analysed to date. There would be benefits to the monitoring of ABS uptake, similar to the monitoring of passenger vehicle technology uptake.

2.5 Encouraging uptake

There are a number of mechanisms that can be used, particularly by the government, to encourage uptake of safety technologies. These can be incentive based through taxation and subsidy schemes, or may involve regulations, education and promotion. Recommendation 48 of the Victorian Inquiry into Motorcycle Safety was that, "Transport Accident Commission and VicRoads investigate the use of

[7] This was based on an unpublished 2008 UK survey of eight motorcycle manufacturers, six of which were in the top ten of UK motorcycle sales.

incentives and public education campaigns to increase the number of motorcycles being purchased with Antilock Braking Systems" (Parliament of Victoria, 2012, p XXXV).

In recognition of the safety benefits of ABS (and the lack of Australasian New Car Assessment Program (ANCAP) ratings for motorcycles), Transport for New South Wales (TfNSW) released a discussion paper pertaining to vehicle registration initiatives. One of the initiatives proposed to encourage the purchase of safer motorcycles is effectively to charge lower registration costs for motorcycles that have ABS and lower power to weight ratios, and no penalty for lack of ABS (TfNSW, 2014).

The Western Australian Motorcycle and Scooter Action Group proposed a number of action statements with regard to motorcycle safety features. These included concessions and/or reduced insurance premiums for riders purchasing motorcycles with safety features such as ABS, encouraging manufacturers to have ABS on motorcycles though reductions in import duties and taxes, or by mandating ABS on motorcycles. (Western Australian Motorcycle and Scooter Action Group, n.d.).

Under the United Nations "Global Plan for the Decade of Action for Road Safety 2011-2020" the UN encourages universal deployment of crash avoidance technologies with proven effectiveness including ABS on motorcycles (Pillar 3: Safer vehicles, Activity 4) and concurrently encourages the use of financial or other incentives for motor vehicles that provide high levels of road user protection (Pillar 3: Safer vehicles, Activity 5, United Nations, 2011). These activities were further emphasised recently by the Secretary General of Global NCAP at the recent Global NCAP 2014 Annual Forum (Ward, 2014).

Groups such as ANCAP, motoring organisations and insurance companies have had significant influence in encouraging early adoption of passenger vehicle safety technologies. This has been achieved through consumer testing programs, fleet purchasing policies, publicity, lobbying and insurance schemes (Searson et al., 2014). Additionally, ANCAP have been increasing the requirements to achieve five star safety ratings for vehicles and requiring more vehicle "safety assist technologies" under the ANCAP Rating Road Map (ANCAP, 2012). In combination with the various ANCAP "Stars on Cars" marketing programs around Australia, (that appear to be associated with increased sales of ANCAP five-star cars, Leyson, 2013) promoting ANCAP five-star rated cars concurrently promotes vehicle safety technologies (Searson et al., 2014).

In evidence submitted by Victorian Police to the Victorian Road Safety Committee Inquiry into Motorcycle Safety, Deputy Commissioner K. Walshe proposed "The consideration for an ANCAP-type rating - an amendment to the Australian design rules, legislative change to include anti-lock braking systems on new motorcycle purchases..." (Road Safety Committee, Parliament of Victoria, 2011, p22).

One of the actions for the first three years of The National Road Safety Strategy 2011-2020 is to prepare Regulatory Impact Statements (RISs) to consider mandating of ABS for motorcycles (Australian Transport Council, 2011) and this has been supported by all governments around Australia. A component of Victoria's Road Safety Action Plan 2013-2016 is indeed to "Encourage the Federal Government to introduce an Australian Design Rule for ABS to be fitted on all new motorcycles in Australia" (Road Safety Victoria, 2014). The research into the potential effectiveness of ABS in Australia to support such a RIS will shortly commence through a partnership between MUARC, the federal government and VicRoads (C. Jones, personal communication, June 6, 2014).

The European Union has already undertaken all of the required processes to regulate ABS, and have adopted a regulation for safety (and environmental requirements) from 2016 for new models, and 2017 for all new motorcycles with an engine capacity of more than 125 cc. According to the Council of the European Union "new motorcycles of more than 125 cc are to be equipped with an enhanced ABS (anti-lock braking system), whereas the incorporation of anti-lock or combined braking systems for motorcycles under 125 cc will be left to the choice of the vehicle manufacturer" (Council of the European Union, 2012, p1). The results of this regulation will be monitored (with respect to crash statistics), with a possible future proposal to include mandatory installation of ABS on smaller motorcycles. It is anticipated that the initial regulation will assist the EU with halving the number of road user casualties by 2020 (Council of the European Union, 2012).

It is recognised that crash testing motorcycles may not be feasible or meaningful given their obvious lack of a protective structure, and hence it is more important to focus on the primary safety features such as CBS, ABS and TCS. While there is no NCAP style testing program for motorcycles, Euro NCAP recently crash tested a number of Quadricycles (originally derived from motorcycles), that are not required to undergo crash tests by law and are street legal (in Europe). The Euro NCAP crash tests (although different to the tests for passenger vehicles and not directly comparable) indicated that generally, quadricycles provided much lower levels of protection than passenger vehicles. (Euro NCAP, 2014).

In the past, advertising campaigns publicising the need for vehicle safety features have been predominantly focused on passenger vehicles. The Victorian Transport Accident Commission (TAC) have run campaigns encouraging the purchase of passenger vehicles with electronic stability control (ESC) and side curtain airbags (Dore, 2011). Similar campaigns should be considered for ABS and motorcycles.

While effective advertising campaigns have run in the past for motorcycle safety, the focus has predominantly been on the commonly accepted factors involved in motorcycle crashes, particularly speeding and risky behaviour by motorcyclists and other road users, as well as campaigns that encourage safer riding behaviour, improved conspicuity and protective clothing (TAC, 2014; MAC, 2014). Some recent effort has been placed on highlighting the benefits of ABS by VicRoads (VicRoads, 2012) and more recently by the TAC "Spokes" website (Spokes, n.d.). These sources of information also provide lists of motorcycles that have ABS (VicRoads, 2013; Spokes, 2010) and show demonstration videos (VicRoads, 2012).

There is some evidence to suggest that targeted active promotion of vehicle safety features can influence purchasing intentions and vehicle sales. An evaluation of a campaign promoting ESC in regional and remote areas of Western Australia had a positive impact on vehicle purchasing behaviour intentions: of those who saw the campaign 71% said they were more likely to choose a vehicle with ESC when considering their next vehicle purchase (Painted Dog Research, 2013).

The Department of Infrastructure and Regional Development (2013) highlight a real-world advertising campaign by Mitsubishi, for the 2008 Outlander, which focused on ESC as a standard feature; there was a 9.1% increase in sales for the month of February. The authors attributed this increase to the promotional campaign.

Fleet purchasing policies can also influence the proliferation of safer vehicles. In South Australia, the Government has mandated ANCAP five-star passenger vehicles for the state Government passenger vehicle fleet (Government of SA, 2011). Additionally, BHP Billiton has documented in their "fatal risk controls" to "transition all light vehicles to a 5 Star NCAP safety rating by 01 Jan 2016" (BHP Billiton, 2012). These purchasing policies inevitably influence the general fleet composition. Similar strategies could be encouraged in fleets with high numbers of motorcycles.

