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MOTORCYCLE CONSPICUITY AND TRAFFIC ACCIDENTS

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Abstract—An analysis of data from 1508 motorcycle accidents obtained from Victoria Police files for the year 1974 indicates that inadequate motorcycle visibility is an associated factor in 64.5% of automobile/motorcycle collisions. It is the sole identifiable cause of 21.0% of collisions. The conspicuity of the front of the motorcycle is found to be vitally important in these accidents.

INTRODUCTION

In recent years, motor vehicle occupant fatality rates in Australia have shown a downward trend, largely due to the introduction of safety legislation and the compulsory wearing of seat belts. During this same period however, motorcycle numbers, and casualty accidents, have shown a rapid increase. The motorcycle, because of its increased popularity, has become of major concern as a cause of death and injury.

Recognition of the problem is not new; many researchers have discussed it over the past decade. They have stated that a major factor in multi-vehicle accidents involving motorcycles is that drivers of motor cars simply "do not see" the motorcycle, or see it too late to avoid a collision.

In Australia, the Expert Group on Road Safety[Meares *et al.*, 1972] in their review "The Road Accident Situation in Australia", noted that:

> "a frequent factor in motorcycle accidents is that the motorcycle and its rider are not easily seen. This is illustrated by the high number of accidents in which a vehicle turns across the path of the motorcycle".

The purpose of this study was to review the literature concerning motorcycle accidents in which lack of visibility may have been a factor and to investigate motorcycle accidents in the State of Victoria (Australia), in order to obtain a more detailed picture of the types of accident which are occurring and the part that lack of visibility may play in them.

THE RELATIONSHIP BETWEEN INADEQUATE MOTORCYCLE VISIBILITY AND TRAFFIC ACCIDENTS

Numerous investigations of motorcycle collisions have concluded that one of their principal causes is the apparent failure of a motorist to see the approaching motorcycle before impact occurs. The evidence supporting the existence of this phenomenon varies from intuitive feelings of researchers, written statements of accident victims, police reports and statistical inferences drawn from the involvement of motorcycles in certain types of accidents.

Most authors have drawn attention to the existence of the problem and have drawn inferences from accident data regarding the number of drivers who "failed to see" a motorcycle before colliding with it[Robertson *et al.*, 1966; Henderson, 1970; Berenguel, 1971; Messiter, 1972; Shields, 1972; Cararro, 1973; Suzuki, 1973; U.S. Department of Transportation, 1976].

A second group of authors have attempted to quantify more accurately the effect of inadequate motorcycle visibility on traffic accidents[Jamieson and Tait, 1966; McCracken, 1967; Waller *et al.*, 1968; Waller, 1972; Griffin and Waller, 1976; Watson and Lander, 1973].

A final group measured the over-involvement of motorcycles in certain types of collision[Lehmann, 1962; Foldvary, 1967*a*,*b*; Smith, 1975].

The various authors have stated their views on the extent of the problem, the factors which make it a problem, and the solution. The assertions can be summarised as follows:

The problem

(i) Collisions between a motorcycle and another road user are the most common form of motorcycle accident[Robertson *et al.*, 1966; Berenguel, 1970; Henderson, 1976; Messiter, 1972; Carraro, 1973].

(ii) The most common collisions arise when an automobile pulls out of an intersecting roadway at right angles to a motorcycle or when a motorist makes a right hand turn (U.K., Australia designation) across the path of an approaching motorcycle[Robertson *et al.*, 1966; Henderson, 1970; Shields, 1972].

(iii) Motorcyclists are significantly more likely to be the victim in a collision rather than the guilty party[Berenguel, 1970; Waller, 1968; Reiss *et al.*, 1974; Smith, 1975; Lehmann, 1962; Foldvary, 1967*a*,*b*; Henderson, 1970].

(iv) Motorcyclists are over-involved in collisions at intersections which involve turning, right-of-way or signalling errors on the part of other drivers[Waller, 1972; Foldvary, 1967*a*,*b*].

The cause of the problem

(i) The major threat to the motorcyclist is the automobile operator who does not "see" him[Messiter, 1972; Jamieson and Tait, 1966; Waller, 1972; U.S. D.O.T., 1976].

(ii) Motorcyclists are not seen by the other road user in a large proportion of collisions[Henderson, 1970; Berenguel, 1970; Carraro, 1973; Watson and Lander, 1973].

(iii) The overall size and shape of the motorcycle and rider are such that the criteria for reliable perception are frequently not met[Messiter, 1972; Woltmann and Austin, 1974; Shields, 1972; Suzuki, 1973; Lehmann, 1962].

(iv) Motorists choose consciously or unconsciously to ignore the existence of motorcycles[Henderson, 1970].

(v) Motorists may not perceive that motorcycles have right-of-way privileges and capabilities of acceleration and speed that are equal to those of automobiles[U.S. D.O.T., 1976].

(vi) Motorists may have such strong expectancies to find only four-wheeled vehicles on the roadway that even when a motorcycle is detected it is perceived only as a non-automobile[Cumming, 1967; McLean, 1971].

The solution

(i) Improve the visibility of the rider[Carraro, 1973; Suzuki, 1973; Woltmann and Austin, 1974].

(ii) Increase the frontal area of the motorcycle[Shields, 1972; Messiter, 1972].

(iii) Ride with low beam headlights on at all times[Carraro, 1973; Waller, 1972; Smith, 1975].

(iv) Ensure that motorcycles and rider's clothing are brightly coloured or reflective to aid visibility and recognisability[Waller, 1972; Watson and Lander, 1973; Foldvary, 1973].

