Submission
No 5

FIRST REVIEW OF THE EXERCISE OF THE FUNCTIONS OF THE LIFETIME CARE AND SUPPORT AUTHORITY OF NEW SOUTH WALES AND THE LIFETIME CARE AND SUPPORT ADVISORY COUNCIL OF NEW SOUTH WALES

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First Review of the exercise of the functions of The Lifetime Care and Support Authority of New South Wales and the Lifetime Care and Support Advisory Council of New South Wales

Comments on LTCS in NSW

5 May 2008

MOTORCYCLE COUNCIL
OF NEW SOUTH WALES
INCORPORATED

To
Standing Committee on Law and Justice,
Legislative Council, Parliament House,
Macquarie Street, Sydney

Motorcycle Council of NSW
15 Huddleston Street Colyton, NSW

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Scope of Comments

With the introduction of the Lifetime Care and Support Scheme, motorcyclists have received significant increases in the overall cost of purchasing CTP insurance.

The current method of calculating the LTCS levy through percentages of CTP premiums requires further investigation and explanation.

About the MCC of NSW

The Motorcycle Council of NSW represents over 36,000 motorcycle riders in NSW through their club affiliations.

The MCC of NSW welcomes the opportunity to work with all agencies concerned with motorcycle issues.

The MCC of NSW recognises the concern the community has regarding fair and reasonable crash victim compensation, as this can happen to any one of us.

The MCC of NSW is keen to support an accident compensation scheme that is fair and reasonable

INTRODUCTION

The LTCS system is already unfair

Motorcycle riders in NSW are mindful of the failures that exist in the Commonwealth State Disability Agreement and that motivated the LTCS in NSW.

When the LTCS scheme was first proposed, the levy was pitched to cost $20 across all registrations without regard to vehicle type.

"The LTCS scheme will be fully funded through a levy on motorists collected in conjunction with CTP insurance. It will require an extra $20 per CTP policy." [1]

This same dollar figure appears in Hansard, given by the Government during Parliamentary debate on the Motor Accidents (Lifetime Care and Support) Act 2006.

When consulted by the Motor Accidents Authority in 2006, the Motorcycle Council of NSW recognised that such a Scheme would benefit the community in NSW and further, agreed that a flat $20 levy on all vehicles registered in NSW was a fair and reasonable manner of funding the Scheme.

Since that time, much has changed. The Levy has not only been significantly increased, but it is now a variable amount based on inappropriate criteria.

In his paper to the Institute of Actuaries Australia of April 2007 [2], Andrew Stone notes that s50 of the Act provides authority for such a levy and that "This levy is currently in the order of $40-$60 per premium"

Motorcyclists are currently being levied anywhere up to $200 for "MCIS levies", of which the LTCS levy is the major component.

A lack of transparency exists. The vehicle owner is unable to clearly identify the levy for LTCS separate from various other administrative charges.

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[1] MAA [2005], Lifetime Care and Support, p17, MAA Publication ISBN 1 876958 22 7

[2] Institute of Actuaries of Australia [2007], The NSW Lifetime Care and Support Scheme p5, Andrew Stone

We note that:

- the LTCS scheme is an effort to address the community burden of catastrophic injuries.
- the community burden of costs is not shared fairly
- only the owners of registered vehicles pay into the LTCS scheme
- pedestrians, bicycle riders, children, etc, do not contribute to the scheme
- The LTCS levy is a motor vehicle tax that has been "associated" with the CTP scheme
- LTCS is not an insurance scheme
- LTCS is in fact a tax to fund a State or community Health budget

The LTCS levy is now an individually variable amount depending on

- the cost of the CTP premium
- rating applied to that particular vehicle

Applying any form of "rating" to any vehicle for the purposes of an LTCS levy denies that the LTCS scheme is a "no-fault" or "blameless" scheme

We note that:-

- Fully funding the scheme may lead to price fixing of base CTP premiums to ensure the LTCS funding budgets are met, OR
- It may encourage the MAA to approve higher CTP premium prices lodged by the CTP insurers to ensure that the funding of the scheme is met
- Either will deliver unearned windfall profits to the CTP insurers.

QUESTION (1)
In respect of potential shortfall in funding LTCS, what safeguards are in place to prevent subsidy of CTP insurers?

Variability of Charging LTCS Levy

Considerable variability exists in the LTCS levy charged to any individual due to the nature of current practice and competiveness with CTP premium price setting.

The correlation to LTCS is simply that as the CTP premium cost increases so does the LTCS levy amount due to the MCIS percentage charged against the CTP premium.

There is great disparity in the percentage charged for the MCIS levy of which the LTCS is a major component. The percentage charged changes based on the following factors,
- the type of vehicle
- engine size of the motorcycle
- geographical area

Further variance may occur due to other calculations applied to an individual owner for a CTP policy by the individual insurers.

Whilst these factors may be relevant in calculating CTP policy prices, they are an irrelevant distraction in relation to LTCS. The word "camouflage" is relevant.

LTCS benefits the entire community. CTP is based on individual blame as determined at law. LTCS is for "blameless" crashes hence rests upon the entire community.

Funding for LTCS must be exactly the same for all members of he community.

LTCS funding must at the very least, be a flat rate across all vehicle registrations.

QUESTION (2)
What reasons are given for the present method of calculation of the LTCS tax based upon CTP criteria?

QUESTION (3)
Why is the LTCS levy not shown as a separate line item on the owners Greenslip?

QUESTION (4)
Why is this inequitable tax camouflaged with percentages and other administrative levies?

Who Benefits from the LTCS scheme?

A narrow band of the community who are catastrophically injured

- Particularly children
- Those injured in apparently off-road areas that fall under the definition for a road related area under the Australian Road Rules
- Pedestrians
- Bicycle riders
- Mobility vehicles
- Motorised toys
- Other wheeled toys (e.g. rollerblades, skateboards etc)
- Plus those paying into the scheme via registration requirements

Who Takes Responsibility for funding LTCS?

RESPONSIBILITY – the core thrust for NSW Tort Law reform is to "enhance personal responsibility"[3]

The operational function and levy collection of LTCS as a "no-fault scheme" does not encourage increased responsibility throughout the community.
In fact it does the exact opposite, shifting responsibility in several areas, or allowing the externalisation of responsibility.
Yet, it remains a scheme whereby the whole community, which includes the government, can take responsibility for the lifetime care of its catastrophically injured members.

Areas of responsibility that immediately arise for examination include:-

- Parental supervision of children on the street or around moving motor vehicles
- Pedestrians taking responsibility for their own safety
- Unlicensed drivers in unregistered cars
- Bicycle riders taking responsibility for their safety and that of other road users
- Road Authorities taking responsibility to create a forgiving crash environment for all road users including Vulnerable Road Users (VRU's), not just for cars

For example, use of unregistered vehicles by unlicensed persons is currently addressed through laws, the courts and enforcement as well as though education programs. It is a "generic" community problem.

Road safety programs are directed primarily towards cars. It may be argued that road building is generic, but "fitments" and "tweaks" are done for specific road users.

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[3] Institute of Actuaries of Australia [2007], The NSW Lifetime Care and Support Scheme p10, Andrew Stone

NSW Parliament provides funding in the order of 12 to 15 million dollars each year for bicycle and pedestrian safety, yet the total expenditure upon motorcycle safety since 1990 is paltry. Since October 2002, the sum total spent on motorcycle safety is less than $3 million. Between 1996 and 2002, the only identifiable funding was the sum of $25,000 per annum provided to the Motorcycle Council of NSW in support of Motorcycle Awareness Week. Prior to that, nil, as evidenced by the 1986 Staysafe report which could not identify any motorcycle safety funding for the previous ten years.

Lack of funding has resulted in a high incidence of motorcycle casualties.

One area of casualties may be illustrated by looking at rider casualties from "roadside furniture".

Engineering of cars has dramatically improved their "crash worthiness" and progressively reduced casualties. However, roadside engineering remains stuck in the 1930's. Motorcycle riders and other Vulnerable Users are at the mercy of roadsides provided by the community through the agencies of government and road authorities.

It is unreasonable, within a no-fault or "blameless" scheme, to use a vehicle tax to blame motorcycle riders for their injuries arising from collisions with inappropriate crash barriers or other road treatments. The chosen barriers may make the road marginally safer for cars, but simply cost the motorcycle rider in injury to body and wallet via externalisation of responsibility by road authorities.

Quoting from an MCC of NSW report of 2000.[4]
NSW roads consistently account for approximately 30% of Australian motorcycle fatalities (RTA, 1995) and for 25% of motorcyclists seriously injured (FORS, 1992).
Using the figures of 2.5% and 3.6% for the proportion of motorcyclist fatalities and casualty admissions respectively involving crash barrier impacts, we can obtain an indication of the annual number of motorcyclists injured in crashes, which involve impacts with crash barriers. The calculations are outlined below:[4]

No. Killed *50-60 x 2.5%/30% = 4-5*
No. Seriously Injured *630-40 x 3.6%/25% = 91-92*
No. of Other Injured *1,200-300 x 3.6%/25% = 173-187*

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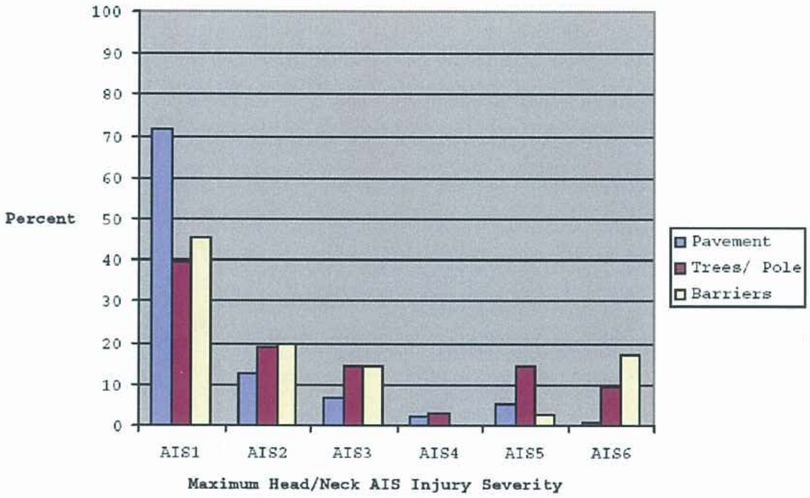
[4] **Gibson T. & E. Benetatos** (2000), *Motorcycles and crash barriers* prepared by Human Impact Engineering for the **Barriers to Safety** campaign, NSW Motorcycle Council, Sydney.

Figure 1 Proportion of Motorcyclists with Head or Neck Injuries from Impacts with a Class of Object in each Injury Severity Category, from Ouellet (1982).



The graph above appears in Gibson & Benetatos,[4] constructed from data in Oullet's 1982 [5] study of motorcycle injury outcomes. It is clear that collisions with vertical posts, trees and crash barriers will result in a greater likelihood of a rider receiving injuries that qualify them for LTCS. A considerable body of literature points to this problem, yet it remains unaddressed in NSW.

Blaming the victim for injuries from these collisions is externalising responsibility by the road authority.

Overall Community burden for LTCS must be shared fairly

Consider the following examples:-
(1)
A person too young to hold a license, is playing on a motorcycle in the front of a friends house. He accidentally accelerates, out of control and travels across the road, crashing into the steps of the house on the opposite side of the street, suffering catastrophic injuries. As he travelled on, then off a public road, he is covered under the LTCS.

The cost of his unfortunate lack of responsibility is paid for by the responsible registered road users, not the community as a whole. Similarly an unlicensed driver in an unregistered car is also covered for the catastrophic injuries they may cause to themself.

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[5] Oullet, J.V. (1982) Environmental Hazards in Motorcycle Accidents, 26th Annual Proceedings, American Association for Automotive Medicine, Ottowa, 1982

(2)
As a result of poor road maintenance on a bend, a motorcyclist falls and strikes several upright posts of an Armco fence at the very edge of the road. The rider cannot take responsibility for the roadside furniture, only the Road Authority can

(3)
A Bicycle rider who fails to stop at a red light and is catastrophically injured by through traffic is covered under the LTCS. There is no discounting of the LTCS benefit they receive due to contributory negligence on their part.

