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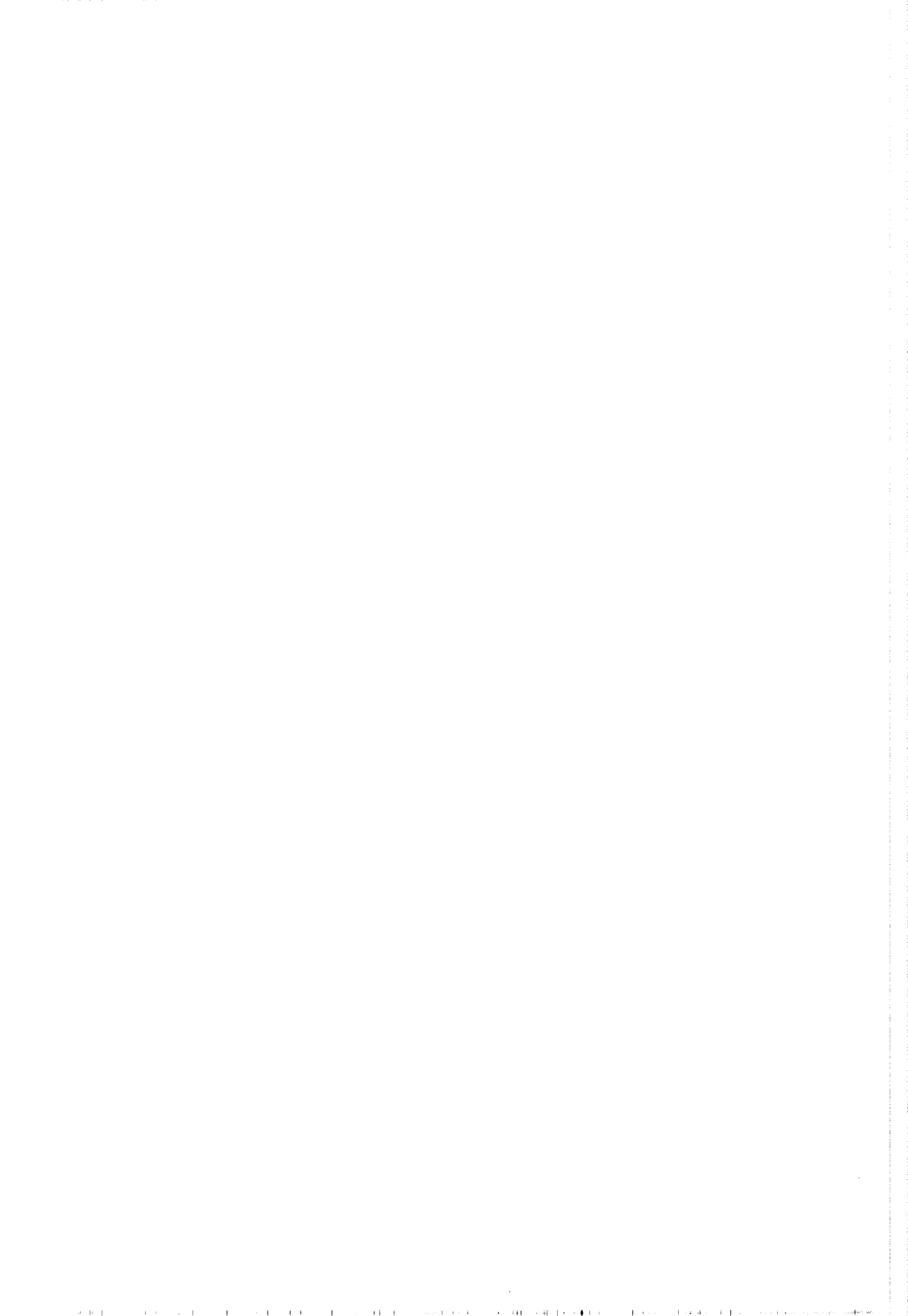
Accident Research Centre

**VEHICLE CRASHWORTHINESS RATINGS:
VICTORIA 1983-90 AND NSW 1989-90 CRASHES**

SUMMARY REPORT

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-

Abstract:

Crashworthiness is the relative safety of vehicles in preventing injury and/or severe injury in crashes. Crashworthiness ratings for 1982-90 model vehicles were developed based on crash data from Victoria and New South Wales. Crashworthiness was measured by a combination of injury severity (of injured drivers) and injury risk (of drivers involved in crashes). Injury severity was based on over 22,000 drivers injured in crashes in the two States. Injury risk was based on over 70,000 drivers involved in crashes in New South Wales where a vehicle was towed away. The results measure the crashworthiness of the makes and models of vehicles, free from the effects of driver sex and speed zone differences between models. The analysis suggested that the different results were predominantly due to vehicle factors alone. The results are reliable in indicating the crashworthiness of the vehicles specified to the extent indicated by the error limits, and can be used to make reliable comparisons of the crashworthiness of pairs of models when the error limits do not overlap. However the results and conclusions are based on a number of assumptions and warrant a number of qualifications which should be noted.