(v) Increase the probability of detection of motorcycle by any means[U.S. D.O.T., 1976].

None of the studies provided sufficient information about the problem of inadequate motorcycle visibility. Although it has been established that motorists "did not see" motorcycles prior to a large proportion of collisions, no attempt was made to put the problem into perspective. There was no apparent attempt to determine whether there was some plausible explanation for their failure; perhaps that the motorist's view of the small motorcycle was physically obstructed, that the motorist was concentrating on some other vehicle or section of the roadway at the time or that the motorcycle blended into its background.

More importantly there was typically no attempt to ascertain whether another serious factor such as speed, alcohol or aberrant driving had a significant influence on the outcome of the individual accidents in which motorcycle visibility played a role. The hypothetical explanations for motorists failing to see motorcycles are certainly plausible. They deserve thorough investigation, but without this confirmation they cannot be regarded as other than conjecture.

The suggested solutions to the problem all entail an increase in the visibility of the

motorcycle or rider, *per se*. There was no apparent consideration of vital details of the traffic accident situation which strongly affect the practicability of these suggestions: the separation of the two vehicles, the section of the motorcycle facing the other driver, background conditions, the influence of other traffic. None of the proposals can be regarded as valid until these details are known.

The aim in commencing a new study of motorcycle accidents was to make a more rigorous assessment of the influence of inadequate motorcycle visibility than any of the published studies had performed and to determine the characteristics of those accidents for the purpose of assessing the nature of the problem.

METHOD

This study involved an examination of legal documents prepared by Victoria Police describing 1508 of the 1577 fatal and injury producing motorcycle accidents reported to The Force during 1974. Files were available for all 76 fatal motorcycle accidents and 1432 of the injury producing accidents. The remainder, 69, were subject to legal proceedings at the time of the study.

The purpose of the study was two-fold: (a) to assess conservatively the magnitude of the visibility problem. Operationally, because of the shortcomings of the police data, it was necessary to adopt as a criterion measure, accidents in which no factor other than inadequate visibility was mentioned in the recorded evidence. (b) To examine individual traffic accidents identified in (a), and thus ascertain features of the vehicles, vehicle users, roadway conditions and the traffic system which could have influenced the outcome of the accident.

Sources of accident information

In Victoria, police officers attending accidents record details of the location, the vehicles involved and other statistical data and interview accident victims and witnesses whenever possible. Their primary obligation is to ascertain whether any person has violated a road traffic regulation and, if so, prepare a legal case against him. The original records and legal briefs are kept by the Police Traffic Branch; summarised information is passed on to the Road Safety and Traffic Authority and the Australian Bureau of Statistics. In this analysis the original information was used. No summary or other subjective assessment of the situation was used.

The main documents used were: (a) Accident Report Form 513 (description of accident, environmental conditions, vehicles, drivers and other statistical data). (b) Deposition of a Witness (signed statements made by drivers, riders, passengers or independent witnesses). (c) Certificate of Analysis (breathalyser test or blood sample test). (d) "Information from Drivers Record" form. (e) Certification of Scientific Tests (mechanical defects). (f) Post-mortem Report. (g) Photographs of the vehicles and the accident site.

Many of these files contained extensive reports of the accidents, particularly those relating to fatal accidents. In that situation, investigating police officers were required to prepare a submission for a Coroner's Court of Inquiry so extra effort was expended in ascertaining the cause of death.

Virtually all the files contained statements made by accident participants and in most cases it appeared that a police officer had attended the accident scene. The latter feature is evidently in contrast to the situation for casualty accidents involving larger vehicles.

Possibly the reason for the high rate of police attendance was the fact that the motorcyclists were very often incapacitated after the accident.

Reliability of information

The fundamental defect in data of this type is the errors of both omission and commission which almost certainly exist in its various components.

The material is collected by police who are obliged to search for breaches of road traffic regulations in accident situations. Their line of questioning and reporting is naturally directed towards this end. If accidents are not attended by police the accident reports depend on the completeness, accuracy and reliability of participants' versions of events. It is probable that many minor accidents go unreported to police. This would bias the available information towards serious motorcycle accidents.

Finally, the information obtained from the files may be considered to have varying levels of reliability, depending upon the amount of subjective interpretation fed into the data either by the police, witnesses or the authors. In the following analysis, information with all levels of reliability has been used in order to gain as complete a picture as possible of the many factors which could have influenced the outcome of an accident.

The types of information and their levels of reliability may be described as follows:

(a) *Factual.* The date, time, day of week, place of accident, type of road, speed limit, weather and lighting conditions, the type of vehicle involved, age and sex of participants, injuries sustained, driving experience, licence condition, results of breathalyser and blood alcohol tests, record of prior convictions and convictions resulting from the accident, that is, more or less incontestable data of a statistical nature. The main sources of unreliability would probably be human error, possible approximation or an inability to obtain information in some circumstances.

(b) *Recorded statements.* Signed statements made by participants or witnesses to the accidents proved to be very useful. They usually gave considerable background material into the circumstances of the accident and were more illuminating than the accident summaries. Naturally this information was subject to bias; it depended not only on the veracity of witnesses interested in self preservation but also on the interviewing skill of the police officer. Some of the statements were directly incriminatory ("... I just began to turn right and the motorcycle hit..."); most resulted from a road user's attempts to justify or explain his actions ("... I just did not see it..."); and some were apparently factual ("... the back wheel slipped on a tramline....").