(4)
An intoxicated Pedestrian walks out of the local pub and steps into the path of oncoming traffic. Their catastrophic injuries and are covered under the LTCS.

(5)
A child on a tricycle loses control going downhill and collides with a trailer that is connected to vehicle parked in a driveway.

Are those child's injuries covered under LTCS? Where is the dividing line for the community to decide who is covered by LTCS and who is not?

(6)
Consider a surfer who drives to the beach and suffers a catastrophic injury to his neck whilst surfing. It appears he is not covered by LTCS. This is despite the fact that he used the public road to reach the beach.

There is no community scheme to cover catastrophically injured people unless they fall under the LTCS guidelines. There will be increasing pressure via the courts to include as many cases as possible under the LTCS as it is the only available "no-fault" scheme for the community.

Responsible, registered motorcycle riders are concerned that they are being forced to unfairly shoulder more than their share of the community burden.

Off-road motorcycles present a particular issue. National Parks and Wildlife provide no managed areas for trail riding of motorcycles, yet provide for many other classes of recreational pursuit.

In NSW there are approximately 130,000 registered motorcycles and approximately 100,000 unregistered/off road motorcycles. Off road riders lack managed spaces for recreational pursuits and many end up in areas that are not "roads" per se, but are gazetted or classed as "road related areas" and thus will be covered under LTCS.

Approximately half of all motorcycle crashes admitted to hospital arose from off-road motorcycle activities.

Holistic solutions are required

Government policy must reflect overall community management of risk through various programs across a wide range of Government agencies Presently it does not do this. Simply ignoring or banning activities does not make them disappear, it merely creates a duck-shoving of responsibility and blame. e.g. lack of managed areas for off road activities

Some issues that arise
A motorcyclist can strike a barrier in ways that a car can not
Placement of advertising signs, bus shelters and kiosks that block vision of pedestrians for road users
Road User Educational Issues
Alcohol issues
Bicycles and road rules
Pedestrians and road rules
Education of road engineers
Transport Planning
Failure to include motorcycles and scooters
Car centric road planning and management
Lack of adequate public transport

The LTCS as a No Fault scheme

- No individual responsibility is appointed
- Only the registered road user cohort within the community is required to take responsibility for funding
- At the very least the LTCS levy must be the same for all vehicles
- An alternative is that the LTCS levy be evenly applied to all holders of vehicle licenses
- Preferably the LTCS will be funded by the entire community to evenly distribute the burden and responsibility

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MOTORCYCLES AND CRASH BARRIERS

Prepared for the NSW Motorcycle Council

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1 November 2000

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Preface

This report was funded by the Motorcycle Council of NSW Incorporated.

The authors wish to thank the members of the Council for this support.

The opinions expressed in this report are those of the authors and not necessarily those of the Motorcycle Council of NSW.

Contents

1. Introduction

This report has grown out of a need to better quantify the threat to motorcyclists from crash barriers within Australia. The available mass data for vehicle crashes in NSW gives an indication of the scope of the problem. There are about 60 motorcycle fatalities in the state each year, of which slightly less than half involved a single vehicle (RTA, 1996).

The aim of this report was to collect the data to assist in defining the requirements of crash testing to encourage the use of crash barriers more appropriate for motorcycles and their riders.

To achieve this aim, this report consists of the following sections:

- A review of published international and Australian papers of motorcycle crash studies;
- A comparison with the overall motorcycle crash situation in NSW.
- The methodology and results of an analysis of the NSW Coroners fatal motorcycle crash files for 1998 and 1999, a total of 113 cases, with special emphasis for those involving roadside objects;
- Detailed case studies of the fatal motorcycle cases, which involved crash barriers.

2. Review of Published Data

2.1 International Crash Study Data

Motorcycle crashes into crash barriers represent a small proportion of all motorcycle accidents, but a disproportionate number of motorcycle fatalities. In the United Kingdom, Department of Transport data indicates that 137 (0.3%) of the 41,451 motorcycle accidents reported in that year involved crash barriers yet they represented 14 (2.1%) of all motorcycle fatalities (BMF, 1998).

Similarly in Canada, collisions with crash barriers represented 34 (0.4%) of all motorcycle accidents but accounted for 2 (1.5%) of all motorcycle fatalities (Transport Canada 1980).

US Fatal Accident Reporting System FARS crash data shows that impacts with crash barriers account for 4.0% of fatal motorcycle impacts (NHTSA, 1989).

The situation in Australia for motorcycle fatalities involving crash barriers is similar. In a South Australian study of fatal motorcycle crashes 2.6% of fatal motorcycle impacts were found to involve initial impacts with safety barriers (ATSB, 2000). This same paper reported on the results of an analysis of Australian Coronial records for 1994-96, which identified 9 motorcyclist fatalities involving impacts with a crash barrier. This represents 2.4% of all motorcyclist fatalities during those years.

The proportion of motorcycle casualties as opposed to fatalities involving crash barriers in Australia appears to be slightly higher again. An in-depth study of 222 motorcycle casualty crashes in the Melbourne metropolitan found that 8 (3.6%) of the crashes involved crash barriers (ATSB, 2000).

2.2 Injury Incidence for Motorcycle and Crash Barriers in Australia

An estimate of the number of motorcyclist injuries in Australia resulting from motorcycle impacts with crash barriers can be obtained by extrapolating from traffic accident data and the results of the Australian investigations cited above. National road accident data indicates that 2,826 motorcyclists were hospitalized and a further 199 killed in 1992 (FORS, 1992). In addition, NSW data from police reports indicates that the number of motorcycle injuries has stabilized in this state since 1992 with approximately 50-60 killed, 630-640 seriously injured and 1,200-1,300 suffering minor injury (RTA, 1995).

NSW roads consistently account for approximately 30% of Australian motorcycle fatalities (RTA, 1995) and for 25% of motorcyclists seriously injured (FORS,1992). Using the figures of 2.5% and 3.6% for the proportion of motorcyclist fatalities and casualty admissions respectively involving crash barrier impacts, we can obtain an indication of the annual number of motorcyclists injured in crashes, which involve impacts with crash barriers. The calculations are outlined below:

No. Killed	50-60	x	2.5%/30%	=	4-5
No. Seriously Injured	630-40	x	3.6%/25%	=	91-92
No. of Other Injured	1,200-300	x	3.6%/25%	=	173-187

Alternatively using the 1992 Australian data the proportions killed or injured in collisions involving crash barriers are estimated to be:

No. Killed	199	x	2.5%	=	5
No. Hospitalized	2,826	x	3.6%	=	101

Reasonable minimum estimates of the numbers of motorcyclists killed and seriously injured in motorcycle impacts involving crash barriers in Australia therefore, would be 5 fatalities and 90 to 100 seriously injured per year. The estimate of 180 for those otherwise injured in motorcycle crashes involving crash barriers should be treated cautiously as the proportion of the number of other injured motorcyclists resulting from crash barrier impacts is derived from studies of casualty impacts. Nevertheless, it is reasonable to assume that the number of 'other' injured motorcyclists is significantly greater than the number seriously injured in crashes involving safety barriers.

A number of motorcycle crash studies shed some light upon the issues involved in minimising injury to motorcyclists involved in impacts with crash barriers. The existing research can be divided into crash investigation studies and crash barriers testing.

2.3 Crash Investigation Studies

Introduction

Real world crash investigations relevant to motorcycle impacts with crash barriers have been conducted by Domhan (1987), Hell and Lobb (1993); Ouellet (1982); Otte (1994); Quincey et al (1988); and Transport Canada (1980). The study, on which the paper by Ouellet (1982) was based, by Hurt et al (1981) was amongst the first to specifically raise the issue of motorcyclist impacts with crash barriers.

Ouellet (1982)

The Hurt et al (1981) study was of 900 motorcycle impacts in the Los Angeles area and was conducted over a 5 year period. Other reviewers have made the comment that the study was "well designed, the fieldwork was careful and conscientious and a very valuable report produced" (Ryan and McLean, 1988). The study used a formal sampling technique, monitoring of the notification system, with alterations made to ensure a useful sample and a control group of riders to obtain predisposing factors to the crashes. It does however, now suffer from being out of date.

In a paper based on this research (Ouellet, 1982), the author noted that 63 (or 7%) of the 900 motorcyclist crashes involved bodily (excluding head and neck) contact with a crash barrier. Six (10%) of the 59 rider fatalities involved bodily impacts with W-beam safety barriers and metal mesh fences. He noted that crash barriers are relatively more dangerous than motorcycle crashes generally. There were 9.5 fatalities per 100 motorcyclist impacts with crash barriers as opposed to there being 6.6 deaths per 100 motorcycle crashes generally.

While most impacts involved 2 or more surfaces, the study found that AIS3+ injuries occurred in 46% of crashes involving the rider's body (excluding the head and neck) directly impacting trees or poles, 30% with barriers and 4% of body impacts to the road or pavement. A similar pattern is shown for head and neck impacts with 41%, 34% and 16% of head or neck impacts with poles/trees, barriers and the pavement respectively being associated with AIS3+ injuries[1]. Ouellet suggests that the reason for the greater severity of injuries presented by barriers and posts or trees is that they often present rigid surfaces that are perpendicular to the motion of the rider.

The study further indicates that in the case of head impacts, barriers are particularly injurious when compared to other fixed objects. The author notes that AIS3+ injuries occurred in 66% of head impacts with barriers as opposed to 59% head impacts with trees or poles and 19% of head impacts with the pavement. More details of the injury

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[1] The Abbreviated Injury Scale or AIS is a standard method of categorising injury type and severity, AAAM (1990). The injury severity levels range from AIS1 or minor injury through AIS3, which is serious injury, to AIS6 or maximum injury.

distribution associated with body and head-neck contacts with these surfaces are given in Figures 1and 2.

Figure 1 Proportion of Motorcyclists with Head or Neck Injuries from Impacts with a Class of Object in each Injury Severity Category, from Ouellet (1982).