For example, encouraging Australia Post to require ABS on their fleet of motorcycles will inevitably influence future stocks of motorcycles within the registered Australian motorcycle fleet. According to Australia Post (2011), they have a national fleet of 7,500 motorcycles and renew over 2,000 motorcycles per year. Currently, it appears that while Australia Post consider safety with utmost importance, their safety strategies have related mainly around motorcycle weight balancing improvements, rider training (and regular training refreshment), mentoring, public awareness initiatives (particularly through conspicuity improvements) and behaviour training (Australia Post, 2011). Recently, Australia Post has changed the motorcycles used in their fleet (The Motor Report, 2013), but this motorcycle, although consistent with Australia Post's previous safety requirements, is not available with ABS.

This requirement for ABS already exists for the Victoria Police motorcycle fleet, with ABS being required in order to be consistent with occupational health and safety obligations (Road Safety Committee, 2011) and the South Australia Police motorcycle fleet also consists of motorcycles with ABS fitted (M. Leyson, personal communication, June 24, 2014).

Motorcycles are provided for training in the SA RiderSafe program and these consist of a variety of motorcycles ranging from 110 cm^3 to 373 cm^3. In total there are 102 motorcycles in the RiderSafe training fleet consisting predominantly of entry level motorcycles that can accommodate riders of all statures and skill level. The motorcycles in the RiderSafe fleet are selected on the basis of suitability for learner skills training and learner rider handling characteristics. Most of the motorcycles in the RiderSafe training fleet consist of:

- Honda NSC 110 DIO scooters
- Suzuki TU250 road bikes
- Honda CB125 road bikes
- Yamaha XT250 trail bikes
- KTM Duke 390 ABS road bikes

Bikes are renewed every three years, with approximately one-third of the fleet being replaced each year (D. Roe, personal communication, August 11, 2014). While in the past none of the bikes in the fleet have had CBS or ABS fitted, the Honda NSC110 DIO scooter, for model year 2011 onwards, has CBS fitted (Honda, 2011). When the current fleet of RiderSafe scooters are refreshed in the future, the newer Honda NSC 110 DIO scooters will have CBS.

In the past, motorcycles with ABS have not been considered suitable for the RiderSafe motorcycle fleet (D. Roe, personal communication, October 13, 2014), because ABS was fitted on more expensive, higher performance and higher engine capacity motorcycles. However changes to procurement procedures have allowed RiderSafe to purchase a number of KTM Duke 390 ABS motorcycles and these are distributed to all RiderSafe training centres for learner rider demonstration and training purposes (M. Lohmeyer and M. Leyson, personal communication November 26, 2014).

RiderSafe are also currently looking at including motorcycle ABS theory in the training program, either using a poster, discussing the benefits of ABS during a theory session, or in a video that is shown during lessons. A website similar to Vicroads (see Vicroads, 2012) discussing ABS benefits and availability (D. Roe, personal communication, August 11, 2014) is also being developed.

Finally, insurance incentives may also be an effective method for encouraging purchase of safety technologies; some insurance companies offer a 20% reduction in premium for passenger vehicles with autonomous emergency braking systems (Subaru, 2012; Blackburn, 2009). Similar premium reductions could be applied to motorcycles that are purchased with ABS. Conversely, mechanisms to dissuade purchase of motorcycles without ABS could may also be effective in encouraging purchase of motorcycles with ABS. For example, refusal to insure new passenger vehicles with an ANCAP rating below four stars is being undertaken by an insurance company in trying to promote safer car choice in Western Australia (RAC Group, 2012).

2.6 Availability and cost of ABS on motorcycles

To assist consumers purchasing motorcycles, both VicRoads and TAC provide lists of motorcycle models with ABS (VicRoads, 2013; Spokes, 2010). Increasingly, motorcycle manufacturers are including ABS as standard equipment. For example, since 2013 Harley Davidson has included ABS as standard equipment on all of their motorcycles, except for one model (Harley Davidson representative, personal communication, June 6, 2014). In 2013 all BMW motorcycles (model years 2013 onward) have ABS standard (BMW, 2013). In 2014 it has been indicated that Ducati will also include ABS as standard and more manufacturers are likely to follow suit.

Table 2.1 shows the highest selling road motorcycles (or motorcycles that can be registered) for 2013 (FCAI, 2014), their cost[8] with and without ABS, and whether they are approved as part of the Learner Approved Motorcycle Scheme (LAMS).

ABS is standard on 44% of the motorcycles in Table 2.1. Four of the motorcycles had ABS as optional, and the cost of ABS on all of these motorcycles was around $500 except for one where it was $1000. In 2011, the cost of optioning ABS on a BMW motorcycle was between $1,265 on a $15,215 motorcycle and $1,775 on a $29,000 motorcycle. While it appears that the cost of ABS has decreased relative to the value of the motorcycle it is optioned on, it has remained constant at 6-8% of the value of the motorcycle.

In Table 2.1, there are four motorcycles where ABS fitment is optional, although sales figures do not indicate how many new motorcycles were purchased with ABS fitted. Some manufacturers of motorcycles indicate whether ABS is fitted to a motorcycle based on "ABS" being included in the model name. For example the model of "Kawasaki Ninja 300" with ABS is named "Ninja 300 ABS". This is the case for each of the four motorcycle models in Table 2.1. Based on a snapshot of South Australian registration data (August 2013) for motorcycle years 2011 – 2013:

- 14% of Kawasaki Ninja 300 motorcycles registered in SA have ABS (18 of 127)
- 5% of Honda CBR500R motorcycles registered in SA have ABS (2 of 37)
- 6% of Honda CBR250R motorcycles registered in SA have ABS (12 of 205)
- 2% of Honda CBR1000RR motorcycles registered in SA have ABS (1 of 58)

This provides some indication that take up of ABS as an option on a new motorcycle is quite low, perhaps between 2% and 14%.

Although 44% of the motorcycles in Table 2.1 did not have ABS available at all, some of these motorcycles are considered low value commuter motorcycles (scooters) or motorcycles where the primary function was not necessarily road use. However, all of these motorcycles can be registered and may be ridden on public roads, so the benefits of ABS are equally relevant.

[8] Costs were derived from various websites and sales representatives, and may indicate drive-away price or recommended retail price.

Table 2.1
Top selling motorcycles (that can be registered) January-December 2013 (FCAI, 2014), and their cost, ABS and LAMS characteristics.