Information of this type included the movements made by all vehicles prior to the accident, roadway conditions, the influence of other vehicles at the scene, the presence of objects which obstructed the view of either operator and indications that the driver did not see the motorcycle or underestimated its speed.

(c) *Subjective judgements.* The recorded statements provided some information that contained a high degree of subjective judgement by witnesses. For example it was sometimes necessary to accept estimations of the speeds of vehicles or the phase of the traffic lights at an intersection to categorise accidents.

It was not surprising that most operators claimed to have been travelling within the speed limit prior to an accident, but the severity of some accidents indicated otherwise. Occasionally it was possible to verify the statement from a description of the length of skid marks, the extent of damage or the distance that vehicles or occupants were thrown after the impact. This method was useful only to validate estimates of high or low speed impacts; there was no alternative but to accept the statement made about the large group of moderate speed accidents.

Similarly, most operators involved in a collision at an intersection claimed that they entered it when faced with a green or amber traffic light. Unless there was supporting evidence from an independent witness, accidents which occurred during the changeover period from green to red lights were classified separately.

It was not possible to obtain adequate information about a small group of accidents. It included fatal or serious injury accidents involving only a motorcycle which were not witnessed, cases in which a participant refused to make a statement or failed to stop after an accident and situations in which the signed statements were contradictory in some fundamental way.

It was not necessary to use the brief summary of the accident which indicated the "principal cause" and the "operator at fault".

Data analysis

The aim in processing the data was to identify and record elements of the chain of events which, acting together, produced individual traffic accidents. No attempt was made to oversimplify situations by merely assigning the principal blame to one operator or a single prevailing condition. In conducting the analysis, the authors assessed the available evidence to determine whether any factor other than motorcycle visibility had played a part. If so, the accident was removed from further analysis.

Accidents were classified initially in terms of two main features, the types of road user involved and the movements made by the road users.

(a) *Type of accident*

Multi vehicle accidents. Those situations in which one or both road users made a manoeuvre or acted in a way which directly resulted in a collision. If this action caused another road user to lose control of his vehicle and crash without necessarily striking the first vehicle, the accident was classified as a multi-vehicle accident.

Single vehicle accidents. Those situations in which a motorcycle rider lost control of his vehicle and crashed without having been influenced by another road user.

Pseudo-single vehicle accident. Those situations in which there was considerable evidence to show that one operator lost control of his vehicle and consequently collided with another vehicle whose driver did not contribute to the accident (PSV1—driver lost control; PSV2—rider lost control).

Pedestrian/bicycle/animal. Those situations in which a motorcycle struck or swerved to avoid a pedestrian, bicycle or animal on the roadway.

(b) *Vehicle movement code*

Multi-vehicle accidents were classified according to the initial movement of one or both vehicles which produced the accident, or, if this was not readily identifiable, the orientation and direction of approach of the two vehicles.

Of the six general categories, "Turn", "U-turn" and "Diverge" refer to a specific movement made by one of the vehicles, while "Angle", "Rear End" and "Head On" are based primarily on the relative orientation of the two vehicles prior to the collision. These categories have been coded for convenience: each is described and illustrated in Table 1.

Table 1. Vehicle movement code

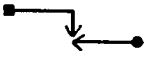
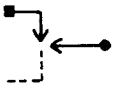
Angle:A	
Two vehicles approached one another from two or more roadways or from a roadway and a private driveway set at an angle, and collided. Most of these accidents occurred at the right angled intersection of two roadways.	
A1. Two vehicles collided at the intersection of two or more roadways. The motorcycle had right of way.	
A2. Same roadway conditions. The motor vehicle had right of way.	
Turn:T	
One vehicle made a right hand turn across the path of a vehicle approaching from the opposite direction.	
T1. Motor vehicle made a right hand turn across the path of a motorcycle approaching from the opposite direction.	
T2. Similar roadway conditions. Motorcycle turned across the path of the other vehicle.	

Table 1. (*Contd*)

U-Turn:U

One vehicle made a 180° turn on the roadway and crossed the path of another approaching vehicle.

U1.1. Motor vehicle driver made 180° turn across the path of a motor cycle approaching from ahead.



U1.2. Motor vehicle driver made a 180° turn into the path of a motorcycle approaching from behind.

U2. Motorcycle made 180° turn into the path of a motor vehicle approaching from behind.

Rear End:R

One vehicle collided with the rear end of another vehicle stationary or moving straight ahead on the roadway.

R1. Motor vehicle ran into rear end of motorcycle stationary or moving straight on the roadway.

R2.1. Motorcycle ran into the rear of stationary or moving motor vehicle ahead of it on the roadway.

R2.2. Motorcycle ran into rear of legally parked vehicle adjacent to roadway

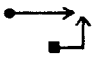
Diverge:D

One vehicle diverged from its direction of travel and crossed the path of another vehicle approaching from behind.

D1.1. Motor vehicle made a right hand turn across the path of an approaching motorcycle.

D1.2. Motor vehicle changed lanes or veered to the right and crossed the path of an approaching motorcycle.

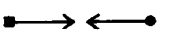
D2.1. Motor vehicle made a left hand turn into the path of an approaching motor cycle.



D2.2. Motor vehicle changed lanes or veered to the left and crossed the path of an approaching motorcycle.

Head-on:H

Two vehicles approached one another from opposite directions and collided head-on.



Code: car ■ cycle ●

RESULTS OF ANALYSIS

Some indication of the general characteristics of motorcycle accidents in Victoria can be obtained from Table 2 which indicates the road users involved and the vehicle movement codes.

