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THE EFFECT OF
AUSTRALIAN DESIGN RULE 22A
FOR HEAD RESTRAINTS

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THE EFFECT OF AUSTRALIAN DESIGN RULE 22A FOR HEAD RESTRAINTS

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Abstract

Australian Design Rule (ADR) 22A requires head restraints to be fitted to driver and front left seats of all new cars in Australia from 1975 models onwards. It upgraded ADR 22 by requiring that head restraints be not adjustable below a specified minimum height.

This study was based on 1977-78 claims to a "no-fault" injury compensation scheme operated by the Motor Accidents Board (MAB) in Victoria. Potential benefit groups (front outboard seat occupants in rear end impacts) and disbenefit groups (front and rear seat occupants in front end impacts) were considered.

The study concluded that ADR 22A head restraints are effective in reducing whiplash injuries to female front occupants aged 17-49 involved in rear end impacts. The analysis was inconclusive regarding the benefits to male front occupants in these impacts due to the possibility that their benefit (if any) from ADR 22A may be off-set or eroded by an increase in whiplash injuries due to increased seat belt wearing in the front seats of ADR 22A cars, resulting in little or no apparent benefit.

(continued)

Abstract (continued)

Regarding the benefits of ADR 22 head restraints in rear end impacts, the study results were consistent with the finding of Cameron and Wessels that the benefits were confined to female occupants of the front left seats.

With regard to front end impacts, there was no evidence of disbenefits from either ADR in terms of increased facial or head injuries to rear seat occupants.

There was also no evidence that ADR 22A head restraints increase whiplash, concussion, major intracranial injury, or total head injury to drivers or front left passengers involved in front end impacts. However, a disbenefit due to ADR 22 head restraints in terms of increased whiplash injuries (but not major intracranial injuries) to drivers in front end impacts, found by Cameron and Wessels (1979), was confirmed.

The absence of information on crash severity and seat belt wearing from the analysed data limited the conclusions to being suggestive, not definitive. However, there appears to be a case for upgrading ADR 22A to increase the minimum height of head restraints, so that male front seat occupants are more frequently protected. Installation of head restraints in rear seats does not appear to be justified by the number of whiplash injuries occurring.

Reference: Cameron, M.H. and Wessels, J.P. (1979), "The Effectiveness of Australian Design Rule 22 for Head Restraints", Report to Road Safety and Traffic Authority, Victoria, and Office of Road Safety, Commonwealth Department of Transport (ORS Report CR 5).

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THE EFFECT OF AUSTRALIAN DESIGN RULE 22A FOR HEAD RESTRAINTS

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INTRODUCTION

AUSTRALIAN DESIGN RULES 22 AND 22A

Australian Design Rule for Motor Vehicle Safety Number 22 (ADR 22) required manufacturers to fit head restraints to the front outboard seating positions of passenger cars and derivatives manufactured on or after 1 January 1972. Manufacturers were permitted to fit either fixed (usually integral with the seat) or adjustable head restraints. To overcome problems of improper adjustment, ADR 22A extended the original rule by specifying a minimum height for head restraints. It applies to vehicles manufactured on or after 1 January 1975. Manufacturers have complied with ADR 22A by using head restraints integral with the seat or ensuring that adjustable head restraints cannot be adjusted below a minimum height.

Results of an unpublished survey by the Office of Road Safety of vehicles on the road in Melbourne in March 1980 indicate that only 18 per cent of vehicles did not have head restraints available and that 79 per cent of available head restraints were of the integral type. Of those vehicles complying with ADR 22A, 83 per cent had integral head restraints.

Cameron and Wessels (1979), in a study on the effectiveness of ADR 22, have reported the results of earlier and more extensive field surveys of the height of head restraints conducted in Sydney, Melbourne and Adelaide late in 1972 by the traffic authority in each State. The surveys showed that 79 per cent of male (and 93 per cent of female) drivers and front left passengers had their integral head restraints, where available to them, satisfactorily located behind their heads. These percentages were almost constant across the two front outboard seating positions for each sex. Basic anthropometrics would suggest that male front outboard seat occupants are less likely to be protected by their ADR 22A head restraints than female occupants of the same seats, as indicated by these surveys, even though manufacturers may have increased the height of head restraints slightly to comply with ADR 22A. No more recent surveys of the height of fixed head restraints have been published.

LITERATURE ON HEAD RESTRAINT EFFECTIVENESS

Cameron and Wessels (1979) have given a detailed review of the overseas literature on the effectiveness of head restraints in preventing whiplash injury.

A further study of American in-depth accident data, by O'Day _et al_ (1975), showed no significant relationships between whiplash injuries and the presence or absence of head restraints. However the authors suggested that the likely small effect of head restraints could be masked by biases in the data, in particular the bias towards severe injury-producing crashes.

In general the literature suggests that head restraints installed in American cars under Federal Motor Vehicle Safety Standard (FMVSS) 202 (which allows fixed or adjustable restraints to be installed) are effective in reducing the probability of whiplash injury in rear impacts and that the effect applies particularly to female occupants.

The factors influencing predisposition to whiplash injury suggested in these studies are:

- sex (with females being more susceptible)
- age
- body build (sitting height)
- cervical spine arthritis
- seating position in vehicle
- posture at moment of impact
- seat back failure
- vehicle crushability at rear
- direction of impact

Cameron and Nelson (1977) in Australia also identified seat belt wearing as a further factor. In particular, they found that drivers and front left passengers more frequently sustained whiplash injury when wearing seat belts (predominantly lap/sash static type) than like occupants not wearing belts. In view of the high rate of seat belt wearing in Australia compared with the situation overseas, the effect of this factor is important in considering the effectiveness of ADR 22A.

The study of the effectiveness of ADR 22 by Cameron and Wessels (1979) analysed data on 1974-75 claims to a "no-fault" injury compensation scheme operated by the Motor Accidents Board (MAB) in Victoria. They concluded that there was weak evidence that ADR 22 is effective in reducing whiplash injuries sustained in rear end impacts. The benefit was almost entirely confined to female occupants of front left seats. There was no evidence of disbenefits in terms of head or facial injuries to rear seat occupants. However there was evidence of disbenefits in terms of whiplash and major intracranial injuries to drivers involved in front end impacts in ADR 22 cars compared with pre-ADR 22 cars.

The absence of information on crash severity and seat belt wearing from the analysed data limited Cameron and Wessels' conclusions to being suggestive, not definitive.

In the data analysed by Cameron and Wessels, there were too few occupants of 1975 model cars to satisfactorily evaluate ADR 22A. To do this, they recommended analysis of later MAB data and that is the subject of this report.

DATA FOR THIS STUDY

The Motor Accidents Board (MAB) in Victoria operates a "no-fault" injury compensation scheme for road accident victims. Claims covered by Worker's Compensation insurance (i.e. usually resulting from road accidents which occurred while travelling to, from or during work) are not generally accepted. Notwithstanding this, the MAB received almost 50 per cent more claims as there were road accident casualties reported to the police in Victoria in 1977-78 (Australian Bureau of Statistics 1977, 1978)

This study was based on claims to the MAB for injury compensation for accidents which occurred in Victoria during the 1977-78 financial year. In particular, it was based on claims resulting from fatalities and on non-fatal claims on which the MAB had made a total payment of $100 or more, up to 11th November 1978. Thus, in contrast with Cameron and Wessels (1979), only a subset of the total claims for 1977-78 was analysed. This subset of fatal and "major" injury claims totalled 11,660 in 1977-78, representing 37.3 per cent of the total accepted claims, but 96.3 per cent of the total payments made as at 11th November 1978 (Motor Accidents Board, 1979). In 1977, the MAB established a new Statistical Section to ensure the accuracy of this subset of claims for the years from 1977-78 onwards (Motor Accidents Board, 1977).

In general, the data available were similar to that described and analysed by Cameron and Wessels. The 8th Revision of the International Classification of Diseases (ICD) continued to be used to classify the injuries; in particular, code 847.0 was used for whiplash injury, as well as other sprains and strains of the neck. One additional available variable which was employed in the analysis was crash location (i.e. Local Government Area in which the accident occurred). Information on crash location was not available to Cameron and Wessels and hence they were not able to control for this important variable related to crash severity.

ANALYSIS

INTRODUCTION

The analysis followed closely that of Cameron and Wessels (1979). Only occupants of cars and station wagons manufactured in 1969 or later were considered; this subset was chosen to control for seat belt fitting in the front outboard seats (due to ADR 4 and its extensions) because there was no information on seat belt use in the MAB claims file. The following year of manufacture groups were used:

- 1969-70 : no head restraints; seat belts fitted to front outboard seats under ADR 4,
- 1971 : some head restraints fitted (see Cameron and Wessels, Appendix C),
- 1972-74 : ADR 22,
- 1975-76 : ADR 22A,
- 1977-78 : ADR 22A and ADR 29 (Side Door Strength).

It was originally intended that the injuries of occupants of rear-impacted cars in these groups would be directly compared to evaluate ADR 22A (and re-evaluate ADR 22). However it was later noted that ADR 4B (which required the fitting of inertia reel seat belts) to the front outboard seating positions) came into effect in parallel with ADR 22A. ADR 4C upgraded ADR 4B by requiring inertia reel seat belts with dual sensing retractors to be fitted to cars manufactured in 1976 onwards. Carter (in press) has shown that the seat belt installations in the front outboard seats of 1975 and later model cars have resulted in higher wearing rates than the static lap/sash belts installed in earlier models. Cameron and Nelson (1977) found that the wearing of seat belts by front outboard occupants involved in rear impacts was associated with increased frequency of whiplash injury, albeit for static lap/sash belts. Thus it is possible that the front outboard occupants of ADR 22A cars in the data had an increased tendency to sustain whiplash injury (due to higher seat belt wearing rates) and that this tendency may off-set or negate any beneficial effect on whiplash injuries due to ADR 22A.

The major differences from the analysis programme employed by Cameron and Wessels (1979) related to the grouping of the ICD codes (to form injury criteria for analysis) and the definitions of the crash types considered. These two subjects will be discussed immediately under separate headings. The final section in this chapter will describe the statistical methods used for significance testing of the results.

CRITERION INJURIES

The criterion injury groupings followed that employed in publications by the MAB (1979, Table 5), with the exception that concussion was separated from other intra-cranial injuries. Only whiplash, fractured vertebrae, concussion and major head and face injuries were considered in the detailed results given here. The definitions of the injury groups in terms of ICD codes are given in Table I.