Make	Model	2013 Sales	Cost without ABS	Cost with ABS	Difference	LAMS Approved
Kawasaki	Ninja 300	3560	$6600	$7100	$500	Yes
Honda	CBR500R	1748	$7690	$8190	$500	Yes
Yamaha	WR450F	1684	$12999	N/A		Yes
Honda	CBR250R	1580	$5990	$6500	$510	Yes
Honda	CT110X	1489	N/A	N/A		Yes*
Honda	CB125E	1218	$2350	N/A		Yes
Yamaha	XVS650	1029	$10499	N/A		Yes
Suzuki	DR-Z400E	990	$7999	N/A		Yes
Harley Davidson	FXSB	748	N/A	$28995		No
Kawasaki	Ninja 650RL	743	N/A	$10290		Yes
Harley Davidson	FXDF	707	N/A	$25495		No
Harley Davidson	FXDWG	607	N/A	$24995		No
Harley Davidson	VRSCDX	597	N/A	$26995		No
Yamaha	YZF-R15	580	$3999	N/A		Yes
Harley Davidson	FXST	577	N/A	$27250		No
Harley Davidson	FXDB	559	N/A	$22495		No
Piaggio	Fly 150	516	$3090	N/A		Yes
Harley Davidson	FLSTF	511	N/A	$28995		No
MCI	Riviera 50	506	$1499	N/A		Yes
Harley Davidson	XL883N	493	N/A	$14999		No
Honda	CB500FA	475	N/A	$7990		Yes
Honda	CBR1000RR	468	$18500	$19500	$1000	No
Triumph	Street Triple	439	N/A	$15390		No
Yamaha	TT250	419	Discontinued	N/A		Yes
Kawasaki	KLR650	399	$7999	N/A		Yes
BMW	R1200 GS	370	N/A	$21700		No
Piaggio	ZIP 50	369	$2100	N/A		Yes
Ducati	M659	366	N/A	$14490		Yes
Ducati	Diavel	363	N/A	$26000		No
Yamaha	FZ6R	357	Discontinued	N/A		Yes
Honda	NVS502	356	$1999	N/A		Yes
Hyosung	GT650R	350	$5990	N/A		Yes

*This can only be purchased second hand for general motorcycle use, and is exclusive to Australia Post brand new.

3 Analysis of crash data

South Australian crash data was analysed to investigate trends and characteristics of motorcycle crashes over the last eleven years. The results demonstrated that while all road injuries and fatalities have been decreasing between 2003 and 2013, the same trend is not evident for motorcycles. Based on measures of exposure (fatalities per 10,000 registrations and per billion vehicle kilometres travelled (BVKT)) there have been declines in vehicle crash injuries as well as motorcycle crash injuries. However, the crash data indicates that, as a proportion of all road users, motorcycle injury representation is increasing, and relative risk of motorcycle fatality per BVKT compared to vehicle related fatalities per BVKT remains unacceptably high.

3.1 Method

Records of motorcycle rider injuries in South Australia were extracted for the period 2003-2013 from the South Australian Traffic Accident Reporting System (TARS) these included hospital treated, hospital admission and fatal injuries. These records were disaggregated according to various rider and motorcycle characteristics and are presented and compared to general characteristics of road injuries and fatalities overall in South Australia, as well as registration data.

3.2 Results

Registrations for motorcycles have been steadily increasing over time. Between 2003 and 2013 motorcycle registrations in South Australia have increased by 78% from 28,454 in 2003 to 50,678 in 2013; the average increase from year to year was 6%. For passenger vehicles the average increase has been only been around 2% per year (ABS, 2014). Consistent with the increase in motorcycle registrations, billions of vehicle kilometres travelled (BVKT) for motorcycles in SA have increased by 88% between 2003 (0.110 BVKT) and 2012 (0.207 BVKT), an increase of around 7.5% per year. This is compared to all other vehicles BVKT that increased by 2.4% between 2003 (15.548) to 2012 (15.918), around 0.3% increase per year.

There was a 38% decline in total road fatalities between 2003 (156 fatalities) and 2013 (97 fatalities), an average decline of 4.6% per year. Over the same time period, motorcycle rider and pillion fatalities have remained steady, fluctuating between a low of eight (in 2007) to a high of 21 (in 2011), with a very slight average decline of around 1.4% per year (see Figure 3.1).

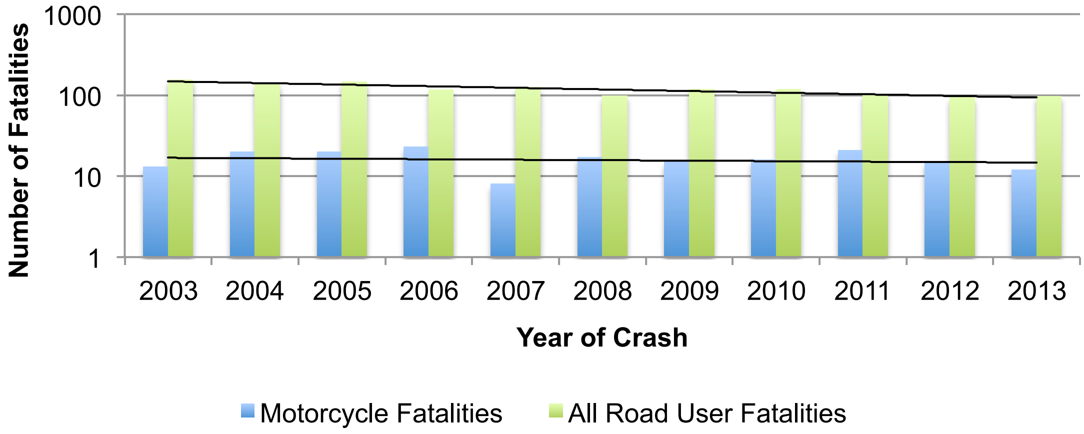

Figure 3.1
Frequency and trend of motorcycle fatalities compared to all road user fatalities in South Australia, 2003 to 2013

There was a 23% decline in all road user injuries of any severity between 2003 (6349) and 2013 (4908); an average decline of 2.4% per annum (see Figure 3.2). Over the same time period, motorcycle rider and pillion injuries of any severity have not followed a trend, fluctuating between a low of 381 injuries in 2005 to a high of 562 injuries in 2008, with a very slight average increase of around 1.1% per year over the same period (See Figure 3.2).

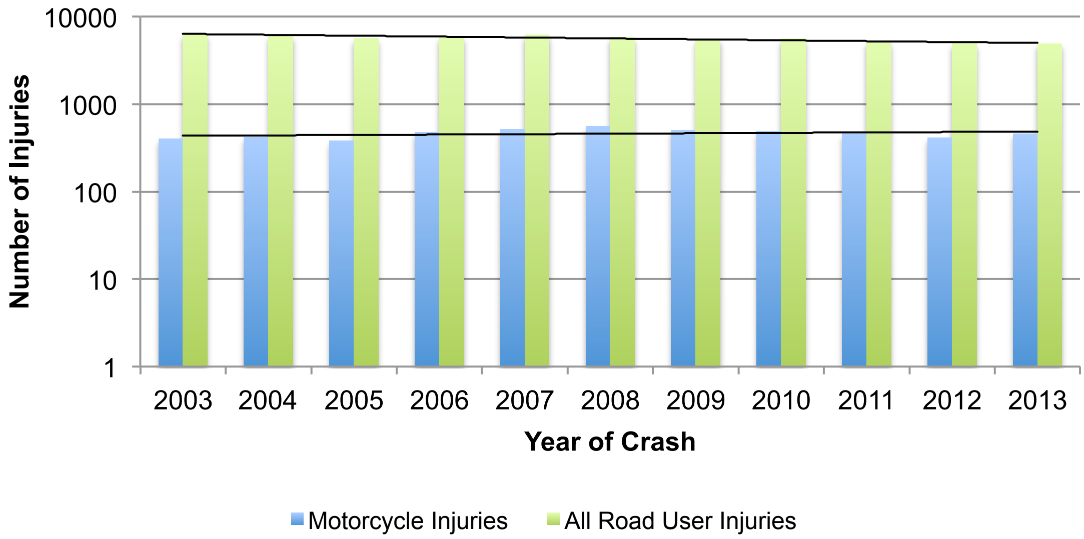

Figure 3.2
Frequency and trend of motorcycle injuries compared to all road user injuries in South Australia, 2003 to 2013

While serious casualties for all road users are decreasing, the proportion attributable to motorcycles is increasing at around 3% per year. This can be seen in Figure 3.3. Motorcycle casualties accounted for 6% of all injuries in 2003 but over the last few years have accounted for around 9% of all road injuries.