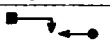
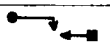
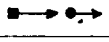
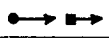
Severity

A total of 1508 fatal and injury producing motorcycle accidents were studied. In 76 of these (5.0%) fatal injuries were sustained by one or more of the persons involved. In only one case was a car occupant killed.

Time of day

63.7% of all accidents occurred during the day, 29.0% at night, 1.7% at dawn and 5.7% at dusk. The distribution of fatal accidents by time of day was somewhat different: 47.4% occurred during the day, 40.8% at night, none at dawn and 11.8% at dusk.

Table 2. Characteristics of motorcycle accidents

	Movement Code	Day	Night	Dawn	Dusk	
Angle Collision	A1 	222(1)	66(3)	5	18	315
	A2 	71(4)	27	2	6	110
Turn Collision	T1 	100(2)	59(4)	10	14(2)	191
	T2 	11	5	-	1	17
U-Turn Collision	U1.1 	12	2	-	-	14
	U1.2 	36(1)	14	1	1(2)	55
	U2 	5	5	-	-	10
Rear End Collision	R1 	13(3)	14	1	1(1)	33
	R2.1 	71(1)	16(1)	1	6(1)	97
	R2.2 	8(3)	20(2)	1	-	34
Diverge Collision	D1.1 	68	17(2)	1	6	94
	D2.1 	13	4(1)	-	2	20
	D1.2 	10	6	-	-	16
	D2.2 	19	2	-	1	22
Head-on Collision	H	36(2)	7(1)	2	3	51
Single Vehicle	SV	124(12)	99(9)	1	9	254
	PSV1	34(4)	12(3)	-	(3)	56
	PSV2	4(1)	5(3)	-	1	14
Other	Ped.	45(2)	14(1)	-	7	69
	Bic.	10	1	-	-	11
	Anml.	11	11(1)	-	1	24
Total		924(36)	406(31)	25(-)	77(9)	1508

( ) indicates fatal accidents.

Dawn/Dusk - accidents occurred within half an hour of the official time of sunrise or sunset (Science Museum Victoria).

Type of accident

Multi-vehicle accidents accounted for 71.6% of total accidents, while single vehicle accidents accounted for 21.6%. Accidents involving pedestrians, bicycles and animals (4.6%, 0.7% and 1.6% respectively, of the total) were relatively infrequent.

Multi-vehicle accidents were more frequent during daylight (66.0%) than at night (25.8%), dawn (2.2%) or dusk (6.0%).

Single vehicle accidents were evenly distributed. 55.2% occurred during daylight, 40.4% at night, 0.3% at dawn and 4.0% at dusk.

Multi-vehicle accidents

Collisions which occurred when two vehicles approached one another at an angle were the most common. They represented 28.2% of total accidents (A1, A2).

Collisions which resulted from a turning manoeuvre when the motorcycle was ahead of the other vehicle accounted for 15.4% of total accidents (T1, T2, U1.1, U2).

Collisions which occurred when the motor vehicle driver moved into the path of a motorcycle approaching from behind represented 13.7% of total accidents (U1.2, D1, D2).

Collisions which involved one vehicle striking the rear end of another which was stationary or moving straight ahead accounted for 10.9% of total accidents (R1, R2).

Head-on collisions between two vehicles moving straight accounted for 3.4% of total accidents (H). The apparent infrequency of this type of accident may be partly due to the separate classification (as pseudo-single vehicle accidents) of interactions in which one operator lost control of his vehicle and then struck a second vehicle whose driver had not contributed to the accident. This group accounted for 4.7% of total accidents (PSV).

"Angle" collisions

The motorcycle rider had right of way according to road traffic regulations in 74.1% of "angle" collisions. This included accidents occurring at signalised and traffic sign controlled intersections.

"Turn" collisions

The motor car turned across the path of an approaching motorcycle in 92.7% of all collisions which involved a right hand turn or a 180° turn when the motorcycle was ahead of the other vehicle (T1, T2, U1.1, U2).

"Rear-end" collisions

In 131 "rear-end" collisions a motorcycle struck the rear end of another vehicle. A motorcycle was struck from behind on only 33 occasions (2.2% of total accidents). Even with this degree of analysis it is obvious that rear end visibility of motorcycles was not a major problem in Victoria during 1974.

AN ASSEMENT OF THE INFLUENCE OF MOTORCYCLE VISIBILITY ON MULTI VEHICLE MOTORCYCLE ACCIDENTS

(a) *Analytic principles*

It is extremely difficult to isolate the role of visibility as a causative factor through a process of retrospective reconstruction from police reported accident data. Nevertheless, in the absence of better data, it was the only viable method of obtaining a reasonable estimate which could be used as a first approximation to the influence of this factor on motorcycle accidents.

The estimate was made by determining the number of multi-vehicle accidents which occurred solely as a result of the apparent failure of a road user to see an approaching motorcycle when there was no physical obstruction to the driver's view of the roadway. If any other serious factor appeared to have influenced the outcome of the accident it was not included in the tally.

In order to make this judgement it was necessary to define those contributing factors which could have affected the accidents.

Contributing factors in multi-vehicle accidents

In multi-vehicle accidents, it was usually possible to identify a manoeuvre or action made by one operator which led directly to the accident. However, it was often apparent that the operator's decision to make an initial movement was influenced by factors related to vehicle or roadway characteristics or the behaviour of other road users. These factors—classified below—mainly reflect the driver's success or failure in noticing a motorcycle which was a dominant factor in the causation of multi-vehicle accidents. They also accounted for aberrant driving behaviour on the part of one or more of the road users.