Following Cameron and Wessels, the criterion variables for the analysis were the separate proportions which the injuries in each injury group represent of the total of all injuries. This choice of criterion variables was made necessary by the absence of information on uninjured occupants in the data file and the lack of such information from other sources. The criterion variables suffer by including the criterion injuries in both their numerator and denominator. Thus they would lack sensitivity to any change to the risk of sustaining one of the criterion injuries in crashes of a given severity. For example, if the proportion of all injuries which were whiplash was 0.3 (approximately correct for front outboard seat occupants in rear-end impacts - see Results chapter) and the risk of whiplash injury was reduced by 50 per cent, then we would expect to find the proportion of injuries which were whiplash reduced by only 33.3 per cent. The lack of sensitivity is less critical for injuries which represent only a small proportion of the total.

TABLE I: Definitions of criterion injury groups in terms of the 8th Revision of the International Classification of Diseases (ICD) codes.

		ICD codes
1.	Whiplash	847.0
2.	Fractured vertebrae	
	- without spinal cord lesion	805
	- with spinal cord lesion	806
3.	Concussion	850
4.	Major intra-cranial injury	851-854
5.	Fractured skull	800,801,803
6.	Fractured face bones	802,804
7.	Open wound of eye and orbit	870

CRASH TYPES CONSIDERED

For this report, only rear end and front end impacts have been considered. Cameron and Wessels considered only a sub-set of such impacts defined in terms of particular Road User Movement (Sach, 1976) codes. The discrepancy is small, however, as the vehicle occupants considered by Cameron and Wessels represented 95 per cent of all those in rear end impacts and 81 per cent of all those in front end impacts (Wessels 1978). Hence the results of this study should be comparable with those of Cameron and Wessels (1979).

STATISTICAL TEST METHODS

Changes in the proportion of each injury group (as a function of all injuries) by year of manufacture were judged for statistical significance by a 2x2 Chi-square test of independence. In some cases (e.g. whiplash injuries in rear end impacts), the sensitivity of the test was increased by conducting "one-tail" tests for a decrease only in the injury proportion when occupants of ADR 22A cars were compared with those occupying pre-ADR 22A cars. This was done by taking the square root of the Chi-square criterion (on one degree of freedom), attaching the sign of the change in injury proportion, and comparing the result with critical values of the lower tail of the Normal (0, 1) distribution. In all other cases, two-tailed tests for an increase or decrease in the injury proportion were conducted.

Tests were also made of the variations (by sex, age and seating position) in the magnitude of the change in injury proportion. This was tested by a three-way Chi-square test of the log-linear model for three-dimensional contingency tables (Bishop, Fienberg and Holland 1975). Maximum likelihood estimates for the frequencies in the elementary cells were fitted by an iterative method. A computer program was written to carry out the method described by Bishop et al and the program is given in Appendix C.

RESULTS

REAR END IMPACTS

1. Summary of number of cases

The total number of injuries sustained by claimants involved in rear end impacts is shown in Table II. The numbers of claimants involved were not obtained from MAB, because they were not considered essential for the analysis. This is because the analysis was based on the proportions of total injuries which were specific types, e.g. whiplash. Other analysis of MAB data has shown that each major-injury claimant during 1977-78 had on average 1.8 injuries recorded in his file (Motor Accidents Board 1980) and this can be used to estimate from Table II the number of claimants involved.

For comparison of Table II with later tables, it should be noted that there were no drivers aged under 17 and no front left passengers aged under 8. All claimants aged under 8 occupied rear seats. Eight years was considered to be the minimum age at which head restraints became relevant, i.e. younger children were considered to have a sitting height lower than the top of seat backs.

2. Need for controlled analysis

Before proceeding to the main analysis comparing whiplash injury proportions between vehicles of different years of manufacture, there was a need to investigate whether occupants of these vehicles were directly comparable in terms of their susceptibility to whiplash injury. If not, the subsequent analysis program would need to attempt to control for any imbalances which may invalidate the inferences reached.

Three variables available in the MAB data and known to be associated with whiplash injury susceptibility and/or crash severity were considered:

- sex
- age (derived from birthdate and accident date)
- accident location.

The variable sex was previously found by Cameron and Wessels

TABLE II: TOTAL INJURIES IN REAR END IMPACTS, by occupant sex and seating position (all ages included).

	Year of manufacture		
	1969-71	1972-74	1975-78
Drivers			
Male	94	93	68
Female	92	81	76
Front left passengers			
Male	7	5	8
Female	41	62	55
Rear passengers			
Male	9	1	18
Female	23	18	13

(and by other investigators) to be associated not only with susceptibility to whiplash injury, but also with the level of effectiveness of head restraints. Hence sex was retained as a control variable in the subsequent results (i.e. injuries to male and female occupants were considered separately), but there remained a need to investigate whether occupant age or accident location should be controlled; in particular, whether they should be controlled within each of the sex categories.

There was evidence that the age distribution of drivers and front left passengers combined varied with the year of manufacture of the vehicle they occupied ($X_2^2 = 11.910$; $p < 0.01$). The newer cars were more likely to have been occupied by older front outboard seat occupants (Table III). There was no statistically significant evidence that the relationship between occupant age and vehicle year differed between the sexes ($X_2^2 = 2.132$). There were similar findings when drivers and front left passengers were considered separately.

There was evidence that the accident location distribution of drivers and front left passengers combined varied with the year of the vehicle ($X_4^2 = 10.411$; $p < 0.05$). The newer cars were more likely to have had a rear impact in the Melbourne Statistical Division (MSD) than older cars (Table IV). There was no statistically significant evidence that the relationship between accident location and vehicle year differed between the sexes ($X_4^2 = 4.693$). There were similar findings when drivers and front left passengers were considered separately.

Injuries to rear passengers in rear impacts were considered in this study in order to examine whether there were any differences in rear impact severity between vehicles of different years. Rear seats were not affected by ADR 22 or 22A. Because of their role in the analysis, it was essential to investigate the need for controlled analysis of the injuries to these occupants as well.

For rear passengers, there was no statistically significant evidence of relationships between vehicle year and either (a) occupant age or (b) accident location (X_2^2 equalled

TABLE III: TOTAL INJURIES IN REAR END IMPACTS. Distribution of total injuries to drivers and front left passengers, by occupant sex and age.

	Year of manufacture		
	1969-71	1972-74	1975-78
Male			
% aged 8-49	84.2	71.4	64.5
% aged 50+	15.8	28.6	35.5
Total injuries	101	98	76
Female			
% aged 8-49	83.5	82.5	73.3
% aged 50+	16.5	17.5	26.7
Total injuries	133	143	131
Both sexes			
% aged 8-49	83.8	78.0	70.0
% aged 50+	16.2	22.0	30.0
Total injuries	234	241	207

TABLE IV: TOTAL INJURIES IN REAR END IMPACTS. Distribution of total injuries to drivers and front left passengers, by occupant sex and accident location.

	Year of manufacture		
	1969-71	1972-74	1975-78
Male			
% in MSD*	81.2	83.7	89.5
% in Other Towns**	8.9	8.2	1.3
% in Rest of Vic	9.9	8.2	9.2
Total injuries	101	98	76
Female			
% in MSD	75.9	80.4	82.4
% in Other Towns	13.5	4.9	5.3
% in Rest of Vic	10.5	14.7	12.2
Total injuries	133	143	131
Both sexes			
% in MSD	78.2	81.7	85.0
% in Other Towns	11.5	6.2	3.9
% in Rest of Vic	10.3	12.0	11.1
Total injuries	234	241	207

* Melbourne Statistical Division (MSD)

** Cities, Boroughs and Towns outside MSD

(a) 4.184 and (b) 1.890, respectively). However, there was evidence of a relationship between vehicle year and occupant sex ($X_2^2 = 15.451$; $p < 0.001$). Rear seat passengers in the older cars were more likely to be female (Table II). The absence of evidence for a relationship between vehicle year and accident location, in contrast with the presence of evidence for such a relationship among front outboard seat occupants, deserves comment and can be explained in a number of ways. First, there may have been too few rear passengers in this study for the relationship (if it exists) to be statistically significant. Second, rear seat passengers occupied only a subset of the cars occupied by front outboard passengers, and the relationship may not exist for this subset. (This latter explanation points out one of the inadequacies of using rear seat passengers' injuries as a measure of differences of crash severities experienced by all front outboard passengers). Notwithstanding the absence of a definitive explanation, for the sake of subsequent analysis all that need be noted is the absence of a statistically significant relationship between vehicle year and accident location (and occupant age, as well).

In summary, there was a need to control the occupant age and the crash location in comparisons of the injuries of drivers and front left passengers of vehicles of different years of manufacture. Failure to control for their sex would not lead to invalid inferences (regarding the overall effect of ADR 22A), but the sexes should be considered separately because of possible different levels of effectiveness of ADR 22A head restraints. Sex of rear seat passengers should be controlled to avoid invalid inferences from comparisons of their injuries between vehicle years.

3. Drivers and front left passengers

The detailed frequencies of the criterion injuries to drivers and front left passengers in rear impacts are given in Appendix A. Of the criterion injuries, only whiplash occurred in sufficient numbers in rear impacts for statistically meaningful results, and hence whiplash proportion was the only criterion variable explicitly considered for rear impacts.

There was a statistically significant decrease, from 42.3 per cent to 33.7 per cent (Table V), in the proportion of whiplash injuries to all drivers and front left passengers when ADR 22A cars were compared with pre-ADR 22 cars $X_1^2 = 3.380$; $p = 0.04$, one-tail). There was no evidence of a decrease in the proportion of whiplash injuries when like occupants of ADR 22 cars were compared with those in pre-ADR 22 cars ($X_1^2 = 0.009$).

There was evidence that the reduction in whiplash injuries in ADR 22A cars varied with the sex of the front outboard seat occupant ($X_1^2 = 3.243$; $p < 0.1$, two-tail). The reduction in the proportion of whiplash injuries to female drivers and front left passengers, from 47.4 per cent to 31.3 per cent (Table V), was statistically significant ($X_1^2 = 6.593$; $p = 0.005$, one-tail), but there was no evidence of a reduction for male front outboard seat occupants of ADR 22A cars ($X_1^2 = 0.002$).

There was weak evidence that the change in the proportion of whiplash injuries to drivers and front left passengers of ADR 22 cars varied with the sex of the occupant ($X_1^2 = 2.003$; $0.2 > p > 0.1$, two-tail). However, neither the reduction in whiplash injuries to female front outboard seat occupants (Table V), nor the increase in whiplash injuries to male occupants of the same seats, was statistically significant (X_1^2 equalled 0.364 and 0.973, respectively).

There was weak evidence that the reduction in whiplash injuries to female front outboard seat occupants of ADR 22A cars varied with the age of the occupant ($X_1^2 = 2.114$; $0.2 > p > 0.1$, two-tail). The reduction appears to be confined to females aged 17-49 only (Table VI). There was no statistically significant evidence of an age-related difference in the change in whiplash injuries to male front outboard seat occupants of ADR 22A cars ($X_1^2 = 0.417$). Nor was there any evidence of such a difference among either female or male front outboard seat occupants of ADR 22 cars (X_1^2 equalled 0.001 and 0.069, respectively).