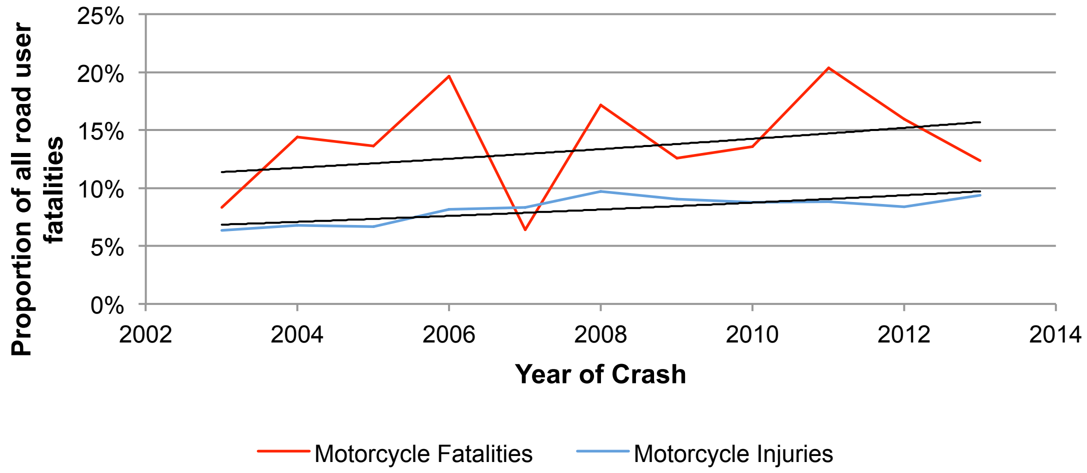

Figure 3.3
Motorcycle rider/pillion fatalities and injuries as a proportion of all road user fatalities and injuries in South Australia, 2003 to 2013.

Per 10,000 registrations, motorcycle fatalities have been declining in South Australia at about 8% per year since 2003 and injuries at about 5% per year. Motorcycle fatalities per billion kilometres travelled have also declined at about 8% per year compared to the per year decline of around 7% for other vehicles in SA. However, the number of fatalities per BVKT is considerably higher for motorcycles than for other motor vehicles. In SA in 2012, there were 72.5 motorcycle fatalities per motorcycle BVKT compared to 4.1 fatalities per BVKT for other motor vehicles. That means the risk of a motorcycle fatality per BVKT was 17.5 times higher for motorcycles than other motor vehicles. Over the period from 2003 to 2012, the motorcycle fatality risk was around 20 times higher than for all other motor vehicles.

3.2.1 Rider demographics

Table 3.1 shows the age and sex of injured motorcycle riders (hospital treated, hospital admitted and fatal injuries).

Table 3.1
Age and sex of motorcycle and scooter riders injured in South Australia 2003 – 2013 (where age and sex is known)

Rider age group	Rider sex		Total
	Male	Female	
15 or younger	37	3	40
16 to 19	365	30	395
20 to 29	1234	126	1360
30 to 39	942	94	1036
40 to 49	902	81	983
50 to 59	595	51	646
60 to 69	196	12	208
70 to 79	56	2	58
80 or older	9	1	10
Total	4336	400	4736

Table 3.2 shows the proportion of riders of particular age groups injured in motorcycle crashes (hospital treated, hospital admitted and fatal crashes) for the period 2003 – 2013. Table 3.2 also shows the proportion of rider injuries for 2013 independently and this is compared to the proportion of motorcycles registered by owners in the same age groups, in the same year. Older riders accounted for a majority of the registrations and injuries. However younger riders had almost three times more injuries per registration, intermediate riders had 1.3 times more injuries than registrations and the older riders only had 0.8 injuries per registration, in 2013[9].

Table 3.2
Age of riders injured in crashes and being the registered owner of a motorcycle or scooter in South Australia 2003 - 2013

Rider age group	Rider % of Injuries		% of Registrations 2013
	2003 - 2013	2013	
Under 16	0.8%	0.2%	0.0%
16 to 29	36.7%	35.0%	12.8%
30 to 39	21.7%	16.6%	13.2%
40 and over	39.8%	47.7%	60.2%
Unknown	1.0%	0.5%	13.7%
Total	100%	100%	100%

Weissenfeld et al., (2011) analysed trends in motorcycle crashes in South Australia from 1990 to 2009, and found a large decline in motorcycle crashes particularly amongst the 16 to 29 year olds (75.2% decrease), and amongst the 30 to 39 year old group (42.9% decrease) but a large increase in the 40 years and over age group (163% increase).

However, for the present study, considering injury data between 2003 and 2013 (See Figure 3.4) injuries for 16 to 29 year old riders appear on average to have remained stable at about 0.1% increase per year. For 30-39 year old riders there has been a 26% decrease in injuries between and 2003 and 2013 (around 4% reduction per year) and for riders 40 years and over, injuries have increased between 2003 and 2013 by 84% (6% increase per year).

[9] While it cannot be assumed that the age of a rider who crashed is necessarily the same as the age of the registered owner of the motorcycle, generally it may be the case.

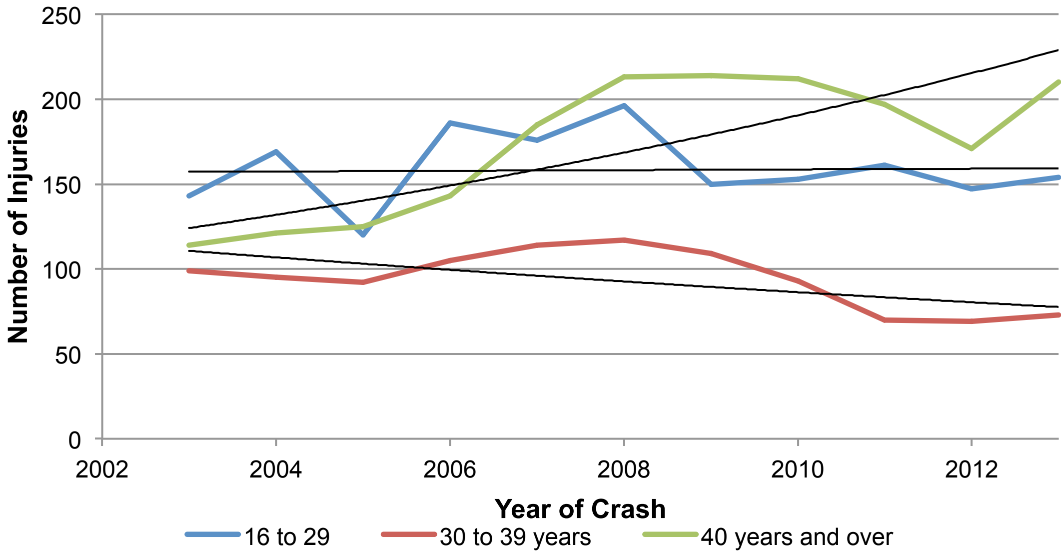

Figure 3.4
Motorcycle rider injuries from 2003 – 2013 for the different rider age groups.