Type 1. *Driver "did not see" motorcycle. No obstruction to vision.* The driver stated that he did not see the motorcycle prior to commencing the initial movement which produced a collision. There was nothing to indicate that the driver's vision of the motorcycle was physically obstructed.

Type 2. *Driver "did not see" motorcycle. Vision obstructed.* The driver stated that he did not see the motorcycle but it was possible that his view of the motorcycle may have been physically obstructed when he decided to make a manoeuvre. The obstructions included moving or stationary vehicles nearby, parked vehicles, fixed objects or a crest or curve in the roadway, glare from a low sun or heavy rain.

Type 3. *Driver "did not see" motorcycle. Concentrating on another vehicle.* The driver stated that he began to move when another vehicle yielded right-of-way. He was probably concentrating on this other vehicle, and/or his view of the motorcycle may have been obstructed at the time he decided to manoeuvre.

Type 4. *Driver saw motorcycle.* The driver stated that he saw the motorcycle but still manoeuvred his vehicle into its path, usually because he underestimated its speed.

Type 5. *Aberrant driving.* There was some indication that at least one of the operators was driving in an irresponsible manner or his faculties were impaired by alcohol. Irresponsible driving included travelling at a speed exceeding the limit or committing some serious breach of road traffic regulations.

The results of blood alcohol concentration tests for all killed and many injured riders and breathalyser tests performed on drivers were available.

Type 6. *Other factors.* It must be emphasised that a number of other important factors are said to influence the likelihood of a motorcycle rider becoming involved in an accident. These include youthfulness and inexperience[Foldvary, 1965; Reiss and Haley, 1968; Henderson, 1970; Messiter, 1972; Foldvary, 1973]; motorcycle power[Jeffcoate and Garwood, 1956; Munden, 1964; Widen, 1973; Bygren, 1974; O.E.C.D., 1975; Johnston *et al.*, 1976]; and psychological factors[Menzies, 1968; Nicholai, 1970].

It was not often possible to ascertain whether these factors had a direct bearing on the individual accidents examined in this study. The data for the entire group of accidents would need to be compared to population and exposure data pertaining to motorcycle use in Victoria during 1974 to determine their importance. General conclusions could then be drawn but the influence of these factors could not be related back to individual accidents.

(b) *Analysis of accidents*

Using these principles it was possible to eliminate entire groups of multi-vehicle motorcycle accidents of particular types and to progressively refine the data into the required form. The six main steps taken to achieve this result are described below.

(i) *Influence of rearward visibility.* Accidents in which a motorcycle approached another vehicle from behind were disregarded because the driver's view of the motorcycle may have been obstructed by the rear roof pillars of his own vehicle or the field of view of his rear vision mirror may have been too limited to include the motorcycle (type 2 contributing factor). Thus R2, D1, D2 and U2 were omitted.

(ii) *Influence of rider error.* Accidents in which the motorcycle appeared to have breached traffic regulations were ignored (type 5 contributing factor). Thus A2, T2 and U2 were omitted.

(iii) *Influence of other vehicles.* The summaries were checked to determine whether the driver's view of the motorcycle could have been obstructed by another vehicle (type 2 contributing factor), or whether his decision to manoeuvre could have been based on the actions or anticipated actions of another vehicle (type 3 contributing factor).

(iv) *Influence of operator behaviour, weather and roadway features.* The summaries were then checked for evidence that the driving behaviour of either operator could have contributed to the accident, or that the driver's view of the motorcycle could have been obstructed by a fixed object, a crest or curve in the roadway or by weather conditions. More were rejected on these grounds.

(v) *Influence of driver error.* Finally the remaining accidents were classified according to the motor vehicle driver's stated reason for making the initial manoeuvre into the path of the motorcycle. This resulted in the exclusion of many more accidents. (a) The driver stated that he saw the motorcycle. "Misjudged speed". The driver stated that he saw the motorcycle in time but underestimated its speed of approach. "Other reason". The driver gave some special reason for making the manoeuvre. (b) The driver stated that he did not see the motorcycle. "Did not see". The driver stated either that he did not see the motorcycle until after the collision, or that he saw it when it was too late to react. (Retained in tally.) "Saw too late". The driver stated that he saw the motorcycle after commencing a manoeuvre, tried to avoid it, but failed. (Retained in tally.)

(vi) *Pedestrian and bicycle accidents.* The 69 pedestrian accidents and 11 bicycle accidents were analysed in a similar fashion to determine the number where no factor other than the apparent failure of the person involved to see an approaching motorcycle was evident.

This exhaustive method of analysis produced a final group of accidents which, for convenience, were designated "pure-visibility" motorcycle accidents (Table 3).

(c) *Results*

Collisions between a motorcycle and another road user (vehicle, pedestrian, bicycle) accounted for 78.4% of the 1508 motorcycle accidents studied.

In the initial assessment of the effect of motorcycle visibility on these accidents the statements made by the drivers who collided with the motorcycle were recorded. Seven hundred and sixty-three of the 1183 road users who come into collision with a motorcycle stated either that they did not see it at all, or they saw it when it was too late to avoid an accident.

On their face value the figures indicate the half (50.6%) of the motorcycle accidents recorded in Victoria in 1974 were caused, in part, by the failure of a road user to see a motorcycle.