There was evidence of a difference between crash locations when changes in the proportion of whiplash injuries to male

TABLE V: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries, for drivers and front left passengers aged 17 and over, by occupant sex.

	Year of manufacture			ADR 22 effect (2)-(1)	ADR 22A effect (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Male	35.6	43.9	36.8	+8.3	+1.2
Female	47.4	42.7	31.3	-4.7	-16.1
Both	42.3	43.2	33.7	+0.9	-8.6

TABLE VI: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries, for drivers and front left passengers combined, by occupant age and sex.

	Year of manufacture			ADR 22 effect (2)-(1)	ADR 22A effect (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Male					
Age 17-49	36.9	44.3	42.9	+7.4	+6.0
Age 50+	31.3	42.9	25.9	+11.6	-5.4
Female					
Age 17-49	49.5	45.3	28.7	-4.2	-20.8
Age 50+	36.4	32.0	37.1	-4.4	+0.7

front outboard seat occupants of ADR 22A cars rear-impacted in the MSD were compared with those involved in rear impacts in the rest of Victoria ($X_1^2 = 7.729$; $p < 0.01$, two-tail). Any reduction in whiplash injuries appeared to be confined to those involved in rear impacts in the MSD (Table VII), but this reduction was not statistically significant ($X_1^2 = 0.458$). There were too few injuries in the rest of Victoria for a statistical test to be meaningful. There was also weak evidence of a location-related difference in the change in whiplash injuries to male front outboard seat occupants of ADR 22 cars ($X_1^2 = 2.134$; $0.2 > p > 0.1$, two-tail), but no evidence of a real reduction in whiplash injuries in rear impacts in either location (Table VII). There was no statistically significant evidence that the reduction in whiplash injuries to female front outboard seat occupants varied with the accident location, either for occupants of ADR 22A cars ($X_1^2 = 0.007$) or for occupants of ADR 22 cars ($X_1^2 = 0.279$).

There was no statistically significant evidence that the reduction in whiplash injuries to drivers and front left passengers in ADR 22A cars varied with their seating position ($X_1^2 = 1.154$). However there was weak evidence of a seat-related difference in the change in whiplash injuries of front outboard seat occupants of ADR 22 cars ($X_1^2 = 1.872$, $0.2 > p > 0.1$, two-tail). This evidence (Table VIII), coupled with the finding of Cameron and Wessels (1979) that the benefits from ADR 22 appear to be almost entirely confined to (female) occupants of the front left seats, encouraged separate analysis of the injuries of occupants of the two front outboard seats, as follows. However the following results should be viewed against a background that any (unnecessary) partitioning of data must inevitably lead to a weakening of the statistical tests on the component parts.

4. Drivers

The reduction in the proportion of whiplash injuries, when drivers of ADR 22A cars were compared with those driving pre-ADR 22 cars (Table VIII), was not statistically significant

TABLE VII: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries, for drivers and front left passengers aged 17 and over, by occupant sex and accident location.

	Year of manufacture			ADR 22 effect (2)-(1)	ADR 22A effect (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Male					
MSD	39.0	42.7	32.4	+3.7	-6.7
Rest of Victoria	21.1	50.0	75.0	+28.9	+53.9
Female					
MSD	46.5	43.5	30.6	-3.1	-16.0
Rest of Victoria	50.0	39.3	34.8	-10.7	-15.2

TABLE VIII: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries, for drivers and front left passengers, aged 17 and over, by seating position.

	Year of manufacture			ADR 22 effect (2)-(1)	ADR 22A effect (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Drivers	41.4	46.0	35.4	+4.6	-6.0
Front left passengers	45.8	35.8	28.6	-10.0	-17.2
Both	42.3	43.2	33.7	+0.9	-8.6

(X_1^2 = 0.984). However there was weak evidence of a sex-related difference in this reduction (X_1^2 = 2.131; $0.2 > p > 0.1$, two-tail). The reduction in the proportion of whiplash injuries to female drivers of ADR 22A cars, from 46.7 per cent to 32.9 per cent (Table IX), was statistically significant (X_1^2 = 2.761; $p = 0.05$, one-tail). There was no evidence of a parallel reduction in whiplash injuries to male drivers (X_1^2 = 0.011).

The increase in the proportion of whiplash injuries to drivers of ADR 22 cars (Table VIII) was not statistically significant (X_1^2 = 0.592). There was no statistically significant evidence of a sex-related difference in this change (X_1^2 = 0.410).

There was weak evidence that the reduction in whiplash injuries to female drivers of ADR 22A cars varied with the age of the driver (X_1^2 = 1.792; $0.2 > p > 0.1$, two-tail). The reduction appears to be confined to female drivers aged 17-49 only (Table X). There was no statistically significant evidence of an age-related difference in the change in whiplash injuries to male drivers of ADR 22A cars (X_1^2 = 0.310). Nor was there any statistically significant evidence of such a difference among either female or male drivers of ADR 22 cars (X_1^2 = 1.486 and 0.067, respectively).

There was evidence of a difference between crash locations in terms of the change in whiplash injuries to male drivers of ADR 22A cars (X_1^2 = 5.899; $p < 0.025$, two-tail). Any reduction in whiplash injuries appeared to be confined to those drivers rear-impacted in the MSD (Table XI). There was no statistically significant evidence of a location-related difference in the change in whiplash injuries to male drivers of ADR 22 cars (X_1^2 = 1.891), nor was there for female drivers of either ADR 22A cars (X_1^2 = 1.332) or ADR 22 cars (X_1^2 = 0.004).

5. Front left passengers

There was a statistically significant decrease, from 45.8 per cent to 28.6 per cent (Table VIII), in the proportion

TABLE IX: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries, by seating position and sex of drivers and front left passengers aged 17 and over.

	Year of manufacture			ADR 22 effect	ADR 22A effect
	1969-71 (1)	1972-74 (2)	1975-78 (3)	(2)-(1)	(3)-(1)
Drivers					
Male	36.2	44.1	38.2	+7.9	+2.0
Female	46.7	48.1	32.9	+1.4	-13.8
Front left passengers					
Male	28.6	40.0	25.0	+11.4	-3.6
Female	48.8	35.5	29.1	-13.3	-19.7

TABLE X: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries to drivers, by driver sex and age.

	Year of manufacture			ADR 22 effect	ADR 22A effect
	1969-71 (1)	1972-74 (2)	1975-78 (3)	(2)-(1)	(3)-(1)
Male					
Age 17-49	37.2	44.6	43.5	+7.4	+6.3
Age 50+	31.3	42.9	27.3	+11.6	-4.0
Female					
Age 17-49	47.0	53.8	27.1	+6.8	-19.9
Age 50+	44.4	25.0	52.9	-19.4	+8.5

TABLE XI: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries to drivers aged 17 and over, by driver sex and accident location.

	Year of manufacture			ADR 22 effect (2)-(1)	ADR 22A effect (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Male					
MSD	39.5	42.9	34.9	+3.4	-4.6
Rest of Victoria	22.2	50.0	80.0	+27.8	+57.8
Female					
MSD	45.3	47.0	28.1	+1.6	-17.2
Rest of Victoria	52.9	53.3	58.3	+0.4	+5.4

TABLE XII: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries to female front left passengers, by occupant age.

	Year of manufacture			ADR 22 effect (2)-(1)	ADR 22A effect (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Female*					
Age 17-49	57.7	34.6	31.4	-23.1	-26.3
Age 50+	30.8	44.4	22.2	+13.6	-8.6

* There were too few male front left passengers involved in rear end impacts to make meaningful comparisons by occupant age.

of whiplash injuries to front left passengers of ADR 22A cars compared with those occupying the same seats in pre-ADR 22 cars ($X_1^2 = 2.813$; $p = 0.05$, one-tail). There was no statistically significant evidence of a sex-related difference in this reduction ($X_1^2 = 0.279$), but there were relatively few male occupants of front left seats (Table II). The reduction in the proportion of whiplash injuries to female front left passengers of ADR 22A cars, from 48.8 per cent to 29.1 per cent (Table IX), was statistically significant ($X_1^2 = 3.191$; $p = 0.04$, one-tail).

The reduction in the proportion of whiplash injuries to front left passengers of ADR 22 cars, from 45.8 per cent to 35.8 per cent (Table VIII) was not statistically significant ($X_1^2 = 0.788$). There was no statistically significant evidence of a sex-related difference in this reduction ($X_1^2 = 0.659$). Furthermore, the reduction in whiplash injuries to female front left passengers of ADR 22 cars (Table IX) was not statistically significant ($X_1^2 = 1.095$).

There was no statistically significant evidence that the reduction in whiplash injuries to female front left passengers of ADR 22A cars varied with the age of the occupant ($X_1^2 = 0.431$). However there was weak evidence of such an age-related difference among female front left passengers of ADR 22 cars ($X_1^2 = 2.236$; $0.2 > p > 0.1$, two-tail). The beneficial effect, if any, appeared to be confined to females aged 17-49 occupying the front left seats (Table XII).

There was no statistically significant evidence of a difference between crash locations in terms of the reduction in whiplash injuries to female front left passengers in either ADR 22A cars ($X_1^2 = 1.646$) or ADR 22 cars ($X_1^2 = 0.408$). Injuries from rear impacts in the MSD and the rest of Victoria (Table XIII) were consistent with those observed for the whole State (Table IX).

6. Rear passengers

The difference in the proportion of whiplash injuries to rear passengers of ADR 22A cars compared with those in

TABLE XIII: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries to female front left passengers aged 17 and over, by accident location.

	Year of manufacture			ADR 22 effect (2)-(1)	ADR 22A effect (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Female*					
MSD	50.0	38.8	34.1	-11.2	-15.9
Rest of Victoria	46.7	23.1	9.1	-23.6	-37.6

* There were too few male front left passengers involved in rear end impacts to make meaningful comparisons by accident location.

TABLE XIV: REAR END IMPACTS. Whiplash injuries as a percentage of all injuries to rear seat passengers, by occupant sex.

	Year of manufacture			Comparison (2)-(1)	Comparison (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Male	0.0	0.0	22.2	0.0	+22.2
Female	21.7	16.7	15.4	-5.0	-6.3
Both	15.6	15.8	19.4	+0.2	+3.8

pre-ADR 22 cars was not statistically significant (Table XIV; $X_1^2 = 0.003$). There was weak evidence that this difference in proportion was sex-related ($X_1^2 = 2.451$; $0.2 > p > 0.1$, two-tail). However the difference was not statistically significant either for male rear passengers ($X_1^2 = 0.917$) or for female ($X_1^2 = 0.0006$).