3.2.2 Types of crashes

The most commonly reported crash types for motorcycles were rollover crashes and hit fixed object crashes (Table 3.3). Rollover crashes can be assumed to be a crash resulting from some event that resulted in a motorcycle rider losing stability and over-turning. Table 3.4 shows the proportion of crash types where only the crashing motorcycle was involved, and when other vehicles were involved. Rollover crash types and hit fixed object crashes were most commonly associated with only the motorcycle involvement, suggesting perhaps that most motorcycle crashes are the result of loss of dynamic stability without interaction with another vehicle.

For crashes involving other vehicles, not surprisingly the most common crash types were right angle, right turn and side-swipe crashes, the result of a direct interaction with another vehicle.

Table 3.3
Proportion of police reported crash types 2003 – 2013* by vehicle type

Police Reported Crash Type	Two-wheeled vehicle type		Total
	Motorcycle	Scooter*	
Roll over	23.5%	1.4%	24.90%
Hit fixed	16.7%	0.8%	17.50%
Right angle	14.7%	1.5%	16.20%
Rear end	9.8%	0.8%	10.60%
Right turn	8.9%	0.9%	9.80%
Side swipe	8.3%	0.8%	9.10%
Head on	3.8%	0.1%	3.90%
Left road - out of control	2.2%	0.0%	2.20%
Hit animal	2.1%	0.1%	2.20%
Hit parked vehicle	1.1%	0.1%	1.20%
Other	1.0%	0.0%	1.00%
Hit object on road	0.9%	0.0%	0.90%
Hit pedestrian	0.5%	0.0%	0.50%
Total	93.48%	6.52%	100.00%

*Note: disaggregation of scooters from motorcycle category occurred in 2008.

Table 3.4
Proportion of police reported crash types 2003 – 2013 by vehicle involvement

Year of crash	Crash Involvement		Total
	Motorcycle Only	Multiple Vehicles	
Roll over	24.0%	0.9%	25.0%
Hit fixed	17.0%	0.5%	17.5%
Right angle	0.0%	16.2%	16.2%
Rear end	0.1%	10.5%	10.6%
Right turn	0.0%	9.8%	9.8%
Side swipe	0.0%	9.0%	9.0%
Head on	0.0%	3.9%	3.9%
Left road – out of control	2.2%	0.0%	2.2%
Hit animal	2.1%	0.1%	2.2%
Hit parked vehicle	0.0%	1.2%	1.2%
Other	0.7%	0.3%	1.0%
Hit object on road	0.9%	0.0%	0.9%
Hit pedestrian	0.4%	0.0%	0.5%
Grand Total	47.6%	52.4%	100.0%

3.2.3 Age profile of crashed motorcycles

Most of the motorcycles involved in injury crashes are reasonably new. The average age of crashed motorcycles for 2003 – 2013 (of a known age) was 6.8 years and the median age was 4.2 years. In 2013, the average age of registered motorcycles was 9.5 years and the median age was 5.6 years. Figure 3.5 shows the age profile (and cumulative distribution) of the crashed motorcycle fleet 2003 – 2013, compared to the age profile (and cumulative distribution) of the registered motorcycle fleet in 2013.

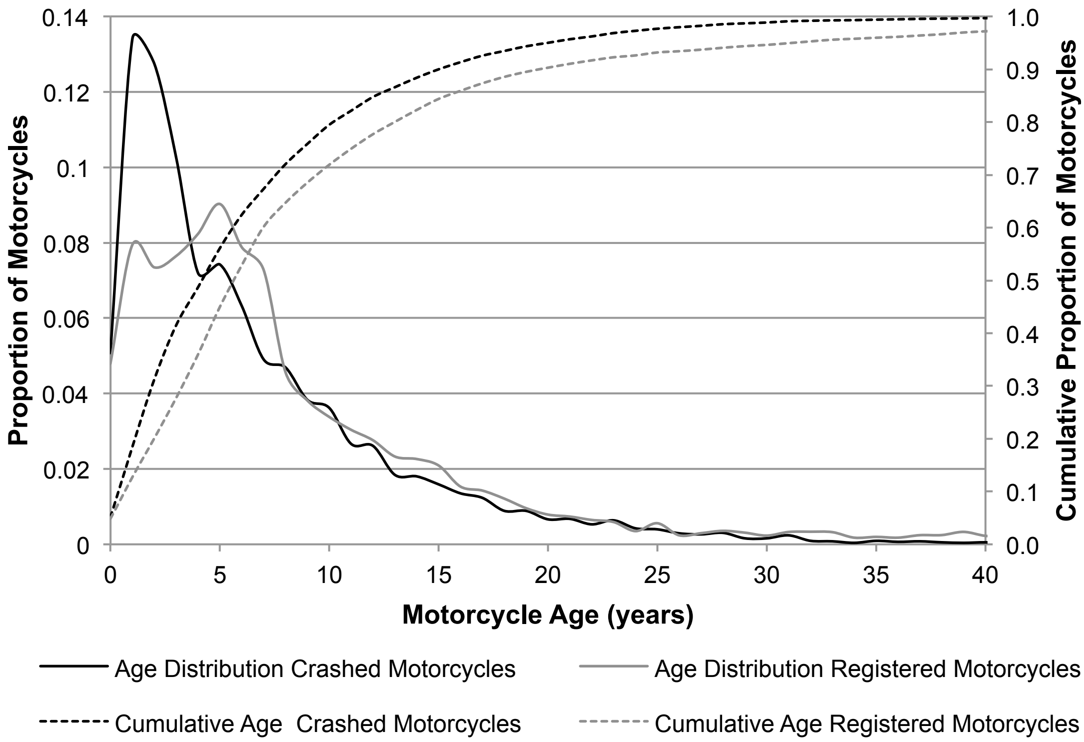

Figure 3.5
Age profile (and cumulative distribution) of the crashed motorcycle fleet 2003 – 2013, compared to the age profile (and cumulative distribution) of the registered motorcycle fleet in 2013.

Tables 3.5 and 3.6 show the motorcycle age disaggregated by crashed rider age and registered owner age respectively. In each rider age category, where the age of a motorcycle was known, a majority of the riders (56%) crashed motorcycles aged between 0 and 5 years of age, and fewer riders crashed older bikes. The distribution of crashed motorcycles is consistent with registration data, with a majority (44.7%) of the motorcycles registered (where the age was known) being between 0 and 5 years of age. Interestingly, in the 40 and over registered age group, there were proportionally more older motorcycles registered to older riders compared to older motorcycles crashed by older riders.

Table 3.5
Motorcycle age disaggregated by crashed rider age

	Motorcycle Age Group (years)					
Crashed Rider Age Group	0 to 5	6 to 10	11 to 15	16 to 20	Greater than 20	Total
Under 16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
16 to 29	21.4%	3.9%	7.8%	1.7%	1.5%	36.3%
30 to 39	12.9%	2.2%	5.1%	1.3%	0.9%	22.4%
40 and over	21.7%	4.4%	10.1%	2.2%	2.9%	41.3%
Total	56.0%	10.4%	23.0%	5.3%	5.3%	100%

Table 3.6
Motorcycle age disaggregated by registered owner age

	Motorcycle Age Group (years)					
Registered Owner Age Group	0 to 5	6 to 10	11 to 15	16 to 20	Greater than 20	Total
Under 16	-	-	-	-	-	-
16 to 29	8.5%	4.0%	1.4%	0.6%	0.7%	15.1%
30 to 39	7.9%	4.4%	1.9%	0.7%	0.8%	15.7%
40 and over	28.3%	19.1%	8.6%	4.4%	8.7%	69.2%
Total	44.7%	27.5%	11.9%	5.7%	10.2%	100%

3.2.4 Licence status of crashing riders

According to the Government of South Australia (2013), between 2007 and 2011, a majority (65%) of riders involved in fatal crashes had a full R (rider) licence, 4% had a learner's permit, an additional 4% were on a R-date licence and 1% on a probationary licence. The remaining 26% were not legally licensed to ride a motorcycle; 18% did not have an appropriate licence or have any licence, and 7% originally had a licence but were disqualified, suspended or held an expired licence.