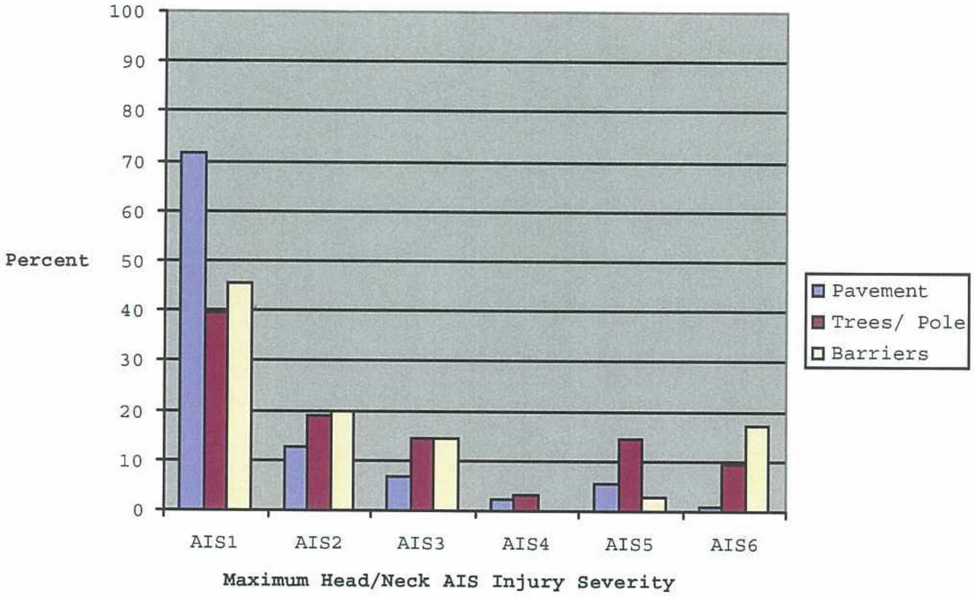
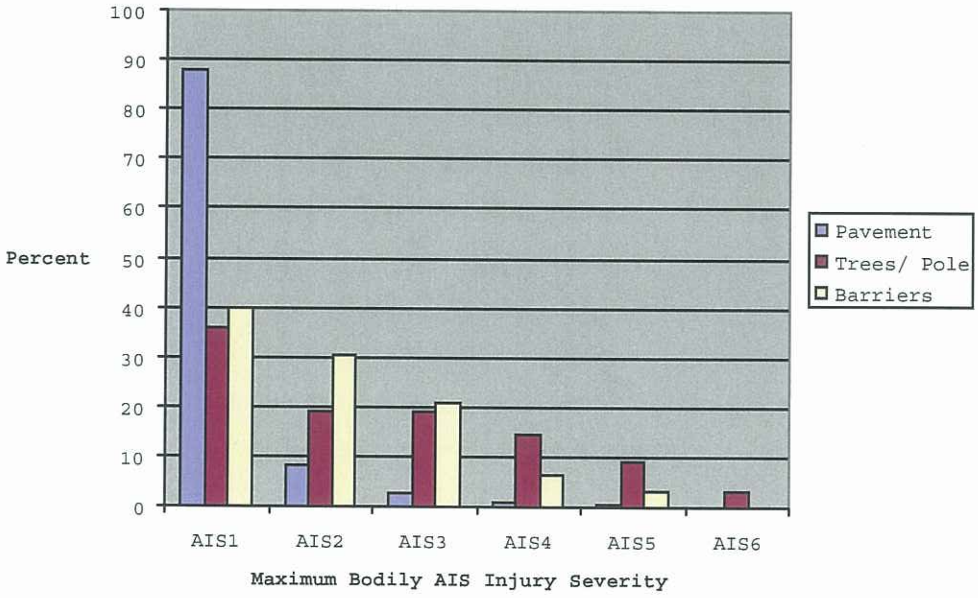


Figure 2 Proportion of Motorcyclists with Bodily (not Head and Neck) Injuries from Impacts with a Class of Object in each Injury Severity Category, from Ouellet (1982).



The author (Ouellet, 1982) observed that every rider that struck a W-beam or metal mesh barrier in their accident investigation suffered at least multiple extremity fractures. In W-beam barrier impacts the motorcyclists tend to strike the barrier “at a shallow angle, and fall and tumble along the tops of the posts”. Alternatively, if they slide into the barrier, they “tumble along striking the bases of the posts”. In the wire mesh barrier impacts the "mounting posts cause the most severe injuries, either by deceleration of the torso or by fractures of the extremities. Ouellet also suggests that the least injurious safety barriers for motorcyclists are smooth concrete barriers, which present no protruding surfaces to the motorcyclist in a crash.

Domhan (1987)
A later paper by Domhan (1987) confirms many of the observations made by Ouellet about crash barriers. In his paper on crash barriers and passive safety of motorcyclists in Germany he reports upon real world data regarding motorcyclist impacts with crash barriers in Germany. The author indicates that German freeways are fully equipped with median barriers (generally using double W-beams with frangible posts) and side crash barriers are in place along 30% to 35% of the length of these roads. He quotes from studies into motorcycle accidents in two regions of Germany by the Federal Road Research Institute (BASt).

In 1984, in the non-metropolitan areas of one region of Germany out of the 2,793 motorcycle crashes studied. Seven motorcyclists were killed (32 per 100 crashes) in 22 motorcycle crashes involving crash barriers; compared with only four fatalities (13 per 100 crashes) out of 30 for the remaining crashes involving fixed objects, and a total of 44 fatalities (1.6 per 100 crashes) recorded for the study.

The severity of injuries incurred by motorcyclists impacting crash barriers was confirmed by the other BASt study also reported on by Domhan. In this study of 207 motorcyclists, injured in a region with a hilly landscape, three out of 50 motorcyclists impacting crash barriers were killed and 31 severely injured. Less than one third escaped with light injuries.

Transport Canada (1980)
A third study provides more specific evidence as to the types of impacts that are most injurious to motorcyclists. A Transport Canada (1980) analysis of motorcycle crash data in Canada during April to September 1980 provides information upon the frequency and importance of fixed objects as a source of injury to motorcyclists. In particular, 1974 data from Ontario's road accident database (TRAID) provides more detailed information upon the number of fatal and non-fatal motorcyclist impacts with different types of fixed objects.

The data from this report indicates that the most injurious types of objects for a motorcyclist to hit are, in order; posts, trees, poles, crash barriers, and culverts/kerbs, see Table 1 below. Five (15%) of the 34 motorcycle-to-post impacts involved fatalities as compared to 2 (6%) of 34 crash barrier impacts and 3 (4%) of 84 'kerb or culvert' impacts. A motorcyclist hitting a post in Ontario therefore has approximately a 1 in 7 chance of being killed compared to 1 in 17 on impacting a crash barrier and less than 1 in 25 on impacting a 'kerb or culvert'.

Table 1 Motorcyclist Collisions with Fixed Objects in Ontario, from Transport Canada, 1980.

Fixed Object	Fatal Crashes	Proportion of Crashes with Object Type (%)	Total Crashes with Object Type
Post	5	14.7	34
Tree	2	8.7	23
Pole	3	6.7	45
Crash Barrier	2	5.9	34
Culvert/Kerb	3	3.6	84
Wall/Bridge Pier	0	0.0	7
Other	4	5.0	80
TOTAL	**19**	**6.2**	**307**

Quincey et al (1980)
Quincey et al (1980) conducted a 3-year on-site investigation of motorcycle impacts with crash barriers on 940km of rural and 70km of urban highways in France over the

period 1978-1979. Median barriers spanned the entire length of both types of highway and roadside crash barriers were placed on 40% of the length of the rural and 62% of the urban highways.

The investigation found that the severity of injuries for motorcyclists impacting crash barriers was generally greater than with other types of motorcycle crashes. In the 27 motorcycle crashes into crash barriers on rural highways the following occurred. Eight motorcyclists were killed (30 fatalities per 100 crashes) and 23 injured (85 injuries per 100 crashes) compared to 11 killed (4 per 100 crashes) and 183 injured (72 per 100 crashes) for other types of motorcycle crashes.

A similar result was obtained on urban motorways although the numbers of fatalities and injuries per crash were somewhat lower probably because of the lower speed limits on these roads. On these roads four were killed and injured (11 per 100 crashes) out of 38 motorcycle crashes with an initial crash barrier impact compared to 2 (2 per 100 crashes) for all other types of motorcycle crashes investigated. Put simply, these figures suggest that motorcyclists were over 5 times more likely to be killed or seriously injured in impacts with crash barriers than in other types of crashes on these roads.

This study also showed that motorcyclists struck crash barriers in different ways, for the 38 fatal barrier impacts:

- 16 (42%) impacted the crash barrier while riding their bike,
- 13 (34%) slid into the crash barrier with their bike, and
- 9 (24%) slid into the crash barrier after separating from the bike.

In a majority of fatal barrier crashes (58%) the rider slide into the barrier, having come off the motorcycle.

Further evidence into the manner in which motorcyclists impact crash barriers is available from the Australian fatal accident database for 1992 (FORS, 1992). This data indicates that approximately 25% of Australian fatal motorcycle accidents are the result of running off the road at a bend and another 10% running off straight roads. This together with the results of the Quincey et al study, indicates that the typical fatal motorcycle impact with a crash barrier involves the rider loosing control on a bend and sliding out into a barrier.

Hell and Lobb (1993)

Hell and Lobb (1993) investigated 173 motorcycle crashes around Munich involving at least minor injuries to motorcycle riders during 1985-90. Crashes were reported by the Bavarian police and were reconstructed and categorized by type of impact, the injuries incurred by the rider(s) and the safety apparel worn following on-site investigation.

Hell and Lobb's figures for motorcyclists with AIS2+ injuries to various body regions in crashes are reported in Table 2. The crashes were of greater injury severity than the average police-reported motorcycle crash in Germany with 50 (24%) of the 210 motorcyclists being killed in the study as opposed to 2% of riders in police-reported crashes in Germany. Nevertheless, the study does indicate that the most likely areas

Table 2 Number and Proportion of Motorcyclists in Different Types of Casualty Crashes in Bavaria with AIS2+ Injuries to Specified Body Regions, from Hell and Lobb (1993).

Body Region	**Collisions with Fixed Objects**		**Free Slipping or Sliding Crashes**		**Motorcyclists in all Accidents**	
Total Riders in Crash Type	N = 27		N = 35		N = 190	
	No.	%	No.	%	No.	%
Head	17	63	7	20	81	43
Thorax	13	48	3	9	48	25
Abdomen	5	19	3	9	30	16
Pelvis	2	7	1	3	15	8
Spine	9	33	3	9	23	12
Upper Extremities	10	37	6	17	57	30
Lower Extremities	10	37	5	14	70	37

of the body to be injured for motorcyclists in collisions are (in order) the legs, head, and thorax. In motorcyclist collisions with fixed objects the chances of AIS2+ injuries to the spine were trebled whilst the chances of AIS2+ injuries to the thorax were doubled and those to the head were increased by 50% above the chances of similar injuries in motorcycle crashes generally.

Otte (1994)
Otte (1994) analysed a the results of a similar study, but with an emphasis upon leg injuries. This research involved the investigation of 496 motorcycle accidents by a multi-disciplinary team from the Accident Research Unit, Hanover during 1985-1992. The motorcycle crashes were documented and classified by the type of crash, injuries sustained and, the presence or absence of leg fairings according to a random sampling plan. The results were then evaluated using a statistical weighting procedure to ensure that they represented all motorcycle accidents in Germany.

A difficulty with this paper is that it does not distinguish between solo crashes involving impacts with fixed objects and solo crashes not involving impacts with fixed objects. Despite this it indicates that the likelihood of AIS2+ head and thorax injuries are increased by over 50% and 100% respectively in solo collisions (including impacts with fixed objects) as opposed to both collisions with cars and solo collisions as a group.

Table 3 Proportion of Motorcyclists in Different Crash Types with and without Leg Protection having AIS2+ Injuries to Specified Body Regions of the Body, from Otte (1994).

	Motorcycles with Leg Fairings		Motorcycles without Leg Fairings	
Body Region	Solo and Fixed Object Crashes	Car and Solo Crashes	Solo and Fixed Object Crashes	Car and Solo Crashes
Total	N = 19	N = 89	N = 62	N = 249
Head	13.4%	8.2%	11.8%	6.9%
Thorax	22.3%	10.8%	13.1%	6.8%

2.4 Motorcycle and Crash Barrier Testing

Quincey et al (1988)
The final area of research reported in the literature is dummy and human cadaver tests of crash barriers. Quincey et al (1988) tested three types of crash barriers with dummies. The dummy was laid upon its back with its head forward on a platform. The platform was accelerated to 55km/h at a 30-degree angle to the crash barrier. It was then stopped so that the dummy slid 2m before impacting the barrier. The three crash barrier types tested included: a lowered W-beam barrier, one with a beam covering the lower posts and a concrete barrier. The Head Injury Criteria[2] values were 110 for the concrete barrier and 175-365 for each of the double crash barriers tested - although the 3ms clipped head accelerations were greatest for the concrete barrier.

Domhan (1987)
Impact attenuators for crash barrier posts have also been designed and tested in Germany. The attenuators are post coverings composed of neoprene and were tested at the Heidelberg University Institute for Forensic Medicine. The results of the tests indicated that 35km/h impacts with IPE-100 crash barrier posts resulted in severe injuries of AIS4 level, whereas the posts covered with attenuators resulted in injuries of only AIS1 to AIS2 (Domhan, 1987).