The comparison of whiplash injuries to rear passengers of ADR 22 cars and of pre-ADR 22 cars was also not statistically significant ($X_1^2 = 0.0002$). There were too few whiplash injuries to male rear passengers of these two groups of cars to test the significance of any sex-related effect on the comparison. However the comparison was not statistically significant for female rear passengers ($X_1^2 = 0.0001$) and was zero for male rear passengers (Table XIV).

FRONT END IMPACTS

1. Summary of number of cases

The total number of injuries sustained by claimants involved in front end impacts is shown in Table XV. The focus is on rear passengers because they are a potential disbenefit group in head restraint-fitted cars involved in front end impacts. The number of rear passengers involved in front end impacts appears to be of the same order of magnitude as the number of drivers and front left passengers involved in rear end impacts.

2. Rear passengers

The detailed frequencies of the criterion injuries to rear passengers in front end impacts are given in Appendix B. Head and facial injuries to passengers in these seating positions and crash configuration were considered to investigate any disbenefits due to head restraints.

There was no evidence of an increase in either (a) facial injuries or (b) total head injuries when rear passengers in ADR 22A cars were compared with those in pre-ADR 22 cars (Table XVI; X_1^2 equalled (a) 0.003 and (b) 1.768, respectively). Similarly, there was no statistically significant evidence of

TABLE XV: TOTAL INJURIES IN FRONT END IMPACTS, by occupant sex and seating position (all ages included).

	Year of manufacture		
	1969-71	1972-74	1975-78
Rear passengers			
Male	89	96	55
Female	113	109	91
Drivers			
Male	547	550	389
Female	283	293	259
Front left passengers			
Male	170	147	104
Female	262	302	232

TABLE XVI: FRONT END IMPACTS. Facial and total head injuries, each as a percentage of all injuries, for rear passengers, by occupant sex.

	Year of manufacture			ADR 22 effect (2)-(1)	ADR 22A effect (3)-(1)
	1969-71 (1)	1972-74 (2)	1975-78 (3)		
Facial injuries %					
Male	6.7	12.5	9.1	+5.8	+2.4
Female	5.3	5.5	3.3	+0.2	-2.0
Both sexes	5.9	8.8	5.5	+2.9	-0.4
Total head injuries %					
Male	31.5	31.3	18.2	-0.2	-13.3
Female	13.3	19.3	13.2	+6.0	-0.1
Both sexes	21.3	24.9	15.1	+3.6	-6.2

increases in these injuries when ADR 22 cars were compared with pre-ADR 22 cars (X_1^2 equalled (a) 0.822 and (b) 0.550, respectively).

Nor was there any evidence that any increase in facial or total head injuries to rear passengers in ADR 22A cars varied with the sex of the occupant (X_1^2 equalled (a) 0.747 and (b) 1.496, respectively). Similar results were found for rear passengers in ADR 22 cars (X_1^2 equalled (a) 0.665 and (b) 0.875, respectively).

3. Drivers

Injuries to drivers in front end impacts were considered in this analysis because of the finding by Cameron and Wessels (1979) of apparent disbenefits in terms of whiplash and major intracranial injuries due to ADR 22. The detailed frequencies of their criterion injuries are given in Appendix B. As well as whiplash and major intracranial injuries, changes in the proportions of concussion and total head injuries were also tested for statistical significance (Table XVII). Notwithstanding the findings of Cameron and Wessels, it was considered appropriate to statistically test the changes in both directions (i.e. two-tailed significance tests), as there were no preconceived hypotheses regarding the direction of change in injury risk to front occupants in front end impacts.

When drivers of ADR 22A cars were compared with those driving pre-ADR 22 cars, there was no statistically significant evidence of changes in the proportion of:

(a) whiplash injury ($X_1^2 = 0.040$),
(b) concussion ($X_1^2 = 0.292$),
(c) major intracranial injury ($X_1^2 = 0.020$), or
(d) total head injuries ($X_1^2 = 0.178$).

Similar results were found when drivers of ADR 22 cars were compared with those driving pre-ADR 22 cars, namely:

(a) whiplash injury ($X_1^2 = 0.423$),
(b) concussion ($X_1^2 = 0.593$),
(c) major intracranial injury ($X_1^2 = 0.165$), or
(d) total head injuries ($X_1^2 = 0.850$).

TABLE XVII: FRONT END IMPACTS. Whiplash, concussion, major intracranial injuries and total head injuries, each as a percentage of all injuries, for male and female drivers.

	Year of manufacture			ADR 22 effect	ADR 22A effect
	1969-71 (1)	1972-74 (2)	1975-78 (3)	(2)-(1)	(3)-(1)
Whiplash %					
Male	3.1	3.6	3.9	+0.5	+0.7
Female	5.7	6.8	5.0	+1.2	-0.6
Both sexes	4.0	4.7	4.3	+0.8	+0.3
Concussion %					
Male	5.7	5.5	4.6	-0.2	-1.0
Female	3.9	1.7	3.9	-2.2	0.0
Both sexes	5.1	4.2	4.3	-0.9	-0.7
Major intracranial injuries %					
Male	2.7	2.7	1.8	0.0	-0.9
Female	1.8	3.1	2.7	+1.3	+0.9
Both sexes	2.4	2.8	2.2	+0.4	-0.2
Total head injuries %					
Male	15.5	12.9	13.6	-2.6	-1.9
Female	10.6	10.9	12.0	+0.3	+1.4
Both sexes	13.9	12.2	13.0	-1.6	-0.9

The absence of statistically significant increases in the proportions of whiplash and major intracranial injury is in disagreement with a parallel finding by Cameron and Wessels (1979). These contradictory findings will be discussed further later.

There was no statistically significant evidence that any changes in any of the above injuries (a) to (d) to drivers of ADR 22A cars (or ADR 22 cars) compared to those driving pre-ADR 22 cars, varied with the sex of the driver:

	Chi-square (1 d.f.)	
	ADR 22A drivers	ADR 22 drivers
(a) whiplash injury	0.440	0.006
(b) concussion	0.147	1.855
(c) major intracranial injury	1.359	0.734
(d) total head injuries	0.772	0.608

4. Front left passengers

Cameron and Wessels (1979) also considered injuries to front left passengers involved in front end impacts, but found no statistically significant evidence of apparent disbenefits due to ADR 22.

When front left passengers of ADR 22A cars were compared with those in pre-ADR 22 cars, there was no statistically significant evidence of changes in the proportion of:

(a) whiplash injury ($X_1^2 = 0.047$),
(b) concussion ($X_1^2 = 0.410$), or
(c) major intracranial injury ($X_1^2 = 0.145$).

However, there was a decrease in the proportion of total head injuries (as a fraction of all injuries) (Table XVIII), which was weakly statistically significant ($X_1^2 = 3.191$; $0.1 > p > 0.05$, two-tail).

When front left passengers of ADR 22 cars were compared with those in pre-ADR 22 cars, there was an increase in the proportion of major intracranial injuries, which was weakly

TABLE XVIII: FRONT END IMPACTS. Whiplash, concussion, major intracranial injuries and total head injuries, each as a percentage of all injuries, for male and female front left passengers.

	Year of manufacture			ADR 22 effect	ADR 22A effect
	1969-71 (1)	1972-74 (2)	1975-78 (3)	(2)-(1)	(3)-(1)
Whiplash %					
Male	2.4	2.7	4.8	+0.4	+2.5
Female	7.3	6.6	6.5	-0.6	-0.8
Both sexes	5.3	5.3	6.0	0.0	+0.6
Concussion %					
Male	2.9	3.4	4.8	+0.5	+1.9
Female	2.7	4.3	3.4	+1.6	+0.8
Both sexes	2.8	4.0	3.9	+1.2	+1.1
Major intracranial injuries %					
Male	4.7	6.8	1.0	+2.1	-3.7
Female	1.5	4.6	2.6	+3.1	+1.1
Both sexes	2.8	5.3	2.1	+2.6	-0.7
Total head injuries %					
Male	21.2	15.0	13.5	-6.2	-7.7
Female	12.2	14.6	9.9	+2.4	-2.3
Both sexes	15.7	14.7	11.0	-1.0	-4.7

statistically significant (Table XVIII; $X_1^2 = 3.077$; $p < 0.1$, two-tail). There was no statistically significant evidence of changes in the proportion of:

(a) whiplash injury ($X_1^2 = 0.018$),
(b) concussion ($X_1^2 = 0.675$), or
(c) total head injuries ($X_1^2 = 0.113$).

There was no statistically significant evidence that any changes in any of the above injuries (a) to (d) to front left passengers of ADR 22A cars (or ADR 22 cars), compared to those in pre-ADR 22 cars, varied with the sex of the occupant:

	Chi-square (1 d.f.)	
	ADR 22A front left passengers	ADR 22 front left passengers
(a) whiplash injury	1.262	0.098
(b) concussion	0.088	0.185
(c) major intracranial injury	3.807	1.037
(d) total head injuries	0.486	2.636

SUMMARY AND DISCUSSION

REAR END IMPACTS

There was evidence that head restraints installed under ADR 22A reduce the risk of whiplash injury for female occupants of the driver and front left passenger seating positions in rear end impacts, but not for male occupants of the same seating positions. The benefit appears to be confined to female front outboard seat occupants aged 17-49. The beneficial effect to females may be partially explained by a roadside survey which showed that 93 per cent of female, but only 79 per cent of male, drivers and front left passengers had their fixed, ADR 22A-type head restraints satisfactorily located behind their heads (Cameron and Wessels 1979). The measured benefits to both male and female front outboard seat occupants may also have been biased low, due to increased seat belt wearing rates in these seats in ADR 22A cars, and the known effect of seat belt wearing on whiplash injury (Cameron and Nelson 1977).

There was no statistically significant evidence that head restraints installed under ADR 22 reduce the risk of whiplash injury to occupants of either sex in either of the front outboard seating positions, in contrast with the results of Cameron and Wessels (1979) who found evidence of benefits to female front left passengers. However Cameron and Wessels analysed a total of 293 injuries to female front left passengers of ADR 22 and pre-ADR 22 cars, compared with only 103 injuries analysed here. The reduction in whiplash injuries to female front left passengers considered in this report would have been statistically significant had it been based on the same amount of data as Cameron and Wessels.

There was no evidence that ADR 22A cars were involved in more or less severe rear end impacts than pre-ADR 22 cars. The difference in the proportion of whiplash injuries between rear seat occupants (to whose seats ADR 22A did not apply) of ADR 22A cars and rear seat occupants of pre-ADR 22 cars was not statistically significant in rear end impacts. A difference in the risk of whiplash injury to rear seat occupants would have been expected in rear end impacts of different severity. There were similar findings and conclusions when rear seat occupants of ADR 22 cars and of pre-ADR 22 cars were compared.

FRONT END IMPACTS

There was no statistically significant evidence that head restraints installed under either ADR 22A or ADR 22 increase the risk of facial or head injuries to rear seat passengers in front end impacts. In the case of the latter ADR, this result confirmed the findings of Cameron and Wessels (1979).