Table 3. "Pure-visibility" motorcycle accidents

Relative Position of Motor-cycle	Movement Code	Time of Day				
		Day	Night	Dawn	Dusk	
Ahead	T1	41	23(1)	5	5(1)	76
	U1.1	8	0	0	0	8
	R1	0	0	0	0	0
	H	2	2	0	1	5
At Right Angles	A1	94	39	4	2	139
	Ped	12	0	0	2	14
	Bic.	1	0	0	0	1
Total		158	67(1)	9	11(1)	245

( ) fatal accidents

Table 4. Causative factors in multivehicle motorcycle accidents

Apparent 'Cause' of Accident	Number	Per cent
Driver's view obstructed by his own vehicle	207	17
Driver's view obstructed by another vehicle	158	13
Driver's view obstructed by natural object	62	5
Rider failed to yield right-of-way	110	9
Motorcycle hit stationary vehicle	123	11
Aberrant driving or riding	70	6
Driver misjudged speed of motorcycle	46	4
Other reason	154	13
Driver did not see motorcycle - no apparent reason	245	21
Total	1183	100

The analysis of these 1183 accidents revealed that in many cases the road user's view of the motorcycle may have been physically obstructed or that some other factor may have had a greater influence on the event. Table 4 summarises the findings.

The last group of accidents, 245 in number, represent the multi-vehicle motorcycle accidents which, on the basis of all recorded evidence, were caused solely by the failure of a road user to see an approaching motorcycle. For convenience, they have been designated as "pure-visibility" motorcycle accidents.

DISCUSSION

The "pure-visibility" accidents all occurred when a road user moved into the path of an approaching motorcycle. In each case the road user stated that he did not see the motorcycle in time to avoid the collision. No other vehicles were involved, there was no indication that the road user's view of the motorcycle was obstructed in any way, and there was no recorded evidence that either operator was acting or using his vehicle in an unsafe manner.

Apparently the road user was oblivious to the presence of the motorcycle whilst the rider assumed that he had been seen and it was safe to proceed.

A total of 158 of these accidents happened in daylight (64% of multi-vehicle accidents), 68 occurred at night (27%), while the remaining 21 (9%) happened at dawn or dusk.

The 158 daytime accidents represent the minimum number of motorcycle accidents which could be affected by some alteration to the daytime visibility of motorcycles. It is probable that other accidents, partly caused by the failure of a road user to see a motorcycle, could also be influenced if the other road user were given earlier warning of its presence.

The existence of 89 accidents which occurred at night or in the reduced visibility conditions of dawn and dusk suggest that night time visibility of motorcycles may also be inadequate.

Position of the motorcycles prior to collision

The "pure-visibility" accidents have been divided into two groups based on the position of the motorcycle relative to the other road user prior to the accident (Table 5). This data was obtained directly from Table 3 in which the "Ahead" and "At Right Angles" designations are explained.

In 90 cases the motorcycle was ahead and slightly to the right of the other road user while in 155 cases, the motorcycle approached the other vehicle at right angles.

It can be assumed that in all cases the motorcycle had approached the other vehicle at approximately 60 km/hr or less. (There was no recorded evidence of excessive speed and the accidents happened in built-up areas.) If, for ease of analysis, it could be assumed that the other

Table 5. Position of motorcycle in "Pure-visibility" accidents

Position of Motorcycle	Day	Night	Dawn	Dusk	Total
Ahead	51 (21%)	27 (11%)	5 (2%)	7 (3%)	90 (37%)
At right angles	107 (44%)	40 (15%)	4 (2%)	4 (2%)	155 (63%)
Total	158 (64%)	67 (27%)	9 (4%)	11 (4%)	245 (100%)

road user was stationary or travelling at a very low speed, the two vehicles would have been separated by a distance shorter than the minimum braking distance of the motorcycle (at 60 km/hr) when the road user began to move into its path.

The Commonwealth Department of Transport[1974] tested the braking performance of twelve 1974 model motorcycles of various types and sizes. Under ideal conditions the average braking distance from an initial speed of 50 km/hr was 9.9 m. The range was from 8.1 to 14.2 m. Thus, taking into consideration the speed differences and allowing a rider response time of 0.7 sec, it can be deduced that the two vehicles were separated by a distance of the order of magnitude of 25–30 m when the motorist began to manoeuvre his vehicle into the path of the motorcycle.

Comparison between Victorian and overseas motorcycle accidents

An important finding of the present study was that whilst 763 of the 1183 road users (64%) who were involved in a collision with a motorcycle claimed that they "did not see" it, when allowance was made for the possibility that other factors may have had an equal or greater influence on the situations, only 256 collisions (21%) could reasonably be said, on the basis of recorded evidence, to have been primarily due to poor motorcycle visibility.

This result is not directly comparable to other findings because no other authors known to have studied motorcycle visibility used similar techniques to establish its importance. In fact only one other author has attempted a similar quantification of one of the results. Waller[1972], in her study of police reports describing 935 motorcycle accidents in North Carolina found that 62% of multi-vehicle motorcycle accidents "were the fault of the automobile driver" and, in most instances, the driver reported that he did not see the motorcycle.

Other bases of comparison do exist. It is possible to compare the overall motorcycle accident experience in five other areas on the basis of published directional analyses of motorcycle multi-vehicle accidents.

The U.S. Department of Transportation[1969] published details of 6000 multi-vehicle motorcycle accidents. Raeder and Negri[1969] provided tables describing 15,631 motorcycle accidents reported in New York State from 1965 to 1968. Waller[1972] tabulated vehicle movements and operator at fault in 935 accidents. Similar descriptions were provided by Inayoshi[1973] on 711 multi-vehicle motorcycle accidents in Japan. Smith[1975] tabulated driving errors made in 1119 motorcycle accidents reported in Western Australia during 1973.