ISO Standards
More recently the International Standards Organisation has developed a standard for the methodology to be used when crash testing of motorcycles and protective equipment and analysing the results (ISO, 1996). This standard is very comprehensive, and includes a specialised adaptation of the Hybrid III crash test dummy (Zellner et al, 1996). It also proposes a means of calculating the cost to society of the injuries to the motorcyclist derived from the dummy responses (Kebschull et al, 1998). The standard has been used for motorcycle/car type impacts; as yet it has not been applied to crash barrier evaluation.

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[2] The Head Injury Criteria limit, for when significant head injury will occur, is usually taken to be 1000.

The ISO standard has been built around a significant amount of development testing. This experience with motorcycle/vehicle impacts has shown that several factors need to be considered when designing the crash testing with motorcycles for it to be of value and be able to show correlation with real crashes. A motorcycle crash is more complex than a vehicle crash as the critical impact is between the rider and the object, not between the motorcycle and the object. A typical motorcycle crash therefore has several stages and each stage must be accurately reproduced. The major injuries often occur after the initial impact between the motorcycle and the barrier, and are due to the secondary impact between the rider and another fixed object such as the road surface, a pole or a part of the barrier.

2.5 Discussion

The literature review indicates that most motorcycle collisions with crash barriers occur at shallow angles with the rider typically sliding into the barrier at a bend (Quincey et al, 1988) and (FORS, 1992).

Approximately 60% of fatal motorcycle collisions with crash barriers involve the rider sliding with or without their bike into the barrier (Quincey et al, 1988). In the other 40% the rider remains upright on the motorcycle.

The severity of injuries to motorcyclists are greater for collisions with fixed objects than with other vehicles and even greater than for crashes in which the rider(s) run off or slide along the road (Domhan, 1987), (Quincey et al, 1988) and (Transport Canada, 1980). Ouellet (1982) suggests that the reasons for this are :

- The rigidity of these objects; and,
- The velocity component perpendicular to the impacting surface is greater than in many other types of collisions.

The probability of being killed as a result of impacting a crash barrier is more than double that for motorcycle crashes generally. The likelihood of incurring fatal injuries upon impacting an object, however, is greatest for posts then, trees, poles, crash barriers and kerbs (Transport Canada, 1980). Although Ouellet's (1982) research suggests that severe head injuries (AIS3+), are much more likely following a head impacts with a crash barrier, than in head impacts with any of the other fixed objects mentioned above.

The chances of injury upon hitting a fixed object appear to be related to the impact area and the rigidity of the object. Thus impacts with small rigid objects such as posts are more likely to cause injury than impacts with trees or walls because the small impact area increases the stress upon the impacted portion of a motorcyclist. This has been supported both by dummy tests (Domhan, 1987) and (Quincey et al, 1988) and real world crash data (Transport Canada, 1980).

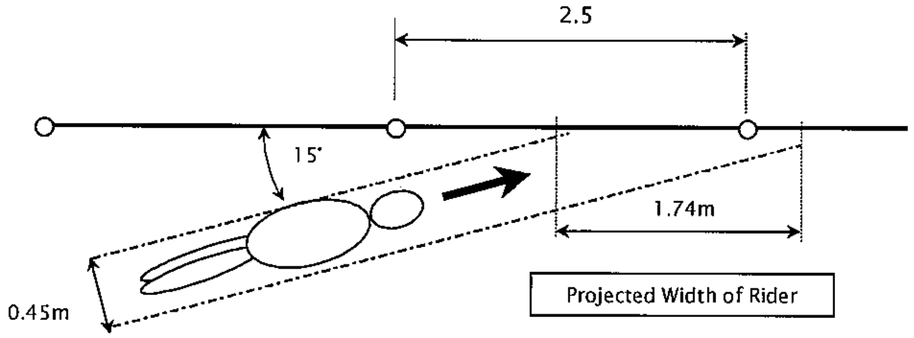
Another factor in the severity of injuries experienced by motorcyclists is the portion of the body struck in a crash. The most likely areas of the body to be injured for motorcyclists in collisions are in order, the legs, head, and thorax (Hell and Lobb, 1993). In motorcyclist collisions with fixed objects however, the chances of AIS2+ head, thorax and spinal injuries are increased far more than for other regions of the body - by over 50% for the head and over double for the chest and spine. (Hell and Lobb, 1993) and (Otte, 1994). This suggests that another factor behind the greater severity of injuries incurred by motorcyclists in barrier crashes may be that they are more likely to strike vital regions of the body.

Ouellet (1982) suggests that for those riders remaining upright on impact with crash barriers (about 40% from Quincey et al, 1988), most injuries occur when, after the shallow impact with the safety barrier, the rider slides and tumbles along the tops of the posts supporting the safety barrier. For those riders who have come off the motorcycle (about 60% from Quincey et al, 1988) before impact with crash barriers, most injuries occur as the rider slides and tumbles along the base of the posts. This is a concern for wire rope safety fences, which require a greater number of posts per length. The smaller gaps between the posts in the wire rope safety barriers are likely to lead to more direct impacts with the supporting posts.

The Flexfence wire rope safety barrier used in Victoria has one post every 2.5m (VICRoads, 1998) and more of each post is exposed in these barriers than the more traditional W-beam safety barriers. A rider is more likely to experience a direct impact with a post.

An illustration of this is provided by considering such a shallow barrier impact, see Figure 3. If it is assumed that the rider slides into the crash barrier at an angle of 15 degrees. The minimum width of a rider is 45cm, when they are sliding lengthwise on their back, head or feet first, into the barrier as illustrated below. In this situation the rider has a 70% chance of directly impacting a barrier post. The chance is still greater for riders sliding or rolling sideways or impacting at even shallower angles.

Figure 3 Projected Width of the Motorcyclist into a Crash Barrier in a Shallow Angled Impact



This is particularly undesirable given that impacts with posts were found to be the most likely to cause severe injuries than impacts with any other types of fixed object. Given that wire rope barrier fences are generally installed on straight roads in Australia (ATSB, 2000), it is probable that most impacts would be at an angle of less than 30 degrees. The likelihood of riders severely injuring themselves should they run off the road would therefore be high with a probability of hitting a post being greater than 35% for 30 degree angle impacts and over 70% for 15 degree angle impacts. The likelihood of death and severe injury upon hitting these the posts would in turn be greater than 14.7% (from Transport Canada, 1980) and over 50% (from Ouellet, 1982) respectively. These figures do not take into account rope only impacts where the likelihood and severity of impacts by motorcyclists is unknown.

The Flexfence wire rope safety barriers used in Victoria are tensioned to 80kN and deflect 1.3m when impacted at 110km/h by a 1.5 tonne vehicle (VICroads, 1988). The barrier will act as a rigid barrier when impacted by a motorcyclist.

The work by Ouellet found that the motorcyclists usually had impacts with several surfaces, and this is supported by data from the NSW fatal case review, where the post barrier impact trajectory of the rider was significant with regard to injury causation. The dummy must be able to respond to the crash with a realistic trajectory post impact. It must also be possible to accurately assess the likely injury from the dummy responses. If these requirements of biofidelity for the dummy[3], are not met then any comparison between different barrier types will most likely be poor, due to non repeatable test results.

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[3] Biofidelity is the ability of the dummy to act in a human-like manner.

3. Fatal Motorcycle Crashes - NSW

3.1 Methodology

Data was obtained from the NSW Coroner files for all fatal motorcycle crashes for the years 1988-1989. Information was obtained upon 102 of 113 motorcycle fatalities, which involved 100 out of 111 separate crashes in that period. Some files were unavailable due to the coronial investigation not yet being completed. Where available, information from the files was obtained and coded to provide a description of the conditions, type of crash and the injuries incurred. See Appendices for a sample coding form. Particular attention was paid to impacts with fixed objects and those impacts involving crash barriers, and roadside posts, fences and walls.

3.2 Analysis

A summary of the crash types overall is provided in Table 4.

Table 4 Motorcycle Fatalities in NSW, 1998-99.

Crash Type	Description of Crash		Fatal Crashes
M/C and Moving Object	M/C on Straight Road	M/C on Wrong Side of Road	15
		Other Vehicle on Wrong Side of Road	5
		Vehicle and M/C on Correct Side of Road	7
		Vehicle Turning	6
	M/C at Intersection	M/C Turning	0
		Vehicle Turning	14
		Vehicle and M/C Continuing in Straight Path	5
	Sub-Total		63
M/C and Fixed Object			39
Other		Off Road	9
		Don't Know	2
Incomplete			9
	Total		113

Sixty-three of the fatalities involved another vehicle, 39 a fixed object, nine were just off the road, two were unknown and nine were incomplete.The impacts with a fixed object are summarised in Table 5 in terms of the initial impact, and in Table 6 in terms of the most likely fatal impact.

Crash barrier impacts were involved in 8 (8%) of all motorcycle fatalities for which data was available in this period. In addition, a further 9% were the result of impacts with fences, posts, or walls. They formed a part of the 39 motorcycle fatalities, which involved impacts with fixed objects representing 39% of all motorcycle fatalities for which data was available. Crash barrier impacts featured in one fifth of these types of crashes.

The fixed objects most frequently hit first were kerbs or culverts, followed by crash barriers, representing 9% and 8% respectively, of all fatal motorcycle accidents for which data was available. Impacts with trees and telegraph poles however, were more likely to be identified as responsible for the fatal injuries incurred in motorcycle accidents than kerbs/culverts and crash barriers. This is primarily due to the fact that motorcyclists frequently hit other objects after an initial impact with a kerb or crash barrier making it difficult to determine the cause of their most serious injuries.

The crash data also indicates the most likely scenarios for impacts with crash barriers. All except one of the impacts with crash barriers were with w-beam barriers. The other fatality involved a concrete median barrier, which the rider impacted first before sliding past the end of the barrier and into a signpost and oncoming traffic. This confirms the findings from the literature review, which indicated that concrete barriers are safer for motorcyclists than W-beam barriers.

It is also clear from the tables that impacts with crash barriers are more likely to be the result of motorcyclists running off the left hand (passenger) side of the road than in impacts with any other fixed object. Five of the eight fatalities involving crash barriers came about in this way, whereas only one arose from riders crossing the right hand side of the road or median strip and one from impacts with crash barriers at intersections. The majority of the fatal impacts were at relatively shallow angles with respect to the crash barriers. This is supported by a more detailed analysis of the crash barrier

Table 5 **Initial Impacts For Motorcycle Fatalities Involving Fixed Objects, NSW 1998-99**

Object Impacted	Off LHS of Road	Off RHS of Road	Intersection/ Roundabout	Off Road Driving	DK/ Other	TOTAL
Crash Barrier	4	1	1			6
Crash Barrier Post	1				1	2
Kerb, Culvert or Median Strip	3	1	4		1	9
Fence	1				1	2
Ground Only		1			1	2
Other					1	1
Post		2		2	1	5
Telegraph Pole	1					1
Tree	2		1	1	2	6
Vehicle/Bike					2	2
Wall						0
Wire (fence)	1	1		1		3
TOTAL	13	6	6	4	10	39

Table 6 **Fatal Impacts For Motorcycle Fatalities Involving Fixed Objects, NSW 1998-99**

Object Impacted	LHS of Road	RHS of Road/Lane	Intersection	Off Road Driving	DK or Other	TOTAL
Crash Barrier	2		1			3
Crash Barrier Post	1				1	2
Kerb, Culvert, Median Strip						0
Fence					1	1
Ground Only		1			1	2
Other						0
Post		1		2		3
Telegraph Pole	2					2
Tree	1		2	1	3	7
Various/Unknown	5	2	2		4	13
Vehicle/Bike	2	1	1	1		5
Wall						0
Wire (fence)		1				1
TOTAL	13	6	6	4	10	39

impacts with 5 out of eight fatalities arising from impacts at an angle of 45 degrees of less. Given the shallow angle of most impacts it is not surprising that two of the eight fatalities arose from impacts with crash barrier posts as a shallow impact increases the likelihood of a direct impact with any barrier posts.

In addition the fatal cases indicate the kinematics of the riders prior to the impact with crash barrier. Two of the eight riders were airborne prior to impact and one slid into the barrier. Three of the remaining riders were riding their motorcycles at impact and the kinematics of the remaining two riders could not be determined from the records.