There was also no statistically significant evidence that head restraints installed under either ADR changed the risk of whiplash, concussion, major intracranial injury, or total head injury to drivers in front end impacts. This is in disagreement with Cameron and Wessels' finding of apparent disbenefits in terms of whiplash and major intracranial injuries to drivers due to ADR 22. For front left passengers involved in front end impacts, there was no statistically significant evidence of increases in the risk of any of the same injuries in the presence of head restraints installed under ADR 22A; in fact there was weak evidence of a decrease in the risk of head injuries considered in total. However, for front left passengers of ADR 22 cars in front end impacts, there was a weakly statistically significant increase in major intracranial injuries. This latter finding is also in disagreement with Cameron and Wessels, who found no evidence of any injury disbenefits to front left passengers of ADR 22 cars in front end impacts.

With the relatively large number of criterion injuries considered, for each of the two front outboard seating positions in each of the two different studies, the possibility existed that the apparent ADR 22 disbenefits (described above) observed in this and the earlier study may have been spurious and that the injury criteria were statistically significant through chance alone. To test this and to resolve the differences to some extent, the relevant results from the two studies were combined. This was considered appropriate for major intracranial injuries, most of which could be expected to result in claims for at least $100 and hence were equally likely to be included in both data sets considered. However, whiplash injuries (which may result in small claims) may be under-represented in the data of this current study. In addition, it should be noted that the earlier data were collected in 1974-75, before the establishment of the MAB Statistical Section to ensure accuracy, and that the MAB have reservations about the quality of these data (Motor Accidents Board 1980). However, Cameron and Wessels (1979) found little evidence that the 1974-75 data were sufficiently lacking in quality to produce erroneous conclusions.

In the combined data, only the increase in whiplash injuries to drivers of ADR 22 cars in front end impacts remained statistically significant (X_1^2 = 6.525; $p < 0.02$, two-tail). Neither for drivers nor front left passengers were the changes in major intracranial injuries statistically significant in the pooled data (X_1^2 equalled 3.421 and 0.292, respectively). Thus it appears that the apparent ADR 22 disbenefits in terms of major intracranial injuries to front passengers in front end impacts may be spurious (though this is somewhat more doubtful for drivers, as evidenced by the magnitude of the Chi-square criterion). However, a disbenefit in terms of whiplash injuries to ADR 22 drivers in front end impacts remains apparent.

Further investigation of the combined data to evaluate the effects of ADR 22 has not been carried out, since this report is primarily directed at the effect of ADR 22A. Sufficient information is given in the appendices of this and Cameron and Wessels' (1979) report to allow the interested reader to pursue this further. Although not explicitly tested, the combined results are likely to confirm the benefits of ADR 22 in rear end impacts (Cameron and Wessels 1979), as the changes in whiplash injuries were in the same direction in both data sets.

OVERALL FINDINGS

Whiplash injury still remains a major problem in rear end impacts. Even in cars with ADR 22A head restraints, one-third of the injuries sustained by claimants were whiplash. Overall, ADR 22A has had only a moderate effect, reducing the risk of whiplash injury by about 30 per cent (though this could be an under-estimate). The benefit appears to be confined to female front passengers, excluding those aged 50 and over. Male front passengers, who due to their greater sitting height are less frequently protected by fixed, ADR 22A-type head restraints, appear to enjoy lesser benefits (though this study must be inconclusive regarding the benefits to males). The minimum height of head restraints set by ADR 22A appears too low and should possibly be increased.

Rear seat occupants are not provided with head restraints under ADR 22A (though some manufacturers have voluntarily fitted them to their cars). There were 14 whiplash injuries to rear seat occupants of cars in rear end impacts in the data analysed, in contrast with 272 whiplash injuries to drivers and front left passengers (Appendix Tables A1 and A10). Thus the need for an ADR to require head restraints in rear seating positions does not appear to be justified.

The absence from the MAB data of information on (a) crash severity and (b) seat belt wearing has limited the conclusions from this study to being only suggestive, not definitive. An attempt to overcome the above deficiencies has been made by (a) using differences in accident location as a proxy for differences in crash severity, and (b) limiting the study to occupants of cars with seat belts fitted in the front outboard seats (when first registered). While there was evidence that newer cars were more likely to have had a rear impact in the Melbourne Statistical Division than older cars, and this was taken into account in the analysis, it was considered that this procedure is a poor way of measuring and correcting differences in crash severity. As far as seat belt wearing is concerned, it was not known whether limiting the study to cars with belts fitted was successful in controlling this variable, but this is unlikely because of the known increases in wearing rates of the inertia reel seat belts fitted to the front outboard seats of ADR 22A cars.

The absence of crash severity information from any injury-based road accident data system may severely limit the inferences which can be derived from that system. If, at a given level of crash severity, a countermeasure (e.g. head restraints) is effective in reducing the probability of a particular injury (e.g. whiplash) and the injury frequently occurs alone in the crash circumstances (e.g. whiplash in rear end impacts), then car occupants successfully protected by the countermeasure may not appear among accident data which have personal injury as the criterion for selection. Thus, the proportion of injured occupants who sustained the particular injury would lack sensitivity to the effect of the countermeasure when injured occupants who had the countermeasure available are compared with those who did not. If, however, a measure of crash severity was available in the data, then car occupants sustaining the particular injury in the presence of the countermeasure (assumed effective) would have been involved in more severe crashes than like occupants without the countermeasure available.

CONCLUSIONS

1. Head restraints installed under ADR 22A are effective in reducing the risk of whiplash injuries to female occupants of the driver and front left passenger seating positions in rear end impacts; the benefit is confined to those females aged 17-49. The analysis was inconclusive regarding the benefits to male front occupants in these collisions due to the possibility that their benefit (if any) from ADR 22A may be off-set or eroded by an increase in whiplash injuries due to increased seat belt wearing in the front outboard seats of ADR 22A cars, resulting in little or no apparent benefit.

2. There was no evidence from this study that head restraints installed under ADR 22 reduce the risk of whiplash injuries to occupants of either sex in either of the front outboard seating positions in rear end impacts. However there was a statistically non-significant reduction in whiplash injuries to female front left passengers, which is in agreement with the beneficial effect to this type of occupant in rear end impacts, as found by Cameron and Wessels (1979) in a larger data file.

3. There was no evidence that head restraints installed under either ADR 22A or ADR 22 increase the risk of facial or head injuries to rear seat passengers in front end impacts.

4. There was no evidence that ADR 22A head restraints increase the risk of whiplash, concussion, major intracranial injury, or total head injury to drivers or front left passengers in front end impacts.

5. In conjunction with the results of Cameron and Wessels (1979), there was evidence that ADR 22 head restraints increase the risk of whiplash injury to drivers in front end impacts. A parallel disbenefit in terms of the risk of major intracranial injury (a finding reported by Cameron and Wessels) to these drivers was not confirmed.

6. The absence from the MAB data of information on crash severity and seat belt wearing limits the above conclusions to being suggestive, not definitive.

REFERENCES

Australian Bureau of Statistics, Victorian Office (1977, 1978), "Road Traffic Accidents Involving Casualties" (Catalogue No. 9401.2), September Quarter 1977-June Quarter 1978.

Bishop, Y.M.M., Fienberg, S.E. and Holland, P.W. (1975), "Discrete Multivariate Analysis", MIT Press (Cambridge, Mass.).

Cameron, M.H. and Nelson, P.G. (1977), "Injury Patterns With and Without Seat Belts", Proceedings, Sixth International Conference of the International Association for Accident and Traffic Medicine, Melbourne.

Cameron, M.H. and Wessels, J.P. (1979), "The Effectiveness of Australian Design Rule 22 for Head Restraints", Report to Road Safety and Traffic Authority, Victoria, and Office of Road Safety, Commonwealth Department of Transport (ORS Report CR 5),

Carter, A.J. (In press), "Effect of Seat Belt Design Rules on Wearing Rates", Office of Road Safety, Commonwealth Department of Transport (Report OR 5).

Motor Accidents Board (1977), "Third Annual Report for the Year Ended 30th June 1976", Victorian Government Printer, Melbourne.

Motor Accidents Board (1979), "Statistics of Persons Killed or Injured in Road Accidents Occurring Year Ended 30th June 1978 for which Claims were Registered with the Board: Preliminary".

Motor Accidents Board (1980), Personal communication.

O'Day, J.. Filkins, L.D., Compton, C.P. and Lawson, T.E. (1975), "Rear-Impacted Vehicle Collisions: Frequencies and Casualty Patterns", Highway Safety Research Institute, University of Michigan, Report No. UM-HSRI-SA-75-2 (U.S. DoT Report No. PB-245053).

Sach, N. (1976), "The Victorian Road Accident Location System", Proceedings, 8th Conference, Australian Road Research Board.

Wessels, J.P. (1978), "Codebook of Motor Accidents Board Claims File 1974-75", (in preparation).

APPENDIX A

DETAILED INJURIES IN

REAR END IMPACTS

TABLE A1 :

DIRECTION OF IMPACT : Rear

SEATING POSITION : Driver plus front left

LOCATION OF ACCIDENT : All Victoria

SEX OF OCCUPANT : Male plus female

AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	70 (41.7)	29 (43.9)	104 (43.2)	51 (32.7)	18 (35.3)
Fractured Vertebrae	1 (0.6)	2 (3.0)		2 (1.3)	
Concussion	2 (1.2)	1 (1.5)	9 (3.7)	2 (1.3)	2 (3.9)
Major Intracranial Injury	3 (1.8)		2 (0.8)	1 (0.6)	
Fractured Skull	1 (0.6)			1 (0.6)	
Fractured Face Bones				1 (0.6)	
Open Wound of Eye and Orbit	2 (1.2)			1 (0.6)	
Total Head Injuries	8 (4.8)	1 (1.5)	11 (4.6)	6 (3.8)	2 (3.9)
Total All Other Injuries	89 (53.0)	34 (51.5)	126 (52.3)	97 (62.2)	31 (60.8)
TOTAL (All injuries)	168 (100.0)	66 (100.0)	241 (100.0)	156 (100.0)	51 (100.0)

TABLE A2 :

DIRECTION OF IMPACT : Rear
SEATING POSITION : Driver plus front left
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	28 (35.9)	8 (34.8)	43 (43.9)	20 (35.7)	8 (40.0)
Fractured Vertebrae	1 (1.3)	2 (8.7)		1 (1.8)	
Concussion	2 (2.6)		5 (5.1)	2 (3.6)	1 (5.0)
Major Intracranial Injury	2 (2.6)		1 (1.0)		
Fractured Skull	1 (1.3)			1 (1.8)	
Fractured Face Bones					
Open Wound of Eye and Orbit	1 (1.3)				
Total Head Injuries	6 (7.7)	-	6 (6.1)	3 (5.4)	1 (5.0)
Total All Other Injuries	43 (55.1)	13 (56.5)	49 (50.0)	32 (57.1)	11 (55.0)
TOTAL (All injuries)	78 (100.0)	23 (100.0)	98 (100.0)	56 (100.0)	20 (100.0)