All authors presented their material in different ways. Thus it was necessary to reanalyse the data to obtain comparable groups of accidents. This task was hampered by the different methods used to describe accidents and the different purposes of the authors in tabulating their data. These difficulties are reflected in the magnitude of figures in the "All Others" category (Table 6).

Table 6. Comparison of overall data: Victoria and other multi-vehicle motorcycle accidents

Type of Collision	Proportion of Total Collisions					
	US DoT [1969]	Raeder [1969]	Waller [1972]	Inayoshi [1977]	Smith [1975]	Present Study
Angle	30.5	26.8	26.5	27.8	30.1	35.9
Turn	14.3	16.2	33.2	16.0	20.3	18.8
Diverge	17.5	18.1	13.3	23.6	7.3	18.3
Rear End	22.8	19.5	10.5	18.8	11.2	13.9
Head on	5.3	5.3	3.7	13.8	11.0	4.3
All others	9.6	17.1	12.9	-	20.1	5.8

In Table 6 the relative frequency of different vehicle manoeuvres is compared, while in Table 7 the proportion of road users "at fault" in certain of the collisions is compared.

In view of the substantial differences in geography, climate, terrain, demographic features, size and traffic systems of the six centres and the coarseness of the data it is not possible to draw rigorous conclusions from the comparisons. However, both the gross statistics and the statements of "operator at fault" recorded in Waller[1972], Inayoshi[1973], Smith[1975] and the present study may provide acceptable information.

The most common form of motorcycle multi-vehicle accident involved two vehicles approaching one another at right angles (about 30%).

Four of the studies showed that the motor vehicle driver was in error, according to road traffic regulations, in three quarters of this type of accident.

About one quarter of the accidents occurred when one vehicle made a right hand turn (left turn in U.S.) across the path of a second vehicle approaching from the opposite direction. In about nine-tenths of this form of collision the motor vehicle driver turned into the path of a motorcycle according to four of the studies.

In about 20% of the accidents one vehicle manoeuvred into the path of another approaching from behind. The automobile driver made the initial manoeuvre in about 80% of this type of accident.

In a further 20% of the accidents one vehicle struck the rear end of a second vehicle. The motorcycle struck the rear end of the other vehicle in about 80% of these collisions.

The other principal form of accident, accounting for about 8% of the total, involved two vehicles colliding head-on.

Mindful of the restrictions imposed by inadequate data for comparison, it can be concluded that the motorcycle accident pattern revealed in this study is similar, in overall terms, to that of the other regions considered. Motorcyclists were involved in similar types of accidents and were the victims of another road users actions with similar frequency. On this basis it may be suggested, cautiously that conclusions drawn from this study may have wider implications.

CONCLUSIONS

(a) Collisions between a motorcycle and another road user accounted for 78.4% of the 1508 motorcycle accidents investigated.

(b) In 64.5% (763) of the collisions the driver involved claimed either that he did not see the motorcycle or that he saw it too late to avoid impact.

(c) A conservative appraisal of these accidents revealed that 21.0% (245) were due solely to the failure of a motorist to see an approaching motorcycle. These were designated "pure visibility" accidents.

(d) One hundred and fifty eight of the "pure-visibility" accidents occurred in daylight, comprising 10.5% of total accidents. They represent the minimum number likely to be affected by some improvement to the daytime conspicuity of motorcycles.

(e) The motorcycles involved in "pure-visibility" accidents were positioned about 25–30 m from the other road users when the latter began to move into their path.

Table 7. Comparison of particular features: Victoria and other motorcycle accidents

Type of Collision		Special Comparison of Proportions			
		Waller [1972]	Inayoshi [1973]	Smith [1975]	Present Study
Angle	Driver at fault	75% of 167	63% of 198	79% of 263	74% of 425
Turn	Driver made turn	87% of 209	86% of 108	90% of 187	92% of 208
Rear End	Cycle hit rear of car	100% of 66	84% of 133	76% of 82	80% of 164
Diverge	Driver manoeuvre	75% of 84	100% of 168	78% of 67	94% of 162

(f) Frontal and side-on conspicuity of the motorcycle are of vital importance. Inadequate rearward conspicuity was not a significant cause of accidents.

(g) The motorcycle accident pattern revealed in this study was similar to that reported in the U.S.A., Japan and Western Australia. (As a result these conclusions may have wider implications.)

REFERENCES

Berenguel A. O., *A motorcycle accident study.* Iowa Department of Public Safety, 1971.

Bygren L. O., The driver's exposure to risk of accident. *Scand. J. Soc. Med.* 2(2), 49–65, 1974.

Carraro B., A look at motorcycle accidents in 1972. *Traffic Safety* 73(12), 16–18, 39–42, 1973.

Cumming R. W., Capabilities and limitations of a driver. *Proc. Symp. Traffic Hazards and the Community.* University of Western Australia, October 1967.

Commonwealth Department of Transport, Braking tests on motorcycles. Private communication, Oct. 15, 1976.

Foldvary L. A., Analysis of age and experience of responsible and non-responsible drivers involved in motorcycle vs other motor vehicle collisions in Victoria 1961 and 1962. *Aust. Rd. Res.* 2(3), 43–50, 1965.

Foldvary L. A., A method of analysing collision accidents: Tested on Victorian road accidents of 1961 and 1962 (Part 1). *Aust. Rd. Res.* 3(3), 22–28, 1967*a*.