3.2.5 Summary of crash data

The actual number of motorcycle fatal and serious injuries each year is relatively small in comparison to other road users as a whole, so a small change in the number of crashes in any year can influence any overall trends, making trends difficult to establish. Trends by age group show a pattern of increased numbers of injuries for older riders.

General reductions in fatality and injury measures are more significant for motor vehicles than for motorcycles but the motorcyclist share of total fatalities and injuries is increasing. Registrations of motorcycles have been increasing in South Australia but there has been a general decline in crashes per motorcycles registered. An increasing number of kilometres are being travelled by motorcyclists but fatalities per BVKT are declining. However, over the period 2003 to 2012, based on BVKT, the motorcycle fatality risk was around 20 times higher than for all other motor vehicles in South Australia.

The most common types of police reported crashes involve motorcycles at intersections (right-turn and right angle crashes), accounting for 26% of crashes, as well crashes where motorcyclists lose control and over-turn (identified in TARS as rollovers), accounting for 25% of police reported crashes. It is these types of crashes for which ABS has been identified as having the greatest safety benefit.

4 Analysis of introduction rates of motorcycle ABS

In Section 2, effectiveness values for motorcycle ABS were discussed. These values can only be interpreted in the context of 100% fleet penetration. Even if motorcycle ABS were made mandatory in the very near future, it would take some time for increased numbers of motorcycles with ABS to filter into the registered fleet and hence the crashing fleet. Thus the benefits of ABS would not accrue instantly, but over time, with the year-by-year benefits being a function of the rate of introduction into new motorcycles, the age profile of motorcycles in the registered fleet and the age profile of motorcycles in the crashing fleet. That said, the previous analysis of the SA motorcycle fleet might suggest that the delay will be relatively short, as the median age of motorcycles appears to be around five years, and about half what it is for other vehicles. Moreover, the age profile of motorcycles involved in crashes is younger again, and much younger than equivalent profiles for passenger vehicles. Therefore, compared to passenger vehicles, the benefits of effective motorcycle safety technology is likely to have a much quicker return than equivalent technologies in passenger vehicles.

In the analysis here, two introduction rates are used in conjunction with the age profile of crashed motorcycles in South Australia to calculate the potential year-by-year future prevalence of ABS in the crashed motorcycle fleet. From this, year-by-year future crash reductions are also calculated.

4.1 Method

The year-by-year reductions in motorcycle crashes were calculated by multiplying the effectiveness of ABS by the proportion of motorcycles in the crashed fleet that would have ABS in a given year. Three different values for ABS effectiveness were used, based on the literature reviewed earlier.

The proportion of motorcycles crashing with ABS for each year was calculated by assuming two different introduction rates of ABS into new motorcycles. The motorcycle crash age profile was assumed to remain the same in future years[10]. Based on these two assumptions, the year-by-year prevalence of ABS in the crashing motorcycle fleet could be calculated based on the gradual accumulation of ABS equipped motorcycles into the new motorcycle fleet.

4.2 Introduction rates

Two introduction rates were used. It was assumed that the prevalence of ABS in new motorcycles has been increasing linearly from 2005 until the present, with an increase of 5% per year. This implies that 35% of new motorcycles would have had ABS in 2012, which is somewhat consistent with the estimates given earlier. The increase of 5% per year is consistent with scenarios discussed by Department for Transport (2011). In both introduction rate scenarios, 50% prevalence is attained for new motorcycles in 2015.

From 2015 onwards, the first scenario continues with a 5% per year increase, which means that 100% of new motorcycles would have ABS from 2025 onwards (scenario 1). This is likely to be achieved by the current level of uptake. The second scenario (scenario 2) uses a 10% per year increase from 2015 onwards, which means that 100% of new motorcycles would have ABS from 2020. The second scenario corresponds to a situation where a regulation might be introduced in Australia that makes ABS mandatory from 2020, hence encouraging manufacturers to introduce ABS into the new motorcycle fleet at a more rapid rate.

[10] For simplicity this was assumed, however as ABS prevalence increases in the new motorcycle fleet, it would be expected that fewer new motorcycles (those with ABS) would be crashing in the future so the motorcycle crash age distribution may likely change. This change cannot be predicted with the limited data that is available.

4.2.1 Motorcycle crashed age profile

The motorcycle crash age profile was based on all motorcycle crashes in the period 2003-2013, with unknown years of manufacture excluded from the sample. The age of each crashed motorcycle was extracted from the crash data. The resulting motorcycle crash age profile (limited to 50 years) is shown in Figure 4.1.

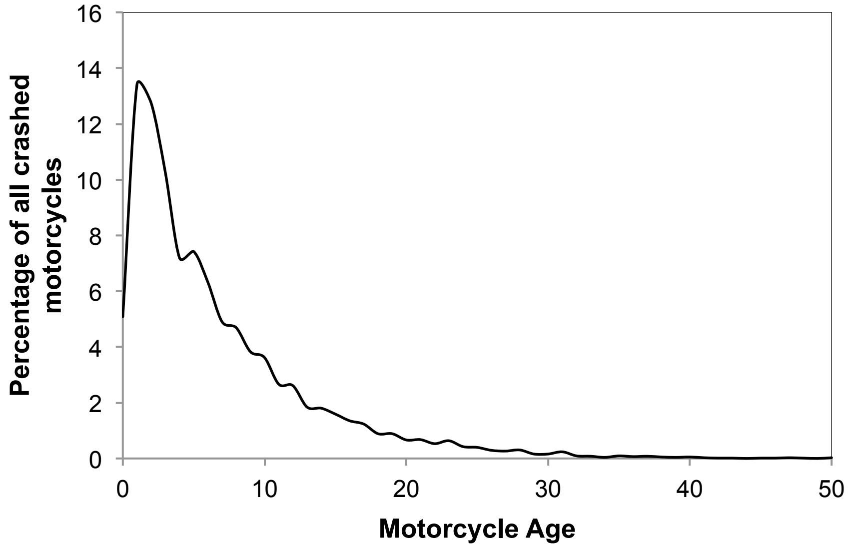

Figure 4.1
Motorcycle age profile for South Australia in 2013.

4.2.2 Effectiveness values

Three effectiveness values were used: 15%[11], 30% and 38%. These are based on various lower and upper effectiveness estimates by Rizzi, Strandroth and Tingvall (2009); Teoh (2013) and The Highway Loss Data Institute (2012; 2013).

4.3 Results

Figure 4.2 shows the introduction curves for both scenarios of ABS take up in the new motorcycle fleet (new motorcycles sales) and the corresponding expected prevalence curves in the crashing motorcycle fleet, based on the crashing motorcycle age profile from the 2003-2013 crash data.