The most frequent type of fatal impacts with crash barriers occurred when the rider lost control on a right hand bend and impacted the barrier on the left-hand side of the road. As would be expected from the literature most crash barrier impacts were at shallow angles.

The speed of the motorcycle at impact is difficult to determine accurately from the files but two measures are available; the police estimate and the speed limit in the area of the crash. Both these indicate that the impacts, which result from loss of control on a corner, occurred at speeds above 60 km/h.

The case studies of fatal motorcycle crashes with barriers are included, in Appendix 1. These confirm that most fatal injuries are the result of impacts with some other object rather than the crash barrier beam (or solid concrete in concrete crash barriers), such as a crash barrier post, some other post/pole, a vehicle or a heavy impact with the ground. To protect motorcyclists, crash barriers need to protect the rider from:

- Impacts with any supporting posts; and
- Subsequent impacts with other vehicles, or other fixed object.

4. Summary

The literature review indicated that:

- The probability of a motorcyclist being killed as a result of impacting a crash barrier is more than double that for motorcycle crashes generally;
- The chances of injury upon hitting a fixed object appear to be related to the impact area and the rigidity of the object. Hence small rigid objects such as posts are most likely to cause injury;
- The severity of injuries experienced by motorcyclists depends on the portion of the body struck in the crash;
- Most motorcycle collisions with crash barriers occur at shallow angles with the rider typically sliding into the barrier at a bend (Quincey et al, 1988) and (FORS, 1992);
- For those riders remaining upright when impacting the crash barriers, most injuries occur when after shallow impact the rider slides and tumbles into the tops of the supporting posts (Ouellet, 1982); and,
- For those riders not remaining upright, most injuries occur when after shallow impact the rider slides and tumbles into the bottom of the supporting posts (Ouellet, 1982).

A study of fatal motorcycle crashes in NSW has shown that:

- Fatal impacts with crash barriers occurred most frequently when the rider lost control on a right hand bend and impacted the barrier on the left hand side of the road;
- Most crash barrier impacts were at shallow angles;
- Fatal injuries were most likely to result from impacts with some other object rather than the crash barrier beam (or solid concrete in concrete crash barriers), such as a crash barrier post, some other post/pole, a vehicle or a heavy impact with the ground;
- The speed of the motorcycle at impact is difficult to accurately assess, but is greater than 60 km/h.

Motorcycle mpacts with crash barriers are estimated to be the cause of 5 fatalities and 100 seroius injuries each year in Australia. The only method available for assessing the safety implications for motorcycles of existing and new crash barrier designs is to carry out full scale crash testing. A test method has been developed by the International Standards Organisation (ISO, 1996), which is designed for assessing protective devices for motorcyclists. This standard presents an approach which is suitable to use as the basis for testing motorcycle impacts with crash barriers.

In summary, the requirements for a test to ensure adequate protection to motorcyclists impacting a crash barrier are as follows:

- Shallow impact angle, between 15° and 45°;
- A helmeted dummy with appropriate biofidelity, to be able to accurately simulate post impact kinematics of the rider with adequate biomechanical responses;
- A minimum of two test configurations are needed with a surrogate motorcyclist (or dummy):
    1. mounted on an upright motorcycle; and
    2. sliding on the ground without the motorcycle;
- Speed of the motorcycle should be greater than 60 km/h.

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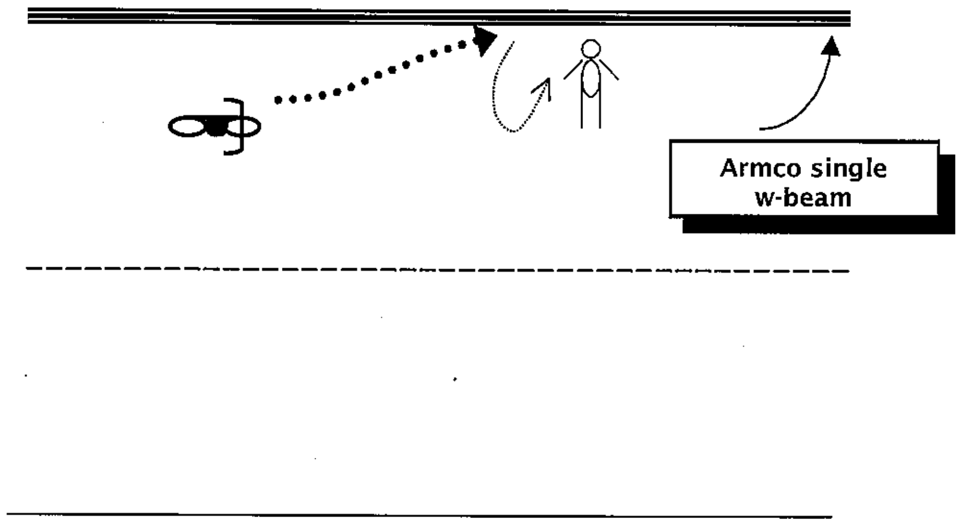
APPENDIX 1 - Fatal Crash Case Studies

The following case studies are based on the NSW Coroner's reports into fatal motorcycle crash barrier impacts in Australia during 1998 and 1999. They highlight some of the most salient aspects of motorcycle impacts with roadside objects. The most frequent type of fatal motorcyclist impact with a crash barrier was where the rider lost control on a right hand bend and impacted a barrier on the left hand side of the road.

Case 1

A motorcyclist rode into a crash barrier at between 70 and 80 km/h and an angle of impact of approximately 30 degrees on the left-hand side of a straight section of road. The rider was thrown into the air and then landed on the road. The rider was riding without a helmet and it is unclear whether the major injuries were sustained upon impact with the crash barrier or the ground.

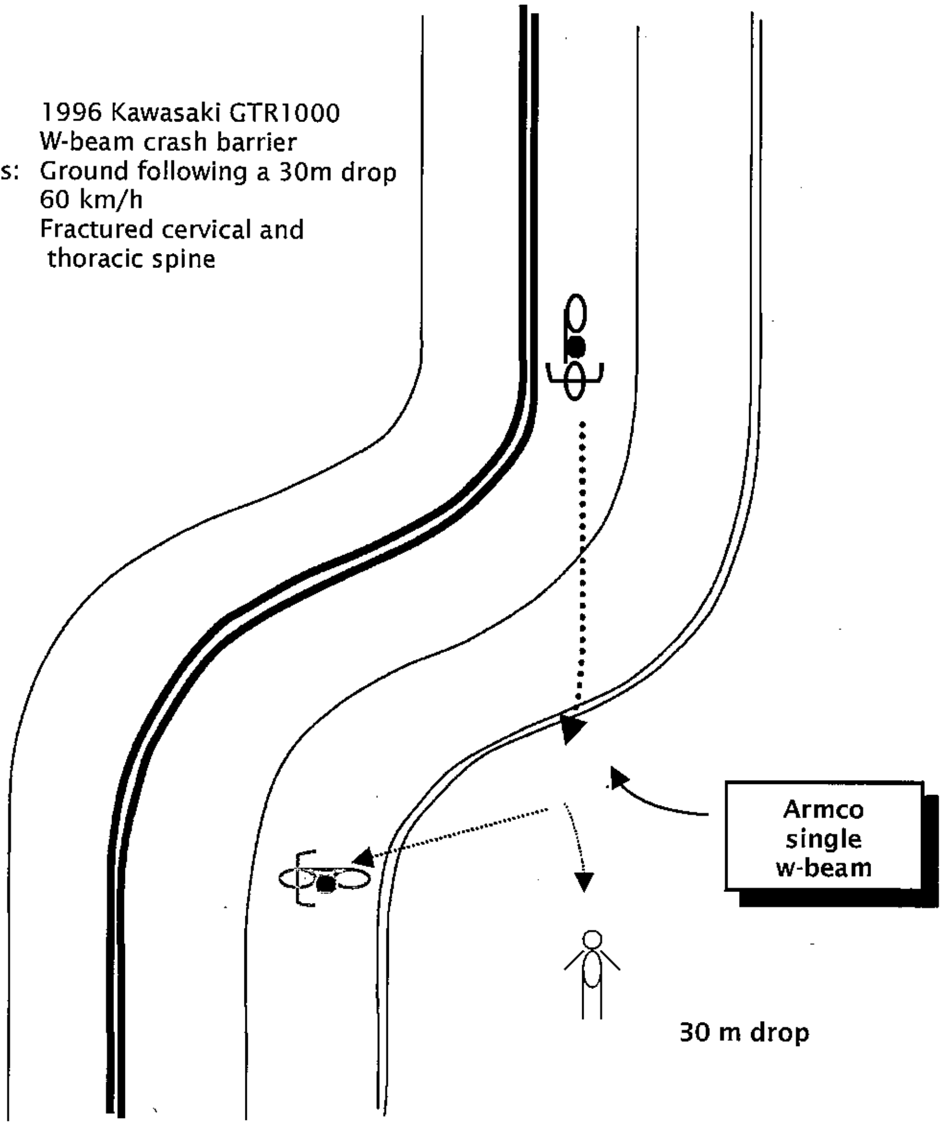
Motorbike: Honda 250cc Trail bike
Barrier: W-beam crash barrier
Other impacts: Ground after being thrown up into the air.
Speed: 70-80 km/h
Injuries: Extensive skull fracture, subaponeurotic bruising and sub-dural haemorrhage,
Comatose, CPR applied.
Other: No helmet worn



Case 2

This crash occurred with a crash barrier in a metropolitan area. The rider impacted a w-beam crash barrier at approximately 45 degrees and an estimated speed of 60km/h after failing to take a sharp right hand bend. The motorcycle, a Kawasaki GTR1000 bounced back into the lane and the rider was launched over the crash barrier and down a 30m drop. The main injuries found were severe neck and chest injuries with fractures of the cervical and thoracic spine.

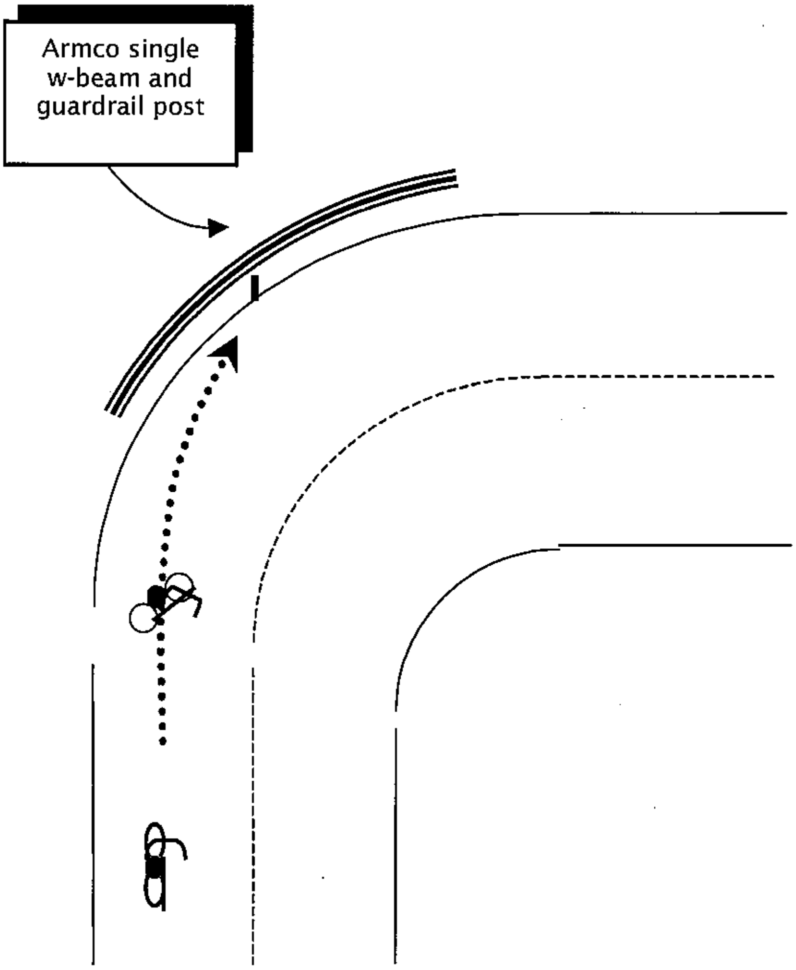
Motorcycle:	1996 Kawasaki GTR1000
Barrier:	W-beam crash barrier
Other impacts:	Ground following a 30m drop
Speed:	60 km/h
Injuries:	Fractured cervical and thoracic spine



Case 3

The motorcycle rider ran off the left-hand side of the road into a crash barrier on the outside of a right hand bend. In this case the rider fell on to their right side and slid into the crash barrier at an angle of approximately 45 degrees. The front of the rider's helmet collided with a crash barrier post causing severe neck and spinal injuries.