Foldvary L. A., A method of analysing collision accidents: Tested on Victorian road accidents of 1961 and 1962 (Part 2). *Aust. Rd. Res.* 3(4), 41–55, 1967*b*.

Foldvary L. A., *A review of pedestrians, pedalcyclists and motorcyclists in relation to road safety.* Australian Government Publishing Service. Canberra, 1973.

Griffin L. I. and Waller P. F., *The impact of a motorcycle lights-on law.* Highway Safety Research Centre, University of North Carolina, 1976.

Henderson M., *Death on motorcycles—a study of* 120 *fatalities.* Traffic Accident Research Unit, Rept 5/70. Department of Motor Transport, New South Wales, 1970.

Inayoshi I., Characteristics of motorcycle accidents in Japan. *Proc. 2nd Int. Cong. Automotive Safety,* San Francisco, California, 1973.

Jamieson K. G. and Tait I. A., *Traffic injury in Brisbane.* National Health and Medical Research Council Special Report, No. 13, 1966.

Jeffcoate G. O. and Garwood F., *A review of information on motorcycle accidents with special reference to the age of motorcyclists.* Road Research Laboratory. RN/2775/GOJ/FG, 1956.

Johnston I. R., Milne P. W. and Cameron H., *Age, experience and motorcycle engine capacity in motorcycle accidents.* ARRB/ADOT Motorcycles and Safety Symposium, Australian Road Research Board 1-23, 1976.

Lehmann K., Zue Ursachenforschung bei strassenverkehrsunfall. *Zeitschrift fuer Verkehrssicherheit* 32, 1 and 2, 1957. Summarised as Research into causes of road accidents. *Australian Road Res.* 1(4), 46–47, 1962.

McCracken D. M., *Liberty Lines.* Liberty Mutual Insurance Company, 1967.

McLean A. J., The other road users: The pedestrian, cyclist and motorcyclist. *Proc. 3rd Triennial Cong. Med. Related Aspects of Motor Vehicle Accidents.* Ann Arbor, Michigan. International Association for Accident and Traffic Medicine, 1971.

Meares C. L. D., Brabham J. A., Campbell E. F., Kenny P. J., Pak-Poy P. G., Robertson J. S., Solomon S. E. and Sweeney M. F., *The Road Accident Situation in Australia.* Australian Government Publishing Service, Canberra, 1972.

Menzies I. E., *Some social and psychological aspects of road safety.* Tavistock Institute of Human Relations, London, 1968.

Messiter G., An assessment of measures to reduce cyclist and motorcyclist accidents. *Proc. Nat. Road Safety Symp.* Australian Government Publishing Service, Canberra, 1972.

Munden J. M., The variation of motorcycle accident rates with age of rider and size of machine. *Int. Road Safety and Traffic Review* 12(1), OTA. London, 1964.

Nicholai A. M., The motorcycle syndrome. *Am. J. Psychol.* 126(11), 1588–1595, 1970.

O.E.C.D., *Young driver accidents.* Organisation for Economic Co-operation and Development. Paris, 1975.

Raeder P. A. and Negri D. B., An evaluation of motor vehicle accidents involving motorcycles—severity, characteristics, effects of safety regulation. *New York State Department of Motor Vehicles, Research Report* 12, 1969.

Reiss M. L., Berger W. G. and Valetti G. R., *Analysis of motorcycle accident reports and statistics.* Motorcycle Safety Foundation, 1974.

Reiss M. L. and Haley J. A., *Motorcycle safety.* Airborne Instruments Lab. N.Y. NTIS Report PB/178/332, 1968.

Robertson J. S., McLean A. J. and Ryan G. A., *Traffic accidents in Adelaide, South Australia.* Australian Road Research Board Special Report No. 1, 1966.

Science Museum of Victoria, *Times of sunset and sunrise for Victoria,* 1974.

Shields J., *Blueprint for safety.* Minnesota Department of Public Safety, 1972.

Smith D. I., *An investigation to determine whether the daylight usage of motorcycle headlights and tail-lights should be made compulsory in Western Australia.* Road Traffic Authority, Western Australia, 1975.

Suzuki T., System, curricular and effects of safety driving education program for young motorcyclists. *Proc. 1st Int. Conf. on Driver Behaviour,* Zurich. Pub. Honda, Toyko, Oct. 1973.

Waller P. F., Barry T. L. and Rouse W. S., *Motorcycles: I. Estimated mileage and its parameters.* Highway Safety Research Centre, University of North Carolina, Chapel Hill, North Carolina, 1968.

Waller P. F., *An analysis of motorcycle accidents with recommendations for licensing and operation.* Highway Safety Research Center, University of North Carolina, Chapel Hill, North Carolina, 1972.

Watson P. M. F. and Lander F. T. W., Motorcycle accidents and injuries. *Proc. Conf. on Vehicle Safety Legislation and its Engineering and Social Implications*. Conf. Pub. 16, I. Mech. E., 1973.

Widen S., *Traffic accidents involving motorcycles* (1970). State Traffic Institute, Report 35. Stockholm, 1973.

Woltman H. L. and Austin R. L., Some day and night visual aspects of motorcycle safety. *Transportation Research Board* **502**, 1–8, 1974.

U.S. Department of Transportation, *Motorcycle safety, Highway Safety Program Manual*. National Highway Safety Bureau, 1969.

U.S. Department of Transportation, *Development and field testing of techniques for increasing the conspicuity of motorcycles and motorcycle drivers*. NHTSA Statement of Work, 1976.