Key Words: (IRRD except when marked*)

Injury, Vehicle Occupant, Collision, Passenger Car Unit, Passive Safety System, Statistics

Disclaimer:

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EXECUTIVE SUMMARY

Consumer advice on vehicle crash performance can rate vehicles on their crashworthiness (the relative safety of vehicles in preventing injury and/or severe injury in crashes) or their crash involvement risk (attributes which assist or prevent vehicles from being involved in crashes). Crashworthiness ratings have the greater potential to find differences between makes and models of cars.

This report describes the development of crashworthiness ratings for 1982-90 model vehicles based on crash data from Victoria and New South Wales. Crashworthiness was measured by a combination of injury severity (of injured drivers) and injury risk (of drivers involved in crashes). Injury severity was based on 22,600 drivers injured in crashes in the two States. Injury risk was based on 70,900 drivers involved in crashes in New South Wales where a vehicle was towed away.

The crashworthiness rating scores were normalised for the driver sex and speed limit at the crash location, the two factors found to be strongly related to injury risk and/or severity, and to vary substantially across makes and models of crash involved cars in each State. Driver age, which could be expected to affect injury susceptibility, did not vary sufficiently between models of cars to have a substantial effect on the results.

It was concluded that the rating scores measure the crashworthiness of the makes and models of vehicles, free from the effects of driver sex and speed zone differences between models. The analysis suggested that the different rating scores were predominantly due to vehicle factors alone. Each rating score is reliable in indicating the crashworthiness of the vehicle specified to the extent indicated by the error limits. The rating score can be used to make reliable comparisons of the crashworthiness of pairs of models when the error limits do not overlap. However the results and conclusions are based on a number of assumptions and warrant a number of qualifications which should be noted.

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- . Mr Andrew Graham and Mr Michael Adams of the NSW RTA who prepared and provided data files from NSW Police accident reports, together with model information supplied by the NRMA
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- . Mr David Kenny of MUARC for updating and refining this logic to determine the models of vehicles recorded in TAC claims records
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- . Dr Alan Miller of the CSIRO Division of Mathematics and Statistics for reviewing the statistical methods used in the project and reporting on their satisfactory nature. He also suggested other methods which could be used to improve the sensitivity of the results when future updates are carried out.
- . Officers of the Victorian and NSW Police Forces and of the Transport Accident Commission who diligently recorded the information on crashes and injuries which formed the basis of this report.

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1.0 INTRODUCTION

The March 1990 report of the Victorian Parliamentary Social Development Committee's Inquiry into Vehicle Occupant Protection recommended that ways should be investigated for Victorian consumers to give high priority to motor vehicle occupant protection in the vehicles they purchase (SDC 1990). There is a need to inform consumers of the relative safety of cars offered for sale as a way of encouraging manufacturers to improve the crash performance of their products (Dowdell 1990a, 1990b). Consumer advice on vehicle safety performance can provide vehicle make/model ratings of two types:

- . Crashworthiness ratings (measuring the relative safety of vehicles in preventing injury and/or severe injury in crashes)
- . Crash involvement ratings (measuring attributes which assist or prevent vehicles from being involved in crashes).

Previous research has shown that vehicle factors play a large role in whether a car occupant is severely injured in a crash (other key factors are the impact speed, point of impact, seating position, restraint use, and the occupant's age and sex). Overseas evidence shows that there are considerable differences between makes and models related to vehicle crashworthiness (Campbell and Reinfurt 1973; Gustafsson et al 1989).

In contrast, vehicle factors have been estimated in several studies (summarized by Johnston 1984) to be the cause of about 10% of crash involvements (road user factors cause about 90% and environmental factors cause about 30%; multiple causes are common). Thus there is much less potential for make/model differences related to crash involvement.

In July 1990, the Monash University Accident Research Centre (MUARC) commenced a project to develop consumer advice on vehicle safety performance from mass accident data as part of the Centre's baseline research program. The development of crashworthiness ratings was given priority in the project because of their greater potential to find significant differences between makes and models.

In November 1990, the NSW Roads and Traffic Authority and the National Roads and Motorists' Association (NRMA) launched a joint project to develop vehicle safety ratings. During 1991, these organisations agreed to a cooperative venture with the Centre for the development of crashworthiness ratings. In October 1991 they provided Police report data on vehicles crashing in NSW, with model information added by the NRMA, for the purpose of integration with Victorian data.

This report summarizes the data and analysis methods used in the project and presents crashworthiness ratings for 1982-90 model vehicles based on crash data from Victoria and NSW combined. Further details are given in the technical report from the project (Cameron et al 1992) which covers the concepts developed, overseas methods, preparation of the data used, preliminary investigations to determine analysis methods, details of the adjustment procedures, and investigations of the separate results from Victoria and NSW.

2.0 CRASH DATA USED

2.1 Victorian Crashes

Detailed injury data have been collected by the Transport Accident Commission (TAC) and its predecessor, the Motor Accidents Board, as part of their responsibilities to provide