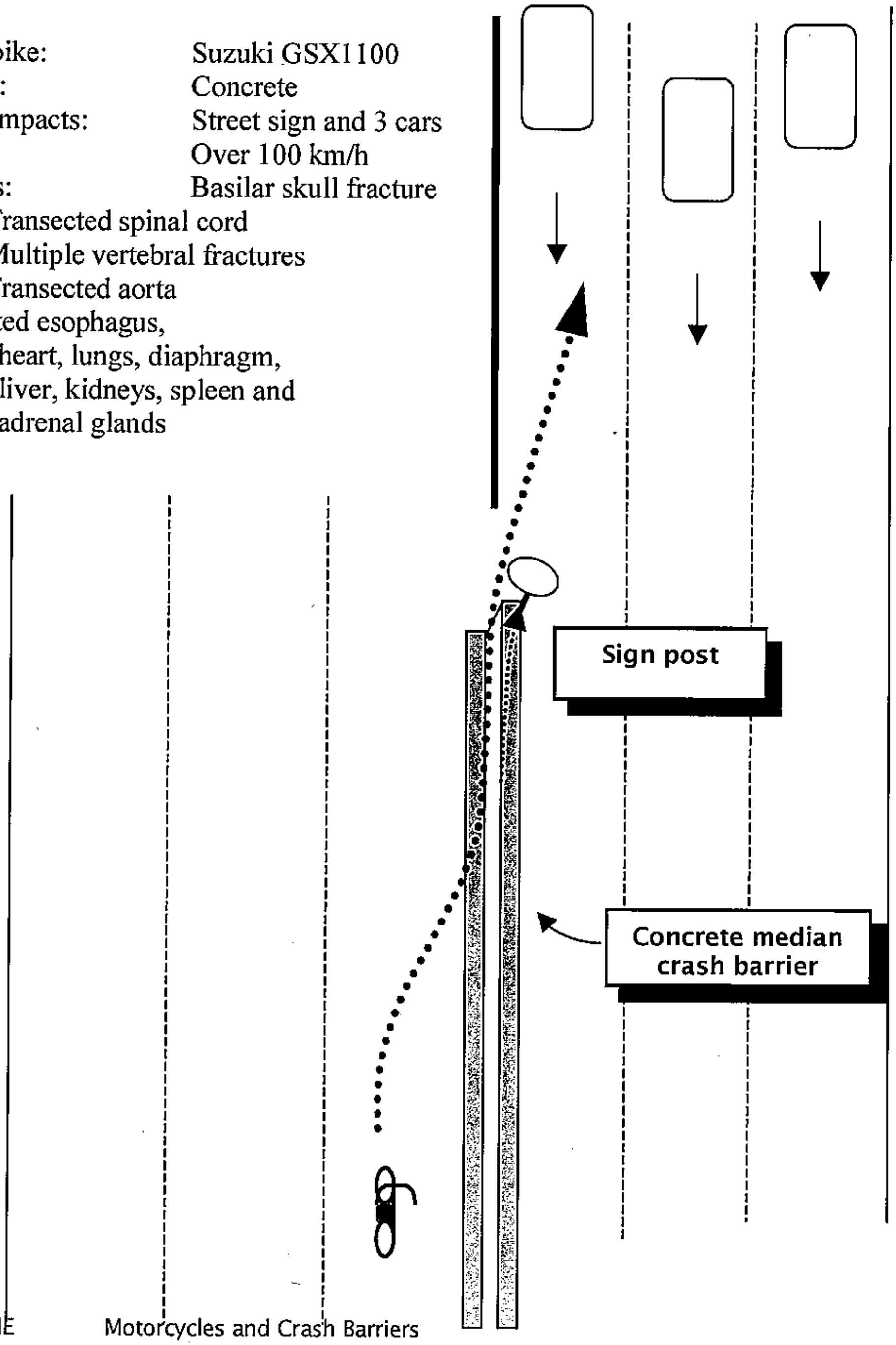
Motorcycle:	1998 Yamaha
Barrier:	W-beam
Other impacts:	Helmet front with guardrail post.
Speed:	Unknown
Injuries:	Transection of spinal cord Fracture and dislocation of cervical vertebrae Severe neck laceration



Case 4

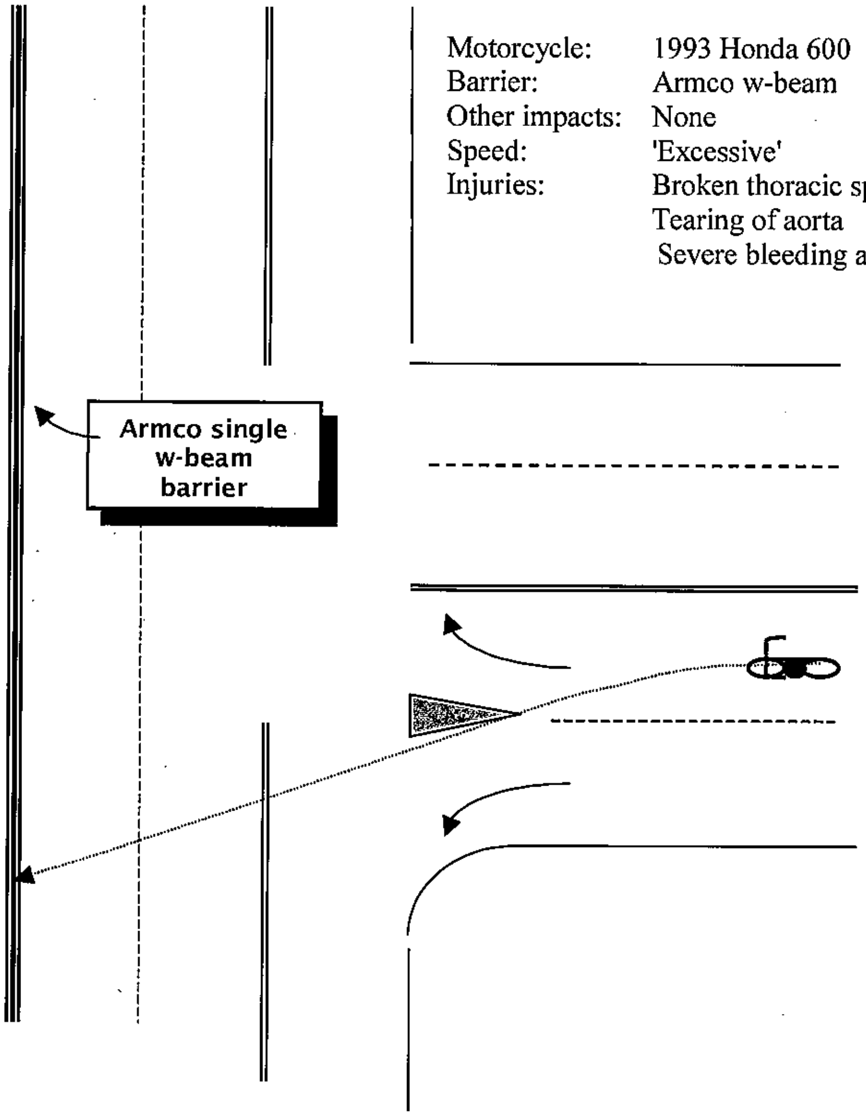
This case was the only one involving a concrete barrier. The rider, travelling in excess of 100km/h collided with the concrete median barrier on a bridge at an angle of approximately 30 degrees. The rider slid along the barrier and hit a road sign at the end of the barrier and then veered into oncoming traffic. The major injuries were probably the result of impacts with the cars or the sign rather than the median barrier

Motorbike:	Suzuki GSX1100
Barrier:	Concrete
Other impacts:	Street sign and 3 cars
Speed:	Over 100 km/h
Injuries:	Basilar skull fracture Transected spinal cord Multiple vertebral fractures Transected aorta Lacerated esophagus, heart, lungs, diaphragm, liver, kidneys, spleen and adrenal glands



Case 5

The rider attempted to turn left from the inside lane of a two-lane approach to a T-intersection. Turning sharply left at excessive speed before a divider for the inside and outside lanes the rider lost control and impacted the crash barrier on the opposite side of the intersection at an angle of roughly 75 degrees



Motorcycle:	1993 Honda 600
Barrier:	Armco w-beam
Other impacts:	None
Speed:	'Excessive'
Injuries:	Broken thoracic spine Tearing of aorta Severe bleeding around lungs

APPENDIX 2 Data Collection Form

MOTORCYCLE AND ROADSIDE BARRIER PROJECT

Case Number:

Major Impact with Roadside Barrier: Yes/No **Rider/Pillion**
Passenger
Barrier Type:
Barrier Description (include sketch):

Type of Motorcycle (Age, make, model, engine size):

Sketch of Crash Site: include angle of impact

Description of Crash:

RUM Code:
Angle of Impact with Barrier:
Estimated Speed of Motorcycle:
Source of Estimate:

Helmet Worn:
Description of Helmet Damage, if available:

Description of Injuries:
Head

Neck and Spine

Thorax

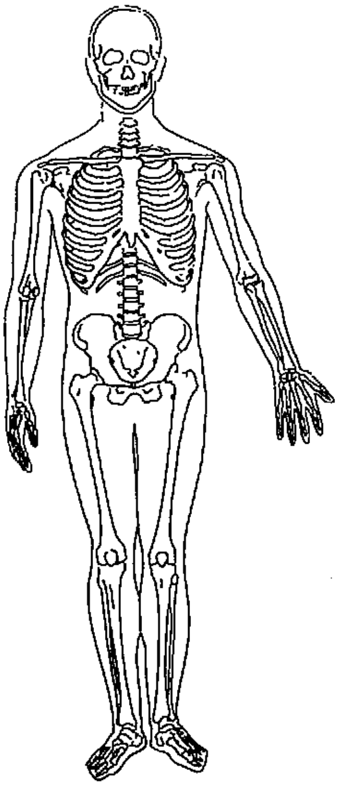
Abdomen

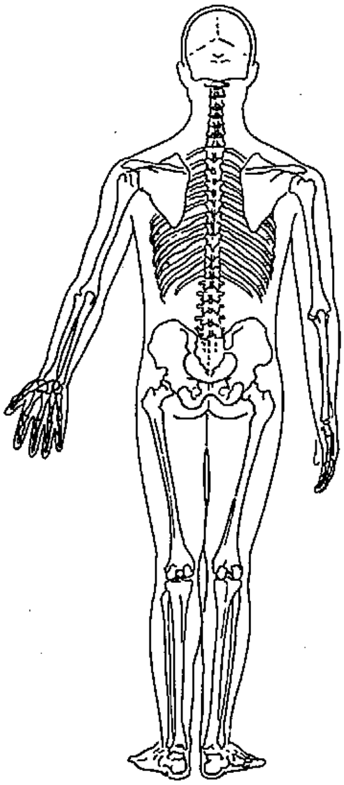
Pelvis

Upper extremities

Lower Extremities

Injury Diagram





Comments

ENVIRONMENTAL HAZARDS IN MOTORCYCLE ACCIDENTS

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ABSTRACT

The roadway environment presents hazards to the motorcycle that differ uniquely from other vehicles. These can be dichotomized generally as motorcycle control hazards or as injury hazards. Those threats to motorcycle control and stability are rare, accounting for less than 3% of accidents. However, the environment is a major source of injuries to motorcycle riders and passengers, who are protected only by the equipment they wear. Considerable research and development effort has been devoted to making the roadway environment a safer place for automobile collisions, but a commensurate effort for motorcycles is lacking. Consequently, roadway fixtures such as dividers, overpasses, poles and fences cause significant injuries which could be avoided. Data collected in 900 on-scene motorcycle accident investigations performed by the University of Southern California are used to identify both types of hazards and suggest ways to reduce injury exposure.