Under a scenario of encouraged uptake of ABS (scenario 1), assuming the rate of uptake of ABS in the new motorcycle fleet as in Figure 4.2, then 100% of new motorcycles would have ABS fitted by 2025. The expected effect of this would be that by 2025, 68.1% of the crashing motorcycles would have ABS. Corresponding to Figure 4.3, this would result in a reduction of motorcycle crashes/injuries by between 10.2% (15% effectiveness for ABS) and 25.9% (38% effectiveness for ABS). This is summarised in Table 4.1.

[11] An effectiveness estimate of 15% was used as a slightly more optimistic value of the average (14%) for the effectiveness of ABS in reducing all crashes with injuries by a minimum of 11% and reducing all severe and fatal crashes by a minimum of 17% quoted by Rizzi, Strandroth and Tingvall (2009).

Under a more aggressive scenario of introduction (scenario 2), where a regulation would result in 100% of new motorcycles to be fitted with ABS by 2020, we would expect that by 2025, 77.5% of the motorcycles crashing would have ABS (see Figure 4.2). Again, corresponding to Figure 4.3, this would result in a reduction of motorcycle crashes/injuries by between 11.6% (15% effectiveness for ABS) and 29.5% (38% effectiveness for ABS). This is also summarised in Table 4.1.

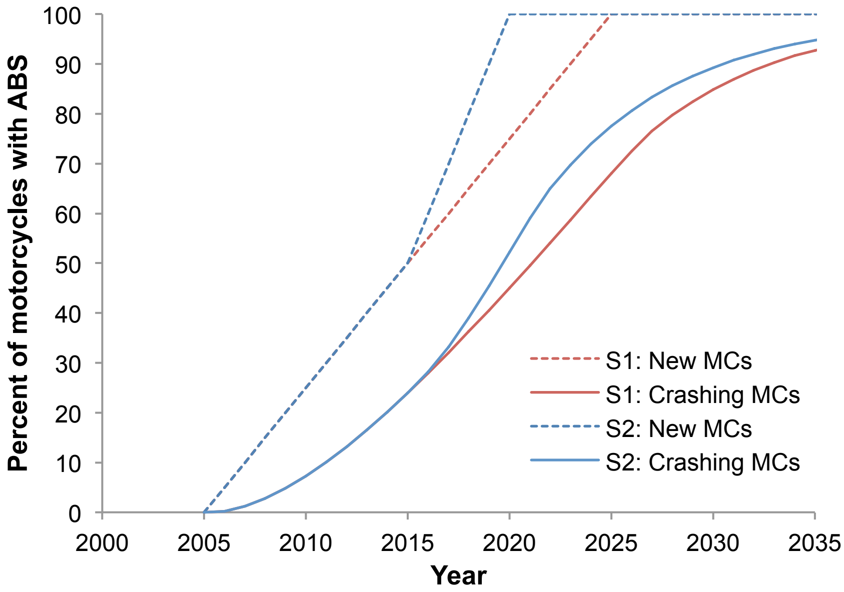

Figure 4.2
Estimated prevalence of new motorcycles with ABS and in the corresponding estimated prevalence in crashing motorcycles, for two different introduction scenarios.

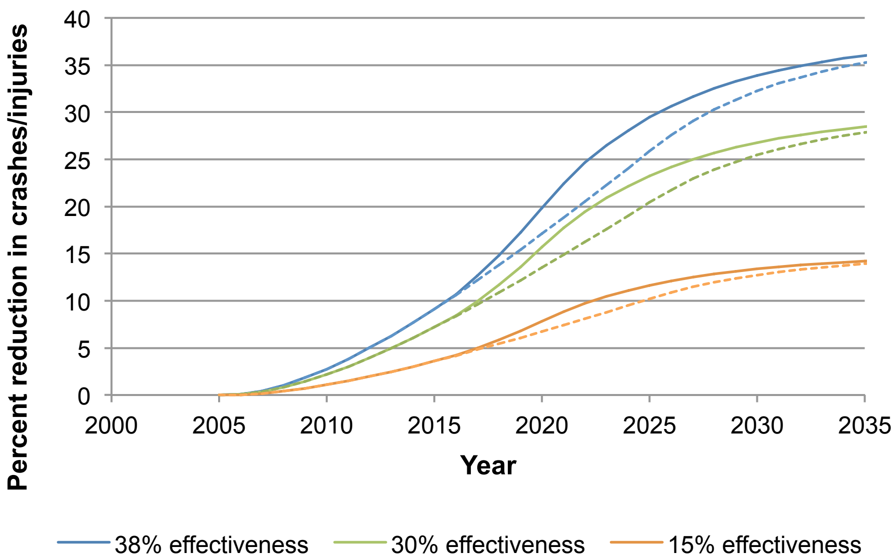

Figure 4.3
Reduction in crashes/injuries for scenario 1 (ABS on all new motorcycles by 2025, dashed curves) and scenario 2 (ABS mandatory by 2020, solid curves), based on the three different estimated effectiveness values for ABS.

Table 4.1
Comparison of the two ABS introduction scenarios and the estimated future effect on the crashed motorcycle fleet.

Variable	Scenario 1	Scenario 2
Year that ABS is sold in 100% of new motorcycles	2025	2020
Result in 2025:		
Motorcycles with ABS in crashed fleet	68.1%	77.5%
Crash reduction at 15% effectiveness	10.2%	11.6%
Crash reduction at 30% effectiveness	20.4%	23.3%
Crash reduction at 38% effectiveness	25.9%	29.5%

5 Discussion

The release of *Towards Zero Together* set the direction for reducing serious casualty trauma in South Australia by at least 30 per cent during the decade to 2020. Targets were set for the 2020 annual road toll of less than 80 fatalities and less than 800 serious casualties. The biggest gains in road safety appear to have been made through improvements in vehicle crashworthiness, and future gains are likely to be achieved through improvements in vehicle safety technologies.

Motorcycle riders are vulnerable road users, and other than a protective helmet for head protection and protective clothing, little can be done to mitigate injuries to a rider in the event of a crash. It is for this reason that technology that can prevent a motorcycle crash or reduce speed in a crash is likely to have the greatest effect in reducing fatal and serious injuries amongst motorcycle riders in the future.

It is well recognised that motorcyclists of all experience levels may not be able to make the correct braking decisions in an emergency situation. Motorcyclists may not be able to optimise braking performance, particularly regarding front and rear brake use. With too little braking, the resulting speed reduction is not as great as it could be and crash energies remain high, as does risk of crash injuries. To some extent these issues can be resolved using combined braking systems (CBS).

However, even with a rider or a system that can optimise braking performance, high braking forces often result in wheel lock and skidding, which can lead to loss of stability and a crash. Antilock braking systems (ABS) on motorcycles can prevent wheel lock and hence improve the stability of a motorcycle during emergency braking. Combined CBS and ABS would appear to give the best opportunities for optimising braking performance, maintaining stability and reducing stopping distance.

There is considerable literature indicating that technically and experimentally, ABS and CBS can optimise braking effectiveness, assist with motorcycle stability, and reduce emergency stopping distances. Real-world crash data also indicates that riders who have ABS on their motorcycles crash less frequently and suffer fewer injuries and fatalities than those who do not have ABS fitted.