TABLE A3 :

DIRECTION OF IMPACT : Rear
SEATING POSITION : Driver plus front left
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	42 (46.7)	21 (48.8)	61 (42.7)	31 (31.0)	10 (32.2)
Fractured Vertebrae				1 (1.0)	
Concussion		1 (2.3)	4 (2.8)		1 (3.2)
Major Intracranial Injury	1 (1.1)		1 (0.7)	1 (1.0)	
Fractured Skull					
Fractured Face Bones				1 (1.0)	
Open Wound of Eye and Orbit	1 (1.1)			1 (1.0)	
Total Head Injuries	2 (2.2)	2 (2.3)	5 (3.5)	3 (3.0)	1 (3.2)
Total All Other Injuries	46 (51.1)	21 (48.8)	77 (53.8)	65 (65.0)	20 (64.5)
TOTAL (All injuries)	90 (100.0)	43 (100.0)	143 (100.0)	100 (100.0)	31 (100.0)

TABLE A4 :

DIRECTION OF IMPACT : Rear
SEATING POSITION : Driver
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male plus female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	56 (42.4)	21 (38.9)	80 (46.0)	38 (34.9)	13 (37.1)
Fractured Vertebrae	1 (0.8)	2 (3.7)			
Concussion	2 (1.5)	1 (1.9)	7 (4.0)	2 (1.8)	1 (2.9)
Major Intracranial Injury	3 (2.3)		1 (0.6)	1 (0.9)	
Fractured Skull	1 (0.8)			1 (0.9)	
Fractured Face Bones					
Open Wound of Eye and Orbit	2 (1.5)			1 (0.9)	
Total Head Injuries	8 (6.1)	1 (1.9)	8 (4.6)	5 (4.6)	1 (2.9)
Total All Other Injuries	67 (50.8)	30 (55.6)	86 (49.4)	66 (60.6)	21 (60.0)
TOTAL (All injuries)	132 (100.0)	54 (100.0)	174 (100.0)	109 (100.0)	35 (100.0)

TABLE A5 :

DIRECTION OF IMPACT : Rear
SEATING POSITION : Driver
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	27 (37.0)	7 (33.3)	41 (44.1)	18 (34.6)	8 (50.0)
Fractured Vertebrae	1 (1.4)	2 (9.5)			
Concussion	2 (2.7)		5 (5.4)	2 (3.8)	1 (6.3)
Major Intracranial Injury	2 (2.7)		1 (1.1)		
Fractured Skull	1 (1.4)			1 (1.9)	
Fractured Face Bones					
Open Wound of Eye and Orbit	1 (1.4)				
Total Head Injuries	6 (8.2)	-	6 (6.5)	3 (5.8)	1 (6.3)
Total All Other Injuries	39 (53.4)	12 (57.1)	46 (49.5)	31 (59.6)	7 (43.8)
TOTAL (All injuries)	73 (100.0)	21 (100.0)	93 (100.0)	52 (100.0)	16 (100.0)

TABLE A6 :

DIRECTION OF IMPACT : Rear
SEATING POSITION : Driver
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	29 (49.2)	14 (42.4)	39 (48.1)	20 (35.1)	5 (26.3)
Fractured Vertebrae					
Concussion		1 (3.0)	2 (2.5)		
Major Intracranial Injury	1 (1.7)			1 (1.8)	
Fractured Skull					
Fractured Face Bones					
Open Wound of Eye and Orbit	1 (1.7)			1 (1.8)	
Total Head Injuries	2 (3.4)	1 (3.0)	2 (2.5)	2 (3.5)	-
Total All Other Injuries	28 (47.5)	18 (54.5)	40 (49.4)	35 (61.4)	14 (73.7)
TOTAL (All injuries)	59 (100.0)	33 (100.0)	81 (100.0)	57 (100.0)	19 (100.0)

TABLE A7 :

DIRECTION OF IMPACT : Rear
SEATING POSITION : Front left
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male plus female
AGE OF OCCUPANT : All ages

	YEAR OF MANUFACTURE				
INJURY GROUP	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	14 (38.9)	8 (66.7)	24 (35.8)	13 (27.7)	5 (31.3)
Fractured Vertebrae				2 (4.3)	
Concussion			2 (3.0)		1 (6.3)
Major Intracranial Injury			1 (1.5)		
Fractured Skull					
Fractured Face Bones				1 (2.1)	
Open Wound of Eye and Orbit					
Total Head Injuries	-	-	3 (4.5)	1 (2.1)	1 (6.3)
Total All Other Injuries	22 (61.1)	4 (33.3)	40 (59.7)	31 (66.0)	10 (62.5)
TOTAL (All injuries)	36 (100.0)	12 (100.0)	67 (100.0)	47 (100.0)	16 (100.0)

TABLE A8 :

DIRECTION OF IMPACT : Rear
SEATING POSITION : Front left
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE 1969-70	1971	1972-74	1975-76	1977-78
Whiplash	1 (20.0)	1 (50.0)	2 (40.0)	2 (50.0)	-
Fractured Vertebrae				1 (25.0)	
Concussion					
Major Intracranial Injury					
Fractured Skull					
Fractured Face Bones					
Open Wound of Eye and Orbit					
Total Head Injuries	-	-	-	-	-
Total All Other Injuries	4 (80.0)	1 (50.0)	3 (60.0)	1 (25.0)	4 (100.0)
TOTAL (All injuries)	5 (100.0)	2 (100.0)	5 (100.0)	4 (100.0)	4 (100.0)

TABLE A9 :

DIRECTION OF IMPACT : Rear
SEATING POSITION : Front left
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	13 (41.9)	7 (70.0)	22 (35.5)	11 (25.6)	5 (41.7)
Fractured Vertebrae				1 (2.3)	
Concussion			2 (3.2)		1 (8.3)
Major Intracranial Injury			1 (1.6)		
Fractured Skull					
Fractured Face Bones				1 (2.3)	
Open Wound of Eye and Orbit					
Total Head Injuries	-	-	3 (4.8)	1 (2.3)	1 (8.3)
Total All Other Injuries	18 (58.1)	3 (30.0)	37 (59.7)	30 (69.8)	6 (50.0)
TOTAL (All injuries)	31 (100.0)	10 (100.0)	62 (100.0)	43 (100.0)	12 (100.0)

TABLE A10:

DIRECTION OF IMPACT : Rear
SEATING POSITION : Rear
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male plus female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	3 (12.5)	2 (25.0)	3 (15.8)	2 (12.5)	4 (26.7)
Fractured Vertebrae				1 (6.3)	
Concussion	3 (12.5)	1 (12.5)			2 (13.3)
Major Intracranial Injury	1 (4.2)				1 (6.7)
Fractured Skull			1 (5.3)	1 (6.3)	
Fractured Face Bones				1 (6.3)	
Open Wound of Eye and Orbit					
Total Head Injuries	4 (16.7)	1 (12.5)	1 (5.3)	2 (12.5)	3 (20.0)
Total All Other Injuries	17 (70.8)	5 (62.5)	15 (78.9)	11 (68.8)	8 (53.3)
TOTAL (All injuries)	24 (100.0)	8 (100.0)	19 (100.0)	16 (100.0)	15 (100.0)

TABLE A11:

DIRECTION OF IMPACT : Rear
SEATING POSITION : Rear
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash				1 (14.3)	3 (27.3)
Fractured Vertebrae					
Concussion	2 (22.2)				1 (9.1)
Major Intracranial Injury					1 (9.1)
Fractured Skull				1 (14.3)	
Fractured Face Bones					
Open Wound of Eye and Orbit					
Total Head Injuries	2 (22.2)	-	-	1 (14.3)	2 (18.2)
Total All Other Injuries	7 (77.8)	-	1 (100.0)	5 (71.4)	6 (54.5)
TOTAL (All injuries)	9 (100.0)	-	1 (100.0)	7 (100.0)	11 (100.0)

TABLE A12:

DIRECTION OF IMPACT : Rear
SEATING POSITION : Rear
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	3 (20.0)	2 (25.0)	3 (16.7)	1 (11.1)	1 (25.0)
Fractured Vertebrae				1 (11.1)	
Concussion	1 (6.7)	1 (6.7)			1 (25.0)
Major Intracranial Injury	1 (6.7)				
Fractured Skull			1 (5.6)		
Fractured Face Bones				1 (11.1)	
Open Wound of Eye and Orbit					
Total Head Injuries	2 (13.3)	1 (12.5)	1 (5.6)	1 (11.1)	1 (25.0)
Total All Other Injuries	10 (66.7)	5 (62.5)	14 (77.8)	6 (66.7)	2 (50.0)
TOTAL (All injuries)	15 (100.0)	8 (100.0)	18 (100.0)	9 (100.0)	4 (100.0)

APPENDIX B

DETAILED INJURIES IN

FRONT END IMPACTS

TABLE B1 :

DIRECTION OF IMPACT : Front
SEATING POSITION : Rear
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male plus female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	3 (2.1)	2 (3.4)	7 (3.4)	1 (1.0)	1 (2.2)
Fractured Vertebrae	4 (2.8)	1 (1.7)	1 (0.5)		
Concussion	12 (8.3)	5 (8.6)	16 (7.8)	2 (2.0)	4 (8.9)
Major Intracranial Injury	4 (2.8)	2 (3.4)	9 (4.4)	5 (5.0)	1 (2.2)
Fractured Skull	4 (2.8)	4 (6.9)	8 (3.9)	1 (1.0)	1 (2.2)
Fractured Face Bones	7 (4.9)	3 (5.2)	18 (8.8)	4 (4.0)	1 (2.2)
Open Wound of Eye and Orbit		2 (3.4)		2 (2.0)	1 (2.2)
Total Head Injuries	27 (18.8)	16 (27.6)	51 (24.9)	14 (13.9)	8 (17.8)
Total All Other Injuries	110 (76.4)	39 (67.2)	146 (71.2)	86 (85.1)	36 (80.0)
TOTAL (All injuries)	144 (100.0)	58 (100.0)	205 (100.0)	101 (100.0)	45 (100.0)

TABLE B2 :

DIRECTION OF IMPACT : Front
SEATING POSITION : Rear
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male
AGE OF OCCUPANT : All ages