MOTORCYCLES DIFFER IN FUNDAMENTAL WAYS from automobiles, and some of the differences are obvious to the most casual observer. Yet the ramifications of the contrast are subtle and frequently overlooked. As a result, motorcycle riders suffer a disproportionate number of accidents and injuries. Roadway factors that would not adversely affect an automobile, or even catch the attention of the highway engineer can spell disaster for the motorcyclist. Indeed, some roadway safety features that benefit automobiles in collision conditions actually increase the severity of injuries when applied to motorcycle riders.

STABILITY - Cars can become unstable, spin or skid out of control and then become involved in a collision, but collision is not necessarily the

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outcome of an instability or control problem. Contemporary passenger vehicles simply do not roll over on their side as soon as some instability develops, but motorcycles often do, and the subsequent slide and tumble to a stop is certainly a collision as any surviving motorcyclist can testify. Thus, motorcycles are vulnerable to any roadway variation that affects stability. These can be changes in friction coefficient, undulations and irregularities of the roadway surface or simply debris and contamination.

PROTECTION SYSTEMS - The basic strategy in the automobile as a protection system is to keep the occupant within the protected environment of the passenger compartment, prevent intrusion, and make the passenger compartment a relatively safe place to decelerate during a collision. The roadway environment is generally designed to enhance the effectiveness of this strategy. Automobile occupants are exposed to the outside environment only in cases of ejection. In contrast, the motorcyclist is exposed continuously to the environment. In an accident, he is protected only by his own apparel; otherwise, he is completely at the mercy of whatever roadway environment he chances into. Except for the motorcycle safety helmet, that apparel can not reduce severe impact loads (1). Protection devices added to the motorcycle, such as crash bars, which might seem to offer some protection to the legs, actually offer no clear benefit and are almost random in their effects (2).

The difference in protection systems between motorcycles and cars is obvious, yet the design of roadway environments is unquestionably oriented to the protection of passenger vehicle occupants, with little or no attention paid to the protection requirements of the exposed motorcyclist. At times the requirements for rider protection are small and rather predictable. The purpose of this paper is to point out what some of those requirements are and to suggest some starting points for future research.

The data presented here were collected as part of a multidisciplinary in-depth investigation of 900 motorcycle accidents in the Los Angeles area. The research was performed by the University of Southern California with funding from the U.S. Department of Transportation - National Highway Traffic Safety Administration. The final report of that research has been released (2,3).

ENVIRONMENTAL CONTRIBUTIONS TO ACCIDENT CAUSATION

Perhaps the most substantial environmental contribution to accident causation is the obstruction of the precrash line-of-sight between the motorcycle and other vehicles with which it collides. Table 1 (2) shows that one third of motorcycle accidents involve obstruction of the motorcyclist's and/or car driver's view of each other in the moments just before collision. The predominating source of view obstruction is other vehicles in traffic and parked vehicles.

Table 1 - Motorcycle-Other Vehicle
Precrash View Obstruction

Obstructed Path	Absolute Frequency	Relative Frequency	Adjusted Frequency
None	446	49.6	65.3
Motorcycle only	17	1.9	2.5
Other Veh. only	57	6.3	8.3
MC and OV	163	18.1	23.9
N/A, No OV	217	24.1	Missing
TOTAL	900	100.0	100.0

This problem of precrash view obstruction is obviously not one of highway design. Rather, it emphasizes the need for rider education to develop a continuous strategy to "see and be seen" by other vehicles in traffic. High conspicuity treatments of the motorcycle and rider are of no use if the view of and from the motorcycle is blocked.

Of the 900 accidents reported in the study, 18 (2.0%) were precipitated primarily by roadway defects. Of these, 15 were single vehicle accidents. This 2% figure is quite low, especially considering the extent to which riders erroneously blame their own motorcycle control failures on gas, sand, potholes, rocks, etc. in the roadway. The proportion of accidents may be somewhat higher in areas with roads damaged by harsh winters.

Adverse weather conditions do contribute to motorcycle accidents, mostly in a microscopic way. Of 900 accidents, only 20 (2.2%) occurred during adverse weather and only a few of those were because of bad weather. In Southern California motorcycles virtually disappear from the streets in rainy weather; in areas with more rain and snow, and where motorcycle exposure in traffic does not drop commensurately, adverse weather may be a more common problem than that reported here. Nonetheless, as with roadway defects, the contribution is small and human error stands out as the overwhelming motorcycle accident cause factor.

Animals pose no threat of impact to cars; the only danger is associated with unsuccessful collision avoidance maneuvers. In the case of motorcycles, both collision avoidance maneuvers and impact are a threat. However, animals accounted for only ten of the 900 accidents; in eight of those the animal was struck. (It appears that in many of those, the animal didn't see the motorcycle.)

ROADWAY DESIGN AND MAINTENANCE HAZARDS TO STABILITY - Roadway undulations and irregularities can, in some instances, help to precipitate loss of control of the motorcycle. Only one accident of the 900 was caused solely by a pavement irregularity. More often the role is contributory when the motorcycle is performing near the limits of turning or braking, or if the motorcycle is operating on a flat tire. For example, in one case a motorcycle was attempting by means of heavy braking to avoid collision with a car turning left across its path. The evasive action would have been successful except that the motorcycle crossed a manhole cover and the inch-high asphalt berm around it, which caused the front wheel to lock up and slide out, throwing rider and passenger to the pavement. In another case, a rider with a flat tire was attempting to move into the center median of the freeway. His maneuvering was successful until his flat tire crossed an inchhigh "lip,"where asphalt and concrete pavement butted together,at a shallow angle. He immediately lost control, fell and slid into the median divider (similar to that in Figure 5) and was critically injured.

Another type of roadway undulation that can cause stability problems for motorcycles is the presence of a dip in turns that can be taken at high speeds (not necessarily those that are **signed** for high speeds, rather those that can be negotiated at roughly 65+ mph with high lateral forces.) Some motorcycles or certain kinds of loads on the motorcycle, combined with a dip in a high speed turn can result in a dynamic instability that may lead to loss of control and collision.

As with roadway irregularities, sudden changes of the friction coefficient can have an adverse effect on motorcycle control, especially during heavy braking or turning maneuvers. A surface as seemingly inocuous as paint stripes on the roadway can cause the tire that is braking heavily to lock up and slide out. In some instances the friction coefficient of the paint differs from the roadway by about 0.1. Often this difference is not a great problem if crossing a short strip of paint. However, crossing a paint stripe nearly parallel to the motorcycle direction of travel may result in prolonged tire-paint stripe contact and serious control problems. In more than a few of the 900 cases, riders attempting to avoid collision with a car locked up their brakes and slid out after crossing pavement with a different (usually lower) friction coefficient. Contrary to some common notions, such "laying the bike down" is a poor way to avoid a collision, and the rider who is down sliding on impact with a car is likely to suffer **more** severe injuries than the rider who is upright on impact.

In addition to paint stripes, changes of pavement type can present the same sort of hazard. This is more serious in light of a recent trend toward putting a cobblestone-type concrete as a street decoration in such areas as shopping districts where motorcycle accidents are especially frequent (Figure 1.)

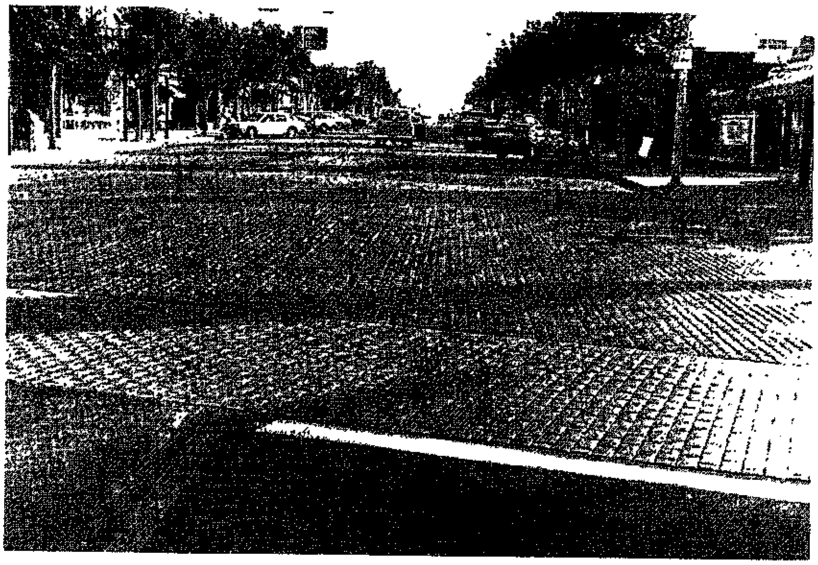

Fig. 1 - Changes in pavement surface, as from asphalt to cobblestone-like concrete shown here, can precipitate loss of control during heavy braking maneuvers.

Of course, changes of friction coefficient occur where there is pavement contamination such as gravel, sand or leaves on the roadway. Contamination is a special problem on the outside edge of curves, since motorcycles that fail the negotiate a turn properly usually do so by running wide on the turn. An automobile that runs wide and onto contaminated pavement may keep at least one set of wheels on normal pavement, but the motorcycle that runs onto contaminated pavement is completely into it, with reduced abilities to maneuver out of danger.

INJURY HAZARDS

The investigation of 900 motorcycle accidents showed 3016 somatic (i.e., all regions except head and neck) injuries, for which 5067 contact surfaces were identified as injury-causing agents (59.5% of the injuries were associated with two contact surfaces.) The roadway environment, excluding the motorcycle and any other vehicles, accounted for 1668 (32.9%) of the 5067 contact surfaces. Of the 1668 environment contact surfaces, pavement accounted for 1384 (82.9%). Trees, poles, fire hydrants, barriers, etc. accounted for 153 (9.2%) of the contact surfaces. However, pavement is a relatively benign injury agent, at least for somatic region injuries. Only 4% of pavement contacts resulted in AIS ≥ 3 injuries (4), and a substantial portion of those severe injuries involved pavement as a secondary surface against which a body part was trapped and crushed by the motorcycle or other vehicle. In contrast, 45.6% of tree, pole, etc. impacts resulted in AIS ≥ 3 injuries, as did 30.2% of barrier impacts.

The more vulnerable head and neck show a similar pattern, although there is a higher proportion of the severe injuries in all contact surface categories. The data show that 18.5% of head impacts to pavement resulted in AIS ≥ 3 injuries; for trees and poles, the figure is 58.7%, and for protective barriers it is 65.7%. The data are shown in Table 2 below, which portrays a crosstabulation of injury contact surface by injury severity only for pavement, trees and poles, and barriers (3).