There is some speculation that riders who choose ABS on motorcycles are a particular subgroup of riders who are perhaps conservative, 'safer' riders who make 'safer' choices and might be inherently more careful (for example commuter motorcyclists). Riders who don't choose ABS might be 'thrill seekers' or riskier riders and have a preference for non-intervening motorcycles. However, Rizzi et al., (2009) suggest that perhaps riders who purchase ABS bikes may in fact ride more aggressively, engage in riskier behaviour, ride faster and brake later, relying on ABS to manage the braking.

The benefits of traction control systems are not well studied, and little can be discussed regarding these systems. However, stability control systems that offer a suite a safety technologies, including CBS, ABS and traction control, seems to becoming more popular on motorcycles.

There is considerable and consistent international evidence supporting the benefits of ABS on motorcycles in reducing crashes that would otherwise lead to motorcycle related injuries and fatalities, although there is no Australian specific evidence of the benefits. The few negative perceptions relating to ABS on motorcycles seem largely unfounded or can perhaps be addressed by providing both experienced and inexperienced riders with real-life demonstrative capabilities of ABS in controlled emergency situations. Vavryn and Winkelbauer (2004) reported that while ABS improved braking performance on motorcycles compared to those without ABS, correct instruction and practice of braking technique further improved braking performance for motorcyclists of all experience levels with motorcycles fitted with ABS.

The RiderSafe training program in South Australia is a fundamental part of a beginner motorcycle rider's education, playing a critical role in the initial development of riding proficiency, motorcycle control and braking ability. Previously, barriers to adopting motorcycles with ABS in the RiderSafe fleet related to the non-suitability of the various LAMS motorcycles fitted with ABS for the RiderSafe training program (D. Roe, personal communication, October 13, 2014). However, changes to procurement procedures have allowed RiderSafe to purchase a significant number of ABS motorcycles that are distributed to all RiderSafe training centres for learner rider demonstration and training purposes.

With LAMS bikes fitted with ABS now part of the RiderSafe motorcycle fleet, it is expected that they will continue to increase in prevalence as the technology becomes more firmly established in the class of bikes used in the RideSafe training program and ABS availability in entry level motorcycles increases. Some motorcycles fitted with ABS are perhaps not yet the ideal training motorcycle for beginner riders to learn basic skills, as in the past they have been mostly installed on higher performance, higher engine capacity and expensive motorcycles. However, once riding skills have been learned and are developed, motorcycles fitted with ABS may be more suited and should be encouraged.

There may be benefits in the idea of 'ABS motorcycle demonstration days' with publicity. Motorcycle riders could be given correct instruction on the use of ABS on motorcycles as recommended by Vavryn and Winkelbauer (2004) as well as the opportunity to test motorcycles fitted with ABS, compared to non-ABS motorcycles in a safe and controlled environment. This would allow motorcycle groups and safety conscious motorcycle riders (young and returning) to be exposed to the benefits of this technology and therefore be encouraged to purchase a motorcycle with ABS. Any incentives, financial or otherwise could also be used to encourage riders (who may otherwise perceive the technology as too expensive) to purchase motorcycles with ABS.

Given that the braking task for motorcycles is so complex, and often ill performed in emergency situations, it is important that riders of all motorcycles undertake rider education programs to learn correct braking techniques. This includes riders of low powered scooters who are required to only have a driver's licence, as it is unlikely that these motorcycle types will be fitted with ABS in the near future.

Investigating the factors motivating the increased use of motorcycles in South Australia was beyond the scope of this report. However, it is recognised that different people use motorcycles for different reasons; be it commuting, thrill seeking, weekend riding, low-cost transport or environmental reasons. Regardless of the reasons, there are three distinct age groups represented in the crash data. Older motorcycle riders (40 and over) are over represented in injuries, and the trend in this over representation appears to be increasing. Further research is required to investigate the issues surrounding this age group to ensure it is understood what is contributing to this increase, and whether there might be mechanisms specific to this age group that reduce injuries. Concurrently, other age groups should be monitored.

It is important to emphasise that the various methods of encouragement described in this report be considered to increase the prevalence of ABS on motorcycles in South Australia. Particularly given that a high proportion of crashing motorcycles are new, strong encouragement of the purchase of motorcycles with ABS can have a strong effect on a considerable number of motorcycle crashes. Further, as it takes considerable time for new motorcycles sales to penetrate the registered fleet, it is also important to use methods of encouragement without delay. The earlier increased ABS uptake occurs in the registered fleet, the quicker the significant safety benefits will arrive.

6 Conclusion

This report presents information relating to ABS, CBS and TCS for motorcycles. ABS and CBS in particular have the potential to produce significant safety benefits and can reduce the likelihood of motorcycle loss of control and improve braking capacity in emergency situations. Any motorcyclist, regardless of skill level and experience, will receive the safety benefits of these technologies, although novice riders would be expected to receive the greatest benefit.

Many studies regarding real-world motorcycle crashes have singled out ABS as the single most effective technology and it is likely to have the greatest influence in reducing the number of motorcycle crashes. An analysis of motorcycle crashes in South Australia indicated that ABS has significant potential to reduce motorcycle serious injury and fatal crashes.

There is reluctance among some organisations to accept the benefits of ABS. This reluctance can be attributed to the belief that the evidence for ABS is overstated and that having this technology on a motorcycle reduces rider skill and control.

The current level of ABS uptake for the new and registered motorcycle fleet is not clear as the literature review identified a lack of consistency in the data available. It would be beneficial to start monitoring ABS uptake, in a similar manner to the monitoring of passenger vehicle technology.

There are a number of mechanisms that can be used to encourage the uptake of ABS on motorcycles. These include government incentives, such as taxation and subsidy schemes, regulation, education and promotion. Fleet purchasing schemes, publicity, lobbying and insurance schemes may also help to increase uptake rates.

Currently ABS is standard on 44% of the top selling road motorcycles. The technology is mainly standard on the more expensive motorcycles, while it is generally only offered as an option (or not at all) on less expensive models.

In the crash analysis of this report, it was found that most of the motorcycles involved in injury crashes are reasonably new. The average age of crashed motorcycles was 6.8 years and the median age was 4.2 years. A positive implication of this is that the expected benefits of ABS (particularly in reducing fatalities and serious injuries) can be achieved reasonable quickly if ABS prevalence can be increased in a short timeframe. There would be considerable gains in safety benefits with early increased uptake and significant increases in the prevalence of ABS in the new motorcycle fleet.

The potential benefits of ABS had it been available on all motorcycles in South Australia in 2012 may have resulted in seven fewer motorcycle fatalities and 57 fewer motorcycle serious injuries (at 48% effectiveness). Even using the minimum likely effectiveness of ABS for reducing motorcycle crashes (17%) according to Rizzi, Strandroth and Tingvall (2009), there may have been three fewer motorcycle fatalities and 20 fewer motorcycle serious injuries in South Australia in 2012.

An estimate was made of the prevalence of ABS in the new motorcycle fleet and the likely penetration into the crashed motorcycle fleet up to 2025. The results found that there is a potential to reduce motorcycle crashes by 10.2 to 25.9% under a system of encouraged uptake, while with government regulation potential for motorcycle crash reduction is marginally higher at 11.6 to 29.5%.

There is little doubt that ABS is a beneficial technology for improving the safety of motorcyclists, and this technology represents a potential means to significantly reduce the number of motorcycle injuries and fatalities in South Australia. Therefore, it is important to encourage uptake of ABS so that societal benefits can be achieved sooner.

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