	YEAR OF MANUFACTURE				
INJURY GROUP	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	1 (1.6)		4 (4.2)		
Fractured Vertebrae	2 (3.1)		1 (0.1)		
Concussion	8 (12.5)	3 (12.0)	6 (6.3)	2 (5.6)	1 (5.3)
Major Intracranial Injury	3 (4.7)	2 (8.0)	5 (5.2)		1 (5.3)
Fractured Skull	3 (4.7)	3 (12.0)	7 (7.3)		1 (5.3)
Fractured Face Bones	4 (6.3)	1 (4.0)	12 (12.5)	3 (8.3)	
Open Wound of Eye and Orbit		1 (4.0)		1 (2.8)	1 (5.3)
Total Head Injuries	18 (28.1)	10 (40.0)	30 (31.3)	6 (16.7)	4 (21.1)
Total All Other Injuries	43 (67.2)	15 (60.0)	61 (63.5)	30 (83.3)	15 (78.9)
TOTAL (All injuries)	64 (100.0)	25 (100.0)	96 (100.0)	36 (100.0)	19 (100.0)

TABLE 83 :

DIRECTION OF IMPACT : Front
SEATING POSITION : Rear
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	2 (2.5)	2 (6.1)	3 (2.8)	1 (1.5)	1 (3.8)
Fractured Vertebrae	2 (2.5)	1 (3.0)			
Concussion	4 (5.0)	2 (6.1)	10 (9.2)		3 (11.5)
Major Intracranial Injury	1 (1.3)		4 (3.7)	5 (0.8)	
Fractured Skull	1 (1.3)	1 (3.0)	1 (0.9)	1 (1.5)	
Fractured Face Bones	3 (3.8)	2 (6.1)	6 (5.5)	1 (1.5)	1 (3.8)
Open Wound of Eye and Orbit		1 (3.0)		1 (1.5)	
Total Head Injuries	9 (11.3)	6 (18.2)	21 (19.3)	8 (12.3)	4 (15.4)
Total All Other Injuries	67 (83.8)	24 (72.7)	85 (78.0)	56 (86.2)	21 (80.8)
TOTAL (All injuries)	80 (100.0)	33 (100.0)	109 (100.0)	65 (100.0)	26 (100.0)

TABLE B4:

DIRECTION OF IMPACT : Front
SEATING POSITION : Driver
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male plus female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	23 (4.3)	10 (3.3)	40 (4.7)	16 (3.4)	12 (6.7)
Fractured Vertebrae	8 (1.5)	3 (1.0)	14 (1.7)	6 (1.3)	3 (1.7)
Concussion	29 (5.5)	13 (4.3)	35 (4.2)	24 (5.1)	4 (2.2)
Major Intracranial Injury	11 (2.1)	9 (3.0)	24 (2.8)	10 (2.1)	4 (2.2)
Fractured Skull	4 (0.8)	3 (1.0)	6 (0.7)	5 (1.1)	2 (1.1)
Fractured Face Bones	19 (3.6)	17 (5.7)	33 (3.9)	21 (4.5)	9 (5.1)
Open Wound of Eye and Orbit	4 (0.8)	6 (2.0)	5 (0.6)	4 (0.9)	1 (0.6)
Total Head Injuries	67 (12.6)	48 (16.0)	103 (12.2)	64 (13.6)	20 (11.2)
Total All Other Injuries	432 (81.5)	239 (79.7)	686 (81.4)	384 (81.7)	143 (80.3)
TOTAL (All injuries)	530 (100.0)	300 (100.0)	843 (100.0)	470 (100.0)	178 (100.0)

TABLE B5:

DIRECTION OF IMPACT : Front
SEATING POSITION : Driver
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	13 (3.5)	4 (2.2)	20 (3.6)	9 (3.3)	6 (5.1)
Fractured Vertebrae	4 (1.1)	1 (0.6)	9 (1.6)	4 (1.5)	2 (1.7)
Concussion	22 (6.0)	9 (5.0)	30 (5.5)	14 (5.1)	4 (3.4)
Major Intracranial Injury	8 (2.2)	7 (3.9)	15 (2.7)	6 (2.2)	1 (0.9)
Fractured Skull	2 (0.5)	2 (1.1)	3 (0.5)	4 (1.5)	2 (1.7)
Fractured Face Bones	17 (4.6)	11 (6.1)	21 (3.8)	11 (4.0)	7 (6.0)
Open Wound of Eye and Orbit	4 (1.1)	3 (1.7)	2 (0.4)	3 (1.1)	1 (0.9)
Total Head Injuries	53 (14.4)	32 (17.8)	71 (12.9)	38 (14.0)	15 (12.8)
Total All Other Injuries	297 (80.9)	143 (79.4)	450 (81.8)	221 (81.3)	94 (80.3)
TOTAL (All injuries)	367 (100.0)	180 (100.0)	550 (100.0)	272 (100.0)	117 (100.0)

TABLE B6 :

DIRECTION OF IMPACT : Front
SEATING POSITION : Driver
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	10 (6.1)	6 (5.0)	20 (6.8)	7 (3.5)	6 (9.8)
Fractured Vertebrae	4 (2.5)	2 (1.7)	5 (1.7)	2 (1.0)	1 (1.6)
Concussion	7 (4.3)	4 (3.3)	5 (1.7)	10 (5.1)	-
Major Intracranial Injury	3 (1.8)	2 (1.7)	9 (3.1)	4 (2.0)	3 (4.9)
Fractured Skull	2 (1.2)	1 (0.8)	3 (1.0)	1 (0.5)	-
Fractured Face Bones	2 (1.2)	6 (5.0)	12 (4.1)	10 (5.1)	2 (3.3)
Open Wound of Eye and Orbit	-	3 (2.5)	3 (1.0)	1 (0.5)	-
Total Head Injuries	14 (8.6)	16 (13.3)	32 (10.9)	26 (13.1)	5 (8.2)
Total All Other Injuries	135 (82.8)	96 (80.0)	236 (80.5)	163 (82.3)	49 (80.3)
TOTAL (All injuries)	163 (100.0)	120 (100.0)	293 (100.0)	198 (100.0)	61 (100.0)

TABLE B7 :

DIRECTION OF IMPACT : Front
SEATING POSITION : Front left
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male plus female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	19 (6.1)	4 (3.3)	24 (5.3)	15 (6.4)	5 (5.0)
Fractured Vertebrae	5 (1.6)	4 (3.3)	5 (1.1)	7 (3.0)	2 (2.0)
Concussion	7 (2.3)	5 (4.1)	18 (4.0)	8 (3.4)	5 (5.0)
Major Intracranial Injury	9 (2.9)	3 (2.5)	24 (5.3)	6 (2.6)	1 (1.0)
Fractured Skull	8 (2.6)	2 (1.7)	6 (1.3)	3 (1.3)	1 (1.0)
Fractured Face Bones	17 (5.5)	6 (5.0)	14 (3.1)	9 (3.8)	2 (2.0)
Open Wound of Eye and Orbit	8 (2.6)	3 (2.5)	4 (0.9)	1 (0.4)	1 (1.0)
Total Head Injuries	49 (15.8)	19 (15.7)	66 (14.7)	27 (11.5)	10 (9.9)
Total All Other Injuries	238 (76.5)	94 (77.7)	354 (78.8)	186 (79.1)	84 (83.2)
TOTAL (All injuries)	311 (100.0)	121 (100.0)	449 (100.0)	235 (100.0)	101 (100.0)

TABLE B8 :

DIRECTION OF IMPACT : Front
SEATING POSITION : Front left
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Male
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	3 (2.7)	1 (1.8)	4 (2.7)	3 (4.1)	2 (6.5)
Fractured Vertebrae	3 (2.7)	4 (7.0)	2 (1.4)	1 (1.4)	1 (3.2)
Concussion	2 (1.8)	3 (5.3)	5 (3.4)	3 (4.1)	2 (6.5)
Major Intracranial Injury	6 (5.3)	2 (3.5)	10 (6.8)	1 (1.4)	-
Fractured Skull	3 (2.7)	2 (3.5)	4 (2.7)	-	-
Fractured Face Bones	11 (9.7)	4 (7.0)	1 (0.7)	5 (6.8)	2 (6.5)
Open Wound of Eye and Orbit	2 (1.8)	1 (1.8)	2 (1.4)	1 (1.4)	-
Total Head Injuries	24 (21.2)	12 (21.1)	22 (15.0)	10 (13.7)	4 (12.9)
Total All Other Injuries	83 (73.5)	40 (70.2)	119 (81.0)	59 (80.8)	24 (77.4)
TOTAL (All injuries)	113 (100.0)	57 (100.0)	147 (100.0)	73 (100.0)	31 (100.0)

TABLE B9 :

DIRECTION OF IMPACT : Front
SEATING POSITION : Front left
LOCATION OF ACCIDENT : All Victoria
SEX OF OCCUPANT : Female
AGE OF OCCUPANT : All ages

INJURY GROUP	YEAR OF MANUFACTURE				
	1969-70	1971	1972-74	1975-76	1977-78
Whiplash	16 (8.1)	3 (4.7)	20 (6.6)	12 (7.4)	3 (4.3)
Fractured Vertebrae	2 (1.0)	-	3 (1.0)	6 (3.7)	1 (1.4)
Concussion	5 (2.5)	2 (3.1)	13 (4.3)	5 (3.1)	3 (4.3)
Major Intracranial Injury	3 (1.5)	1 (1.6)	14 (4.6)	5 (3.1)	1 (1.4)
Fractured Skull	5 (2.5)	-	2 (0.7)	3 (1.9)	1 (1.4)
Fractured Face Bones	6 (3.0)	2 (3.1)	13 (4.3)	4 (2.5)	-
Open Wound of Eye and Orbit	6 (3.0)	2 (3.1)	2 (0.7)	-	1 (1.4)
Total Head Injuries	25 (12.6)	7 (10.9)	44 (14.6)	17 (10.5)	6 (8.6)
Total All Other Injuries	155 (78.3)	54 (84.4)	235 (77.8)	127 (78.4)	60 (85.7)
TOTAL (All injuries)	198 (100.0)	64 (100.0)	302 (100.0)	162 (100.0)	70 (100.0)