Table 2 - Injury Severity by Contact Surface

A. Somatic Regions

Contact Surface	1	2	3	4	5	6	Total
Pavement	1217	114	35	10	5	2	1384
Trees, Poles	32	17	17	13	8	3	90
Barriers	25	19	13	4	2	0	63
Total	1274	150	65	27	15	5	1537

B. Head-Neck Regions

Contact Surface	1	2	3	4	5	6	Total
Pavement	353	63	34	12	27	4	493
Poles, Trees	25	12	9	2	9	6	63
Barriers	16	7	5	0	1	6	35
Total	394	82	48	14	37	16	591

Trees and poles and barriers are every bit as hard and immovable as pavement, yet there is a simple reason why tree and barrier impacts are so much more severe. Consider a simple vector analysis of rider motion during a fall to the pavement. Initially, the rider has speed in only one dimension: parallel to the roadway surface, If he falls at some speed, he continues to move forward at the same speed, but now his body accelerates downward as well and reaches a maximum velocity usually less than 15 mph. On impact the horizontal velocity component **parallel** to the pavement surface is the original forward velocity, while the vertical component is some low speed in the 10 - 15 mph range. This situation is diagrammed in Figure 2 below. The velocity component parallel to the impact surface usually does not generate injuries more severe than abrasion, but the velocity component **perpendicular** to the pavement can cause severe injuries, especially to the unprotected head.

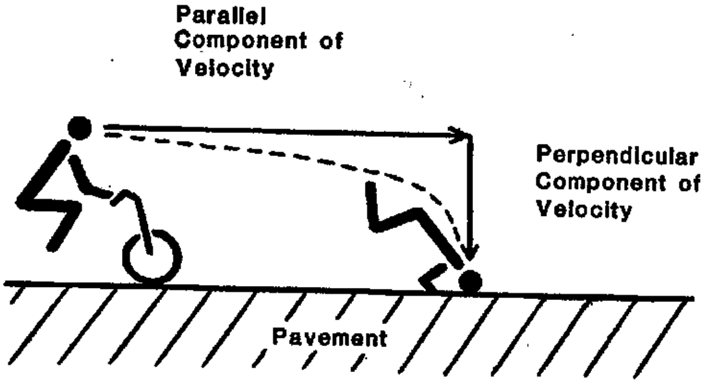

Fig. 2 - Vector diagram of horizontal and vertical components of velocity in a fall to the pavement.

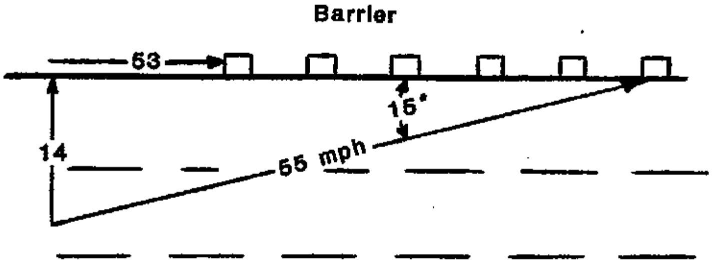

Fig. 3 - Vector diagram of velocity components in a 55mph, 15° impact with a barrier that presents surfaces parallel and perpendicular to the traffic flow.

Now consider how a vector analysis applies to the rider who collides with a guardrail or median barrier, and consider only those velocity components perpendicular to the various barrier surfaces. Assume for this example a 55 mph impact velocity at 15°, as shown in Figure 3. Simple trigonometry shows a velocity component of 14 mph for impact with a surface **parallel** to the traffic flow. However, impact with a surface **perpendicular** to the flow of traffic results in an impact velocity component that is nearly 100% of the total speed. Trees, poles, and many guardrail elements tend to be struck with a very high proportion of the total speed perpendicular to the impact surface and thus generate many severe and lethal injuries.

The implications for barrier and guardrail design are clear: smooth surfaces parallel to the flow of traffic pose a far less lethal hazard than those with surfaces perpendicular to the flow. In the analysis of 900 motorcycle accidents, **every** rider who struck a W-beam barrier (Figure 4) or metal mesh fencing (Figure 5) suffered at least multiple extremity fractures; six were killed, three by partial or total decapitation.

In accidents involving W-beam barriers, motorcyclists tend to strike the barrier at a shallow angle, fall and tumble along the tops of the posts. If they slide into the barrier, they tumble along striking the bases of the posts. The post tops and bottoms present edges which tend to concentrate impact forces and increase the severity of injuries. Additionally the edges of the corrugated metal beam can cause extreme laceration injuries.

The metal mesh barriers injure in a similar way. The mounting posts cause the most severe injuries, either by deceleration of the torso or by fractures of the extremities. The metal edges of the barrier provide numerous lacerating surfaces, and the top edge, with its saw-tooth projections, is at about rider head level.

The recent trend toward solid concrete guardrails and barriers (Figure 6) is likely to prove beneficial to motorcyclists in most cases. Most barrier impacts are at very shallow angles, so tumbling along a smooth concrete barrier is likely to be about as injurious as sliding along pavement. The requirement for a **smooth** barrier surface is emphasized by one case, shown in Figure 7. Here, the motorcycle rider ran wide on a turn, struck the curb, fell and slid on the sidewalk. He slid into the barrier and struck his head on an exposed decorative edge, causing massive skull fractures and extrusion of cranial contents.

Generally speaking, the trees, poles, fire hydrants, bus benches and other roadside hazards that can cause severe injury and death tend to be immediately adjacent to the curb. This is most

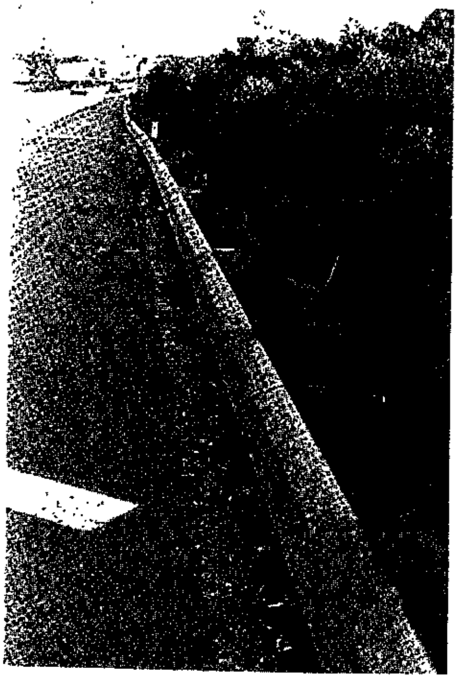

Fig. 4 - W-beam barriers severely injure motorcyclists who tend to tumble on top of posts after impact.

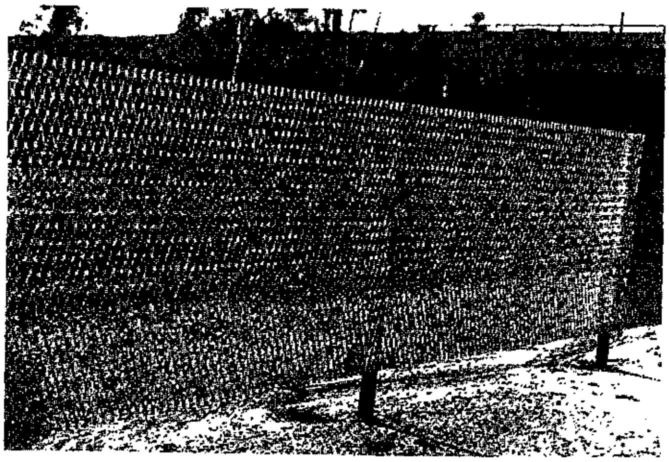

Fig. 5 - Metal mesh fencing provides numerous lacerating surfaces, and support posts can cause lethal deceleration injuries. Sharp-edged fence tops is at rider head level.

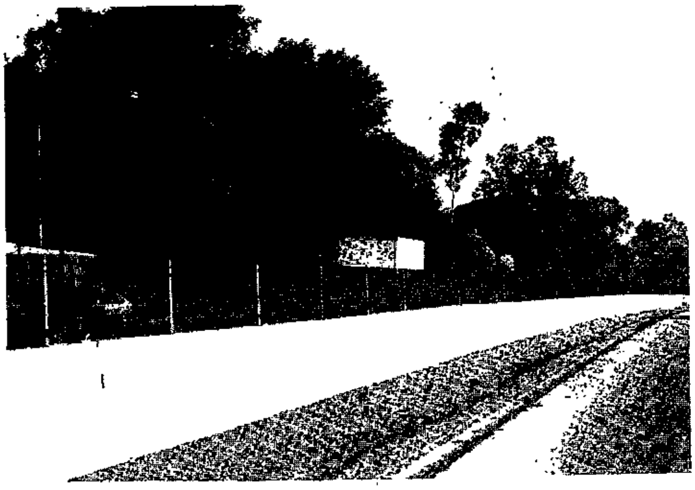

Fig. 6 - Smooth-faced concrete median divider offers minimal injury-producing surfaces. However, glare screen atop barrier offers the same injury potential as the metal mesh fence in figure 5.

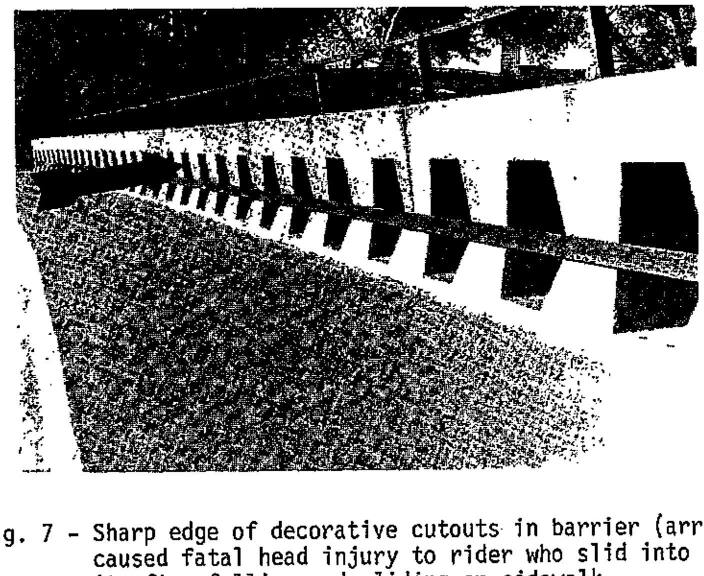

Fig. 7 - Sharp edge of decorative cutouts in barrier (arrow) caused fatal head injury to rider who slid into it after falling and sliding on sidewalk.

unfortunate since few motorcyclists get more than about five feet off the edge of the roadway in the course of an accident. Thus those who do go off the roadway tumble and slide to a stop just adjacent to the curb, precisely where those life-threatenting hazards are located. Of 54 riders and 5 passengers killed in the 900 accidents, 12 (20.3%) were killed by just such roadside obstacles. It is probable that any rider who hits a roadside tree or pole will be killed or severely injured. The task of removing every such obstacle is out of the question, but it may be prudent in the future to limit these obstacles, especially in those areas that are the most likely candidates for single vehicle motorcycle accidents, such as the outside of curves.

Fig. 8 - Cloth marks on top of low bridge railing (arrow) portray rider trajectory just before falling 70 ft. to the street below.

The problem of running wide on turns presents another unique problem for motorcycle riders and a challenge to barrier design. Many barrier systems on curved bridges such as freeway connectors are designed to restrain an automobile, and they do a good job of restraining motorcycles. But they are too low to prevent the motorcycle rider from going over the edge to almost certain death. A review of 375 motorcycle accidents in Los Angeles showed that at least ten (2.7%) resulted from a rider ejecting over a barrier that was too low to restrain his body. In two cases the rider was ejected into opposing traffic; in all others death resulted from falls of 25 - 70 feet. Figure 8 shows the cloth marks of a rider who ejected over a low railing and fell 70 feet. The requirements for prevention of these incidents are simple: a smooth protective barrier that rises to a little higher than the rider center of mass (to perhaps 4½ feet) will suffice. The most obvious candidates for their use would be urban freeway interchanges and elevated off-ramps.

It is well known that motorcycles account for roughly 10% of vehicular fatalities nationwide, even though they account for less than 1% of the traffic (2). What has not been well understood is how highway design features contribute to this toll by failing to consider the special requirements for the protection of motorcyclists. Although government agencies have conducted crash tests of automobiles and buses against guardrails for years, no program to study motorcycles and riders has been undertaken. If a reduction in the motorcycle death toll is to be achieved, the evolution of highway design and barrier systems must take into account the special requirements for protection of motorcycle riders.

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