

## **Exploring an application of the Safe System Approach to a set of self-reported cycling crashes.**

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### **Abstract**

**Introduction:** Vulnerable road users are over-represented in traffic injuries and fatalities. Police reports and hospitalisation data grossly underestimate bicycle crashes, and data on causation are limited. In Australia, the Safe System Approach (SSA) has been adopted for motor vehicles and is an important paradigm for road safety. However, the SSA does not appear to have been explicitly applied in policy documents that address cycling safety.

**Methods:** We undertook a thematic analysis of cyclists' perceived causes of sustained collisions or falls as reported in 145 interviews with participants of the Safer Cycling Study. The interview was structured around the four key areas of the SSA.

**Results:** Qualitative data analysis indicates that cyclists perceived behaviour (road use factors) as being the greatest contributor to crashes, followed by infrastructure (road and roadside factors). Cyclists rarely reported vehicle factors or speed as contributory factors.

**Conclusions:** Consideration of the four key areas of the SSA provides a useful framework for analysing cyclists' self-reported crash causation and may assist in the identification of crash countermeasures.

**Keywords:** Safe System Approach; cyclist safety; safe road use

### **Introduction**

The personal, social and environmental benefits of cycling have been clearly identified (Bauman et al, 2008). Studies have consistently demonstrated a positive relationship between cycling and health, providing 'strong support for the promotion of cycling for public health' (Oja et al, 2011).

However, significant barriers to encouraging more people to cycle are the perceived and real injury risks. In Australia, there was an increase of 7.5% in age standardised rates of life threatening injury for cyclists from 2000-01 to 2007-08, which was the highest of all road user groups (Henley and Harrison, 2011). Official registrations however, often underestimate the number of crashes. For example, research in Australia has demonstrated that police crash records significantly underestimate the number of cyclist crashes (Lujic et al, 2008). Furthermore, crashes where cyclists were injured may not be captured in hospitalisation data if cyclists receive treatment in emergency departments or with local medical practitioners. Lower European cycling injury rates have been attributed to better cycling infrastructure and education for all road users, reduced speed limits (30km/h) and an expectation on drivers that they are responsible for cyclist safety (Garrard et al, 2010) thus suggesting possibilities for improving cycling safety in Australia.

The SSA has been adopted in Australia as an approach to road safety. It emphasises an holistic view of road safety, with shared responsibility for the prevention of crashes (Roadwise, 2011). The SSA has four essential elements for safety promotion: safe road use (behaviour), safe roads and roadsides (infrastructure), safe speeds and safe vehicles (Roadwise, 2011). It aims to reduce the number of crashes by creating a transport system that is more forgiving of human error, keeps crash forces at a survivable level and decreases unsafe road user behaviour as a contributing factor to road crashes (Vicroads, 2012).

To date, application of the SSA within planning documents has focussed on motor vehicles and drivers, for example, the “National Road Safety Strategy 2011-2020” (Australian Transport Council, 2011) applies the SSA throughout. However, there has been minimal application specifically to more vulnerable road users, such as cyclists. For example, the “National Cycling Strategy 2011-2016” (Australian Bicycle Council, 2010) does not mention the SSA. Despite the Austroads “Guide to Road Design” (Austroads, 2009) and “Cycling Aspects of Austroads Guides” (Austroads, 2011) stating the philosophy and objectives of the SSA approach are as relevant to pedestrian and cyclist infrastructure as they are to roads in general, these guides give few suggestions as to how to apply these principles to promote cyclist safety. Furthermore, the “NSW Bike Plan” (Roads and Traffic Authority, 2010) appears to discuss various aspects of the SSA, but the SSA is not applied overtly as a framework for the safety aspects of the plan.

Consistent application of the SSA to cycling should offer improvements to cycling safety, yet currently there is little information regarding the impact of infrastructure, vehicle, speed or behavioural factors, and their interactions, on cyclists (or other vulnerable road users). Moreover, the success of the SSA is likely to be limited in the absence of its widespread application by all levels of government and to all road users. Discussion and debate on what a safe system may look like should be encouraged (Transport Research Centre, 2008). This research aims to assess whether the SSA can be usefully applied to a set of self-reported cycling crashes to classify crash contributors. Telephone interviews were conducted with cyclists who reported crashing during the Safer Cycling Study with questions structured around the four SSA key elements.

## Methods

**Overall study design:** The Safer Cycling Study is a prospective cohort study of cyclists aged 18 years and over, who live in New South Wales, and who usually bicycle at least once a month (Poulos et al, 2011). Over 2000 cyclists were recruited between March and November 2011. Data are collected via web-based online questionnaires. At enrolment, participants completed a baseline questionnaire, which included demographic, attitudinal and behavioural data. In the 12 months following enrolment, cyclists are surveyed on six occasions (weeks 8, 16, 24, 32, 40 and 48 from the week of the enrolment survey). In these survey weeks, cyclists are asked to provide daily reports of: distance travelled; time, location and duration of trips; infrastructure used; crashes, and crash-related injuries. Crashes are defined as collisions or falls, based on the definitions in the reviews by Reynolds et al (2009). A collision is defined as an event in which the bicycle hits or is hit by an object, person or animal regardless of fault; and a fall is defined as an event (not caused by a collision) where the bicycle and/or bike rider lands on the ground.

**Qualitative data collection:** All participants reporting a crash during at least one survey week between May 2011 and March 2012 were contacted and invited to participate in a semi-

structured telephone interview regarding the circumstances surrounding each crash. Cyclists were asked about causal factors based on the four key elements central to the SSA. The number of factors that could be identified was not limited at interview.

**Analysis:** Qualitative data were analysed using ‘template analysis’ (King and Horrocks, 2010). This involved the development of a coding template or framework, composed of hierarchically arranged codes. Each code represented themes identified in the data through multiple readings of the text (King, 2005). The SSA key elements provided the first level categories for template analysis of the data. After analysis of a sample of transcripts, initial templates were developed for the causes of crashes within the SSA key areas. These were then further revised after all research team members coded 20 interviews each and met to reach consensus on refinement of the template. Further refinement occurred as more interviews were coded. Appendix A provides a summary of the finalised template used for analysis.

## Results

**Sample characteristics:** One hundred and thirty six cyclists reported 145 crashes between May 2011 and March 2012. The average age of the cyclists was 43 (sd +/- 9.6) years; 72% (n=98) of cyclists were male and 28% (n=38) were female. Only 1.5% of cyclists (n=2) classified themselves as novices with the remainder rating themselves as being intermediate 18.5%, (n=25), experienced 49%, (n=66), advanced 27%, (n=37) or expert/professional 4% (n=6) of cyclists.

Table 1 shows the average amount of time spent time spent by cyclists on different types of infrastructure over the last 12 months.

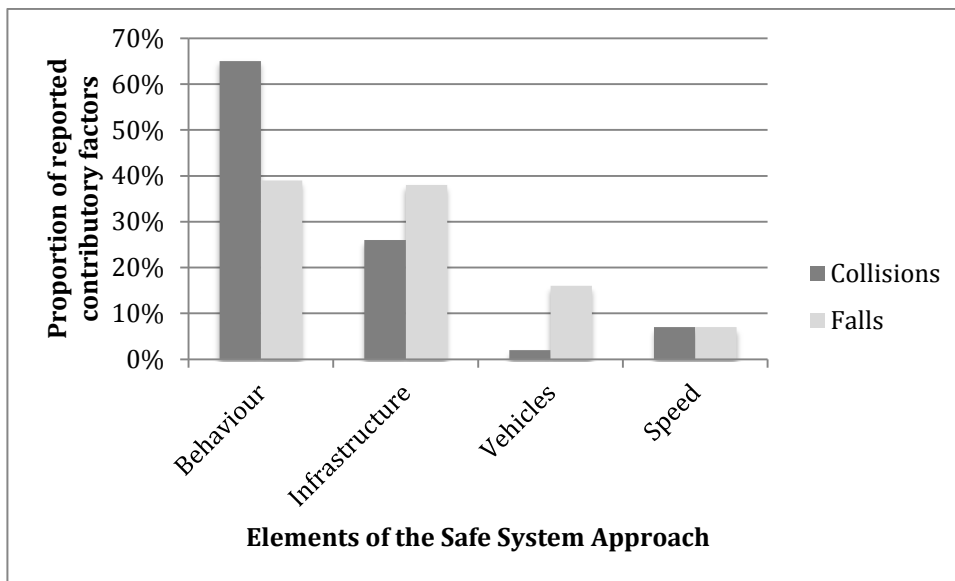
**Table 1 Average amount of time spent on different infrastructure over the last 12 months (n=136)**

Type of infrastructure	% of time spent on infrastructure over last 12 months
Roads	51
Shared paths	17
Bicycle path	9
Pedestrian footpath	5
Bicycle lane	15
Other infrastructure	3

Of the 145 crashes reported, 78 were falls and 67 were collisions. Sixty five crashes (34 falls and 31 collisions) required medical attention by a GP or at hospital. None of the injuries reported required the cyclist to stay in hospital overnight. Three collisions but none of the falls, were reported to the police.

**Factors contributing to crashes:** Cyclists identified a total of 276 factors as contributing to the reported crashes, with between 1 and 3 factors being identified per crash. Figure 1 shows the proportion of the four SSA key elements that contributed towards crashes.

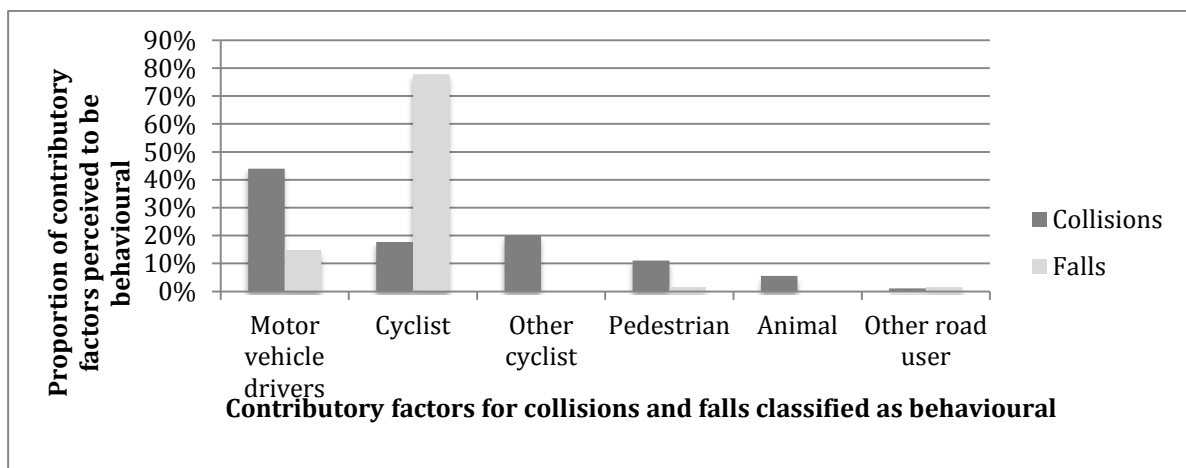
**Figure 1 Elements of the safe system approach classified as contributing towards crashes**



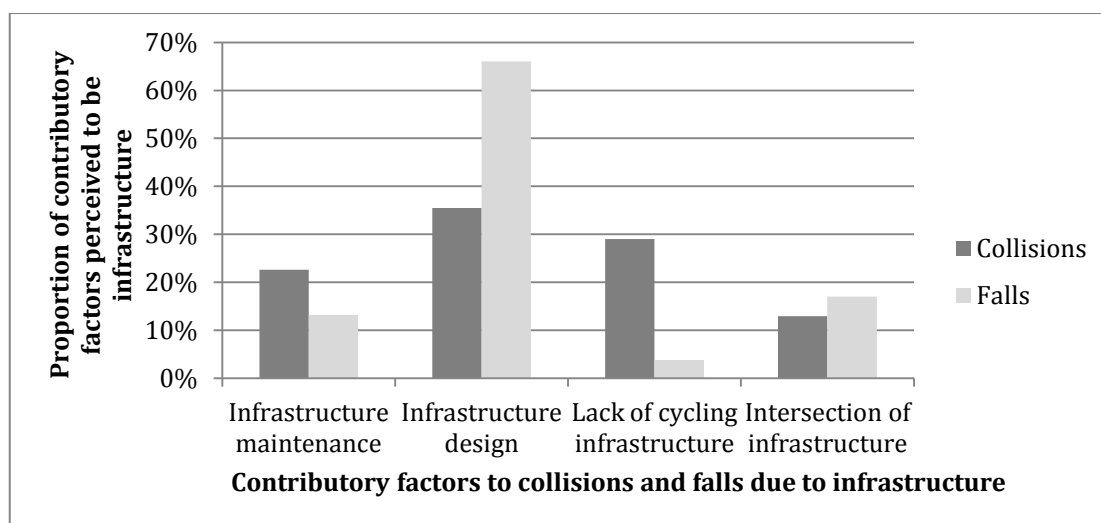
For collisions, behavioural factors were most frequently identified as a contributory factor, followed by infrastructure factors. For falls, behavioural factors and infrastructure factors were reported in almost equal proportions, followed by vehicle factors. For both falls and collisions, less than 10% of the reported contributory factors were categorised as relating to speed of either a motor vehicle or bicycle.

Contributory factors related to behaviour and infrastructure are explored further in Figures 2 and 3, with Figure 2 identifying the specific road user whose behaviour was reported to have contributed the crash, and Figure 3 identifying specific infrastructure issues.

**Figure 2 Proportion of behavioural factors categorised as relating to motor vehicle drivers, cyclists themselves, other cyclists, pedestrians, animals or other road users (collisions n=90, falls n=62)**



**Figure 3 Proportion of falls and collisions perceived to be due to infrastructure maintenance, infrastructure design, lack of cycling infrastructure, or an intersection of infrastructure (collisions n=31, falls n=53)**



Tables 2 and 3 indicate the range of behaviours that were reported by cyclists as having contributed to crashes. Table 2 shows that for collisions, the most commonly reported contributory behavioural factor was motor vehicle driver inattention followed by inattention of other cyclists, the cyclist’s own inattention and pedestrian inattention. Table 3 shows that for falls, the majority were reported to be due to the cyclist’s own behaviour with the single most frequently reported factor being failure to either unclip from cleats in time or of having insufficient experience in using cleats; followed by cyclist inattention and failing to adjust cycling behaviour to the conditions.

**Table 2 Number of reports of behavioural factors contributing to collisions**

<b>Behavioural factors reported for collisions</b>	<b>Number of reports</b>
<b>Motor vehicle driver behaviour (including bus and taxi drivers)</b>	
Driver inattention (e.g. the driver failing to look out for cyclists before performing a manoeuvre or changing lanes)	28
Driver aggression	4
Drivers not following or knowing the road rules	2
<b>Cyclist’s own behaviour</b>	
Cyclist inattention	10
Cyclist poor judgement	3
Cyclists disobeying the road rules	1
Cyclist fatigue	2
<b>Other cyclists</b>	
Apparent inattention	13
Apparent disobedience of road rules	1
Aggressive behaviour	1
<b>Pedestrians</b>	
Inattention	5
Aggression	2
Appearing not to know road/ path rules	1
Animal crossing the path of a cyclist	5

**Table 3 Number of reports of behavioural factors contributing to falls**

<b>Behavioural factors reported for falls</b>	<b>Number of reports</b>
<b>Cyclist's own behaviour</b>	
Cyclist inattention	13
Failing to adjust cycling behaviour to conditions	6
Cyclist's poor judgment (e.g. poor judgement of another's speed or another's road or path position)	2
Cyclist distracted by something	2
Failure to either unclip from cleats in time or of having insufficient experience in using cleats	16
Disobeying or poor knowledge of the road rules	3
Carelessness or recklessness	3
Cyclist impaired by alcohol	2
<b>Motor vehicle drivers</b>	
Not looking out for cyclists/ travelling too close	4
Apparent disobedience of the road rules	1
Apparent aggressive behaviour or deliberately trying to cause a crash	3
<b>Pedestrians</b>	
Pedestrian apparently having poor knowledge of road rules	1
Construction workers didn't take account of cyclist.	1

Tables 4 and 5 indicate the range of infrastructure factors reported as having contributed to crashes. Table 4 shows that for collisions, the most commonly reported contributory infrastructure factor was infrastructure design issues, followed by lack of cycling infrastructure and poor infrastructure maintenance. Infrastructure design issues were also the most commonly reported contributory infrastructure factor for falls, with slippery surfaces being the single most frequently reported factor, followed by poor lay out of existing infrastructure and poor lighting or signage (Table 5).

**Table 4 Number of reports of infrastructure factors contributing to collisions**

<b>Infrastructure factors identified for collisions</b>	<b>Number of reports</b>
<b>Infrastructure design issues</b>	
Ridge on shared path	1
Bike lane ending when it enters a roundabout or poor cycle path marking on the roundabout	3
Tight bend in a shared path or path too narrow	2
Oncoming path users obscured	1
Bike path in dog leash-free area	1
Parking spaces in inappropriate places for major cycling route	1
Many vehicle entry/ exit points along shared path	1
Slippery paint on road	1
<b>Lack of cycling infrastructure</b>	
Poor linkage of cycling infrastructure	4
Cycling infrastructure coming to an abrupt end	3
Lack of cycling infrastructure in busy traffic areas	2
<b>Intersection of infrastructure</b> (e.g. moving from a road onto a driveway or going from a paved surface to an uneven surface)	4
<b>Poor infrastructure maintenance (23%)</b> (e.g. overgrown vegetation; loose gravel; uneven surfaces and potholes in the road or path)	7

**Table 5 Number of reports of infrastructure factors contributing to falls**

<b>Infrastructure factors identified for falls</b>	<b>Number of reports</b>
<b>Infrastructure design issues</b>	
Slippery surfaces (e.g. slippery surface paint on the road, wet weather making the surface slippery, or fixtures on the road being slippery such as temporary roadwork covering)	19
Poor layout of existing infrastructure (e.g. bike lanes ending as they entered a roundabout, tight bends in a shared path, or bollards or barriers in the path)	8
Poor lighting or signage	3
Bicycle inappropriate grates in the roadway	3
Train tracks on the road	2
<b>Intersection of infrastructure</b> (e.g. moving from a road onto a driveway or going from a paved surface to an uneven surface)	9
<b>Poor infrastructure maintenance</b>	
Loose gravel on route	3
Uneven surface	1
Other maintenance problems, e.g. mud on the path	3

## **Discussion**

Effective design, implementation and management of facilities for vulnerable road users needs to be informed by good quality data on the circumstances surrounding injury (Chong et al 2010). However, there has been little research about the circumstances surrounding bicycle crashes which have not resulted in serious injury. The application of the SSA to cyclists' self-reports of their crashes in this study, highlights the importance of factors relating to user behaviour and infrastructure, and potentially identifies particular aspects for remediation.

## **Behaviour**

Participants perceived factors associated with behaviour such as driver and cyclist inattention; apparent disobedience or lack of knowledge of the road rules; and poor judgment, as being the most frequent contributors to crashes, both collisions and falls.

Participants perceived motor vehicle driver behaviour to be a contributory factor in nearly half of behavioural factors identified for collisions, particularly driver inattention (e.g. not looking out for cyclists before performing a manoeuvre or failing to look properly before changing lanes). Other research has found that drivers were at fault in the majority of collision and near-collision events for commuter trips and this was attributed to a lack of awareness by drivers (Johnson et al, 2010). Drivers' lane change behaviour or being seemingly unaware of the presence of the cyclist, has been found to be involved in a majority of events (Johnson et al, 2010). In order to reduce the number of events such as these, adequate overtaking distances are required to ensure cyclists have a safer clearance space on the roads (Johnson et al, 2010). Johnson also suggested that drivers be made aware of their requirement to indicate for at least 5 seconds prior to changing course, which would give cyclists time to adjust their line of travel (Johnson et al, 2010). Several reports from our participants indicated that driver lack of knowledge, failure to follow the road rules and driver aggression contributed to their collision. Poor levels of road rule knowledge and lack of understanding among drivers has

been found to be significantly associated with poor attitudes towards cyclists (Rissel et al, 2002; Benz, 2010).

Inattention (their own or another's) was frequently reported as a contributory factor in both collisions and falls. In many instances, cyclists accepted some responsibility for the crash where they stated behaviour was a contributory factor. These results indicate that cyclists are often willing to admit responsibility, somewhat allaying concerns about misreporting. Schramm et al (2009) identified cyclist error as being a contributory factor in their examination of police data of predominantly nonfatal cyclist crashes. Furthermore, the Australian Transport Safety Bureau (2006) found that in over 60 per cent of national cyclist fatality crashes, it was the cyclist's action that was at fault.

It appears both motorists and cyclists would benefit from increased knowledge of traffic laws and adoption of a more tolerant attitude (Sharpe et al, 2011). Benz (2010) suggests that in order to make the roads safer, the quality and skills of car drivers need to be improved. De Geus (2012) believes actions taken should contain both 'soft' (communication/ education) and 'hard' (enforcement) methods and both should be used simultaneously. Cyclists may also benefit from education or training on how to ride more defensively around cars; being more vigilant of drivers who may lack awareness of cyclists; and increasing their conspicuity by wearing reflective clothing and using front and rear lights (Johnson et al, 2010). Despite this, in Australia local councils are unlikely to be the source of behaviour modification interventions. Of the total expenditure by councils on bicycle related programs in 2009-2010, only 2% was for education/ promotion campaigns (ABC, 2012).

There were 5 reports of inattention and 2 reports of aggression by pedestrians. This suggests that understanding the dynamic relationship between these two vulnerable road user groups is also of importance and requires attention in the SSA. Chong et al (2010) suggest the speed limit for shared bicycle-pedestrian pathways should be set at 10km/h for cyclists. They suggest that if the number of shared pathways for cyclists and pedestrians increases then there may be more potential for collision and injury (Chong et al, 2010). Road safety initiatives and policies therefore need to be developed with consideration of the different user groups and the implications these policies have for each (Johnson, 2011)

### **Infrastructure**

Infrastructure factors are perceived by participants to be the next most important contributory factor to crashes. Bike specific facilities have been consistently shown to provide improved safety for cyclists compared to on-road cycling with traffic (Reynolds et al, 2009). Infrastructure modifications are advantageous as they don't require action by the users in order to achieve widespread benefits (Reynolds et al, 2009). The most common elements in local government bicycle strategies are infrastructure (96% of respondents) and bikeway signage (75% of respondents) (ABC, 2012). However, in 2009-2010 only 4% of the total expenditure by councils on bicycle related programs was for maintenance (ABC, 2012). Cycling maintenance programs should be better integrated into other planning and construction processes and the standard of cycling infrastructure, including maintenance, should be improved to best practice international standards (ABC, 2012).

In some cases where the description of the crash suggested that infrastructure contributed to the crash, the cyclist did not identify infrastructure as a contributing factor – instead taking responsibility for the crash themselves. For example, a participant who slipped when turning on a wet grid reported that it was, "just bad luck". A central tenet of the SSA is that roads and



roadsides should accommodate user errors. This is often missed by policy documents that address cycling safety, which tend to focus on improving cyclists' skills. Whilst this is a commendable aim, it is critically important that roads and roadsides be acknowledged as an important contributor to cyclist crashes and relevant initiatives be adopted. If there were no slippery metal grids then no cyclists would crash because of them.

### **Vehicles**

Vehicle factors were less commonly reported as contributory factors towards crashes. For falls, there were five reports of bicycle failure such as gears jamming, chain falling off and brake failure. Making cyclists aware of the importance of regularly having their bike serviced and encouraging attendance at a bicycle maintenance course may help to prevent some of these crashes happening. There were 16 cases of clip-in pedals contributing to a crash. Participants reported being unable to clip out of their pedals quickly enough when slowing down to make a turn or approaching traffic lights. Patel (2004) reported on three case studies of cyclists presenting to hospital with major soft tissue injuries due to being unable to release their feet in time when they lost control of their bikes. He highlighted the fact that, 'in cycling, major injuries can be caused by the cycle itself. Proper information is needed to allow cyclists to use clip-in pedals safely and effectively'.

No participants identified the influence of motor vehicle design in cycling crashes. This may be because the injuries sustained were relatively minor. Wegman and Zhang (2010) have suggested that the addition of adequate protection around a lorry, crash-friendly car fronts or side under-run protection on heavy goods vehicles could help to reduce the number of overall casualties.

### **Speeds**

In this study, participants rarely perceived speed of surrounding traffic to be a contributory factor in crashes, which probably reflects an underestimation of the importance of speed. Garrard (2008) suggests that reduced motor vehicle speed would undoubtedly mean improved cyclist safety and more people prepared to travel by bicycle.

### **Limitations**

It is likely the sample of cyclists is fairly representative of the general cycling population in New South Wales, though not perfectly so. A broad sampling strategy was used in the recruitment of the participants. Participants were recruited via Bicycle NSW and various community bicycle events (both of which involve a broad range of cyclists), with media publicity about the study reaching the general population as well. Over 2000 cyclists were recruited over a period of 9 months. The only clear systematic bias is towards people who can comfortably access the internet (probably fairly small). There is probably also self-selection of people who are sufficiently motivated to participate in such a study (e.g. have an interest in making cycling safer). It is not possible to compare characteristics of the sample with those of the general cycling population, because the characteristics of the general cycling population are not known.

Participants were asked to report all crashes that they experienced in their six survey weeks over the year and we have no reason to believe that they did otherwise. Participants who experienced more than one crash may have been less inclined to report a second crash, knowing that they would be asked in detail about it. However, this is likely to be a very small proportion of the sample.

We have relied on cyclists' self-reports of their crashes because this offers a broader and deeper insight into cycle crashes than can be obtained via other methods. Recall bias is likely to be limited because of the short time-frame in which cyclists reported, and were interviewed concerning their crashes. Reporting biases were minimised by the assurance of anonymity. Concerns that cyclists may have fabricated or distorted their reports to "get something done for cyclists" are somewhat allayed by the finding that cyclists often took responsibility for their own crashes (rather than blaming inadequate infrastructure).

### **Strengths**

The methodology employed in this study allowed investigation of a far broader range of cyclist crashes than appear in hospital or police records, which have hitherto been the focus of research conducted in Australia. Particularly, single-vehicle bicycle crashes (which account for most falls), which have a lower potential for serious injury (Wegman and Zhang, 2010), are rarely reported in official statistics and therefore little is known about them (Elvik and Mysen, 1999, Heesch et al, 2011;Wegman and Zhang, 2010). None of the reported crashes in this study required overnight hospital admission and only 3 crashes were reported to police. Thus, this study provides data that is likely to be more representative of the experiences of the general population of cyclists, rather than representing only the 'tip of the iceberg'. Semi-structured interviews provided participants with the opportunity for clarification, explanation and elaboration of responses to the survey. This allows for a far more detailed examination of crash circumstances than the limited quantitative data collection offered by police and hospital records.

### **Conclusions**

The SSA offers a useful framework from which to analyse bike crashes and consider countermeasures for cycling safety. It represents a paradigm shift away from focussing on the behaviour of road users, toward developing a system that can accommodate user error through safer infrastructure, safer vehicles, and safer speeds. Whilst the SSA is reflected in many road safety policy documents, policy documents relevant to cycling safety continue to focus on the cyclist. Although it is appropriate that relevant policy documents aim to improve cyclist (and motorist) knowledge and behaviour, it is critical that they also consider the other elements of the SSA. Application of the SSA in cycling safety policy documents would encourage a broader range of strategies to promote safer cycling.

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## Appendix A: Template of causes of crashes

<i>First level category</i>	<i>Second level category</i>	<i>Third level categories</i>
Safe road use	Motor vehicle driver	Travelling too close; driver inattention; disobedience of road rules; aggressive behaviour
	Cyclist	Failed to adjust behaviour; inattention; poor judgment; disobeyed road rules; didn't unclip from cleats; fatigue; aggressive behaviour
	Other cyclists	Travelling too close for conditions; cyclist inattention; disobedience of road rules; apparent aggressive behaviour; deliberately trying to cause accident
	Pedestrian	Walking too close for conditions; inattention; aggressive behaviour; disobedience of road rules; lack of knowledge of rules
	Animal	Crossed path of cyclist
Safe roads and Roadside	Infrastructure maintenance	Overgrown vegetation; loose gravel; cracks in surface; uneven surface; other maintenance problems
	Infrastructure design	Tight bend in shared path, oncoming path users obscured; parking spaces in inappropriate places for major cycling route; shared path too narrow in busy area; bike path in dog leash-free area, grates inappropriate for cyclists; slippery surface; train track on road; roundabout problems; poor lighting; poor signage
	Lack of cycling infrastructure in busy area	Infrastructure comes to abrupt ending forcing cyclist to merge with busy traffic; poor linkage of cycling infrastructure
	Intersection of infrastructure	
Safe vehicles	Driver	Cyclist in vehicle blind spot
	Cyclist	Malfunction of bicycle
Safe speeds		Travelling too fast for conditions: cyclist/ driver