APPENDIX C

COMPUTER PROGRAM FOR
CHI-SQUARE TESTS ON
THREE-DIMENSIONAL CONTINGENCY TABLES

```
      PROGRAM MAXLIK3(INPUT,OUTPUT,FREQ,TAPE5=FREQ,TAPE6=OUTPUT)
C
C
C PROGRAM TO TEST LOG-LINEAR MODEL FOR THREE-DIMENSIONAL
C CONTINGENCY TABLE BY MAXIMUM LIKELIHOOD ESTIMATES FOR
C ELEMENTARY CELLS (ITERATIVE METHOD) AND MARGINAL
C TABLES (DIRECT METHOD).
C
C REFERENCE: "DISCRETE MULTIVARIATE ANALYSIS" BY BISHOP, FIENBERG
C AND HOLLAND (1975), PAGES 31-42, 73-97, 125-126.
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C FOR OFFICE OF ROAD SAFETY, COMMONWEALTH DEPARTMENT OF TRANSPORT.
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C
      DIMENSION TITLE(13),FMT(4),X(10,10,10),XIJ(100),XIK(100),XJK(100),
     1XI(10),XJ(10),XK(10)
      DIMENSION E1(11,11),E2(11,11),C1(11,11),C2(11,11)
      DIMENSION P1(11,11),P2(11,11),D(11,11),R(11,11)
      DIMENSION XAB(10,10),XAC(10,10),XBC(10,10),F(10,10,10),
     1E(10,10,10),EAB(10,10),EAC(10,10),EBC(10,10)
    1 READ(5,2)NI,NJ,NK,IO
    2 FORMAT(4I3)
      IF(NI)3,3,4
    3 STOP
    4 READ(5,5)TITLE,FMT
    5 FORMAT(13A6/4A10)
      READ(5,FMT)(((X(I,J,K),J=1,NJ),I=1,NI),K=1,NK)
      WRITE(6,6)TITLE
    6 FORMAT(1H1,13A6)
      DO 10 J=1,NJ
      DO 10 I=1,NI
      M1=I+NI*(J-1)
      XIJ(M1)=0.
      DO 10 K=1,NK
   10 XIJ(M1)=XIJ(M1)+X(I,J,K)
      DO 20 K=1,NK
      DO 20 I=1,NI
      M2=I+NI*(K-1)
      XIK(M2)=0.
      DO 20 J=1,NJ
   20 XIK(M2)=XIK(M2)+X(I,J,K)
      DO 30 K=1,NK
      DO 30 J=1,NJ
      M3=J+NJ*(K-1)
      XJK(M3)=0.
      DO 30 I=1,NI
   30 XJK(M3)=XJK(M3)+X(I,J,K)
      CALL CHISQ(XIJ,NI,NJ,AB,NAB,I1,XI,XJ)
      CALL CHISQ(XIK,NI,NK,AC,NAC,I2,XI,XK)
      CALL CHISQ(XJK,NJ,NK,BC,NBC,I3,XJ,XK)
      ABC=0.
      CALL SUM(X,NI,NJ,NK,XAB,XAC,XBC)
      DO 200 I=1,NI
      DO 200 J=1,NJ
      DO 200 K=1,NK
  200 E(I,J,K)=1.
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      KOUNT=0
  210 KOUNT=KOUNT+1
      CALL SUM(E,NI,NJ,NK,EAB,EAC,EBC)
      DO 220 I=1,NI
      DO 220 J=1,NJ
      DO 220 K=1,NK
      F(I,J,K)=E(I,J,K)
  220 E(I,J,K)=E(I,J,K)*XAB(I,J)/EAB(I,J)
      CALL SUM(E,NI,NJ,NK,EAB,EAC,EBC)
      DO 230 I=1,NI
      DO 230 J=1,NJ
      DO 230 K=1,NK
  230 E(I,J,K)=E(I,J,K)*XAC(I,K)/EAC(I,K)
      CALL SUM(E,NI,NJ,NK,EAB,EAC,EBC)
      DO 240 I=1,NI
      DO 240 J=1,NJ
      DO 240 K=1,NK
  240 E(I,J,K)=E(I,J,K)*XBC(J,K)/EBC(J,K)
      IFLAG=0
      DELTA=0.01
      DO 250 I=1,NI
      DO 250 J=1,NJ
      DO 250 K=1,NK
      DIFF=ABS(E(I,J,K)-F(I,J,K))
  250 IF(DIFF.GT.DELTA)IFLAG=1
      IF((IFLAG.EQ.1).AND.(KOUNT.LE.50))GO TO 210
      I4=0
      DO 49 I=1,NI
      DO 49 J=1,NJ
      DO 49 K=1,NK
      EM=E(I,J,K)
      IF(EM-1.)40,45,45
   40 I4=1
   45 C=2.*X(I,J,K)*ALOG(X(I,J,K)/EM)
      ABC=ABC+C
      IF(K-2)46,47,47
   46 E1(I,J)=EM
      C1(I,J)=C
      GO TO 49
   47 E2(I,J)=EM
      C2(I,J)=C
   49 CONTINUE
      NABC=(NI-1)*(NJ-1)*(NK-1)
      IF(I1+I2+I3+I4)55,55,50
   50 WRITE(6,51)
   51 FORMAT(36H0  SOME EXPECTED VALUE LESS THAN ONE)
   55 WRITE(6,56)
   56 FORMAT(32H0INTERACTION   CHI-SQUARE      DF)
      WRITE(6,60)AB,NAB,AC,NAC,BC,NBC,ABC,NABC,KOUNT
   60 FORMAT(8H0      AB,F16.3,1X,I7/8H0      AC,F16.3,1X,I7/8H0      BC,F1
     16.3,1X,I7/8H0     ABC,F16.3,1X,I7/14H0ITERATIONS = ,I3)
      IF(I0)61,61,1
61    DO 65 J=1,NJ
      DO 65 I=1,NI
      P1(I,J)=X(I,J,1)
65    P2(I,J)=X(I,J,NK)
      NIT=NI+1
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      NJT=NJ+1
      DO 70 J=1,NJ
      P1(NIT,J)=0.
      P2(NIT,J)=0.
      DO 70 I=1,NI
      P1(NIT,J)=P1(NIT,J)+P1(I,J)
70    P2(NIT,J)=P2(NIT,J)+P2(I,J)
      DO 75 I=1,NIT
      P1(I,NJT)=0
      P2(I,NJT)=0
      DO 75 J=1,NJ
      P1(I,NJT)=P1(I,NJT)+P1(I,J)
75    P2(I,NJT)=P2(I,NJT)+P2(I,J)
      WRITE(6,80)
80    FORMAT(5H0DATA/11H0FACTOR C=1)
      CALL MATIX(P1,NIT,NJT)
      WRITE(6,81)
81    FORMAT(12H0FACTOR C=NK)
      CALL MATIX(P2,NIT,NJT)
      WRITE(6,82)
   82 FORMAT(16H0EXPECTED VALUES/11H0FACTOR C=1)
      CALL MATIX(E1,NI,NJ)
      WRITE(6,81)
      CALL MATIX(E2,NI,NJ)
      WRITE(6,83)
   83 FORMAT(24H0LIKELIHOOD RATIO VALUES/11H0FACTOR C=1)
      CALL MATIX(C1,NI,NJ)
      WRITE(6,81)
      CALL MATIX(C2,NI,NJ)
      DO 85 J=1,NJT
      DO 85 I=1,NIT
      P1(I,J)=P1(I,J)/P1(NIT,J)*100.
85    P2(I,J)=P2(I,J)/P2(NIT,J)*100.
      WRITE(6,90)
90    FORMAT(29H0FACTOR A DISTRIBUTION (PCT.)/11H0FACTOR C=1)
      CALL MATIX(P1,NIT,NJT)
      WRITF(6,95)
95    FORMAT(12H0FACTOR C=NK)
      CALL MATIX(P2,NIT,NJT)
      DO 100 J=1,NJT
      DO 100 I=1,NIT
100   D(I,J)=P2(I,J)-P1(I,J)
      WRITE(6,105)
105   FORMAT(29H0FACTOR A DISTRIBUTION CHANGE)
      CALL MATIX(D,NIT,NJT)
      DO 110 J=1,NJT
      DO 110 I=1,NIT
110   R(I,J)=D(I,J)/P1(I,J)*100.
      WRITE(6,115)
115   FORMAT(34H0FACTOR A DISTRIBUTION PCT. CHANGE)
      CALL MATIX(R,NIT,NJT)
      WRITE(6,120)
120   FORMAT(35H0FACTOR A=ROWS      FACTOR B=COLUMNS)
      GO TO 1
      END
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      SUBROUTINE CHISQ(A,N,M,CS,NDF,IERR,TR,TC)
      DIMENSION A(1),TR(1),TC(1)
      NM=N*M
      IERR=0
      CS=0.0
      NDF=(N-1)*(M-1)
      IF(NDF) 5,5,10
5     IERR=3
      RETURN
10    DO 90 I=1,N
      TR(I)=0.0
      IJ=I-N
      DO 90 J=1,M
      IJ=IJ+N
90    TR(I)=TR(I)+A(IJ)
      IJ=0
      DO 100 J=1,M
      TC(J)=0.0
      DO 100 I=1,N
      IJ=IJ+1
100   TC(J)=TC(J)+A(IJ)
      GT=0.0
      DO 110 I=1,N
110   GT=GT+TR(I)
      IF(NM-4) 130,120,130
120   CS=GT*(ABS(A(1)*A(4)-A(2)*A(3))-GT/2.0)**2 /(TC(1)*TC(2)*TR(1)
     1*TR(2))
      RETURN
130   IJ=0
      DO 140 J=1,M
      DO 140 I=1,N
      IJ=IJ+1
      E=TR(I)*TC(J)/GT
      IF(E-1.0) 135,140,140
135   IERR=1
140   CS=CS+(A(IJ)-E)*(A(IJ)-E)/E
      RETURN
      END
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      SUBROUTINE  SUM(X,NI,NJ,NK,XIJ,XIK,XJK)
      DIMENSION X(10,10,10),XIJ(10,10),XIK(10,10),XJK(10,10)
      DO 10 J=1,NJ
      DO 10 I=1,NI
      XIJ(I,J)=0.
      DO 10 K=1,NK
   10 XIJ(I,J)=XIJ(I,J)+X(I,J,K)
      DO 20 K=1,NK
      DO 20 I=1,NI
      XIK(I,K)=0.
      DO 20 J=1,NJ
   20 XIK(I,K)=XIK(I,K)+X(I,J,K)
      DO 30 K=1,NK
      DO 30 J=1,NJ
      XJK(J,K)=0.
      DO 30 I=1,NI
   30 XJK(J,K)=XJK(J,K)+X(I,J,K)
      RETURN
      END
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      SUBROUTINE MATIX (ARAY,M,N)
      DIMENSION ARAY(11,11),KOL(11)
      K1=0
      K2=0
      KS=0
      DO 74 K=1,N
   74 KOL(K)=K
   75 K1=K2+1
      K2=K1+6
      IF(N-K2)88,89,89
   88 K2=N
   89 KS=KS+1
      IF(N-7)92,92,91
   91 WRITE(6,175)KS
   92 WRITE(6,178)(KOL(K),K=K1,K2)
      DO 93 J=1,M
   93 WRITE (6,179)J,(ARAY(J,K),K=K1,K2)
   98 IF(N-K2)99,99,75
   99 RETURN
  175 FORMAT(5X,7HSECTION,I2,11H FOLLOWS...)
  178 FORMAT (5X,8HCOL. NO.,3X,6I10)
  179 FORMAT (5X,7HROW NO.,I3,4X,6F10.1)
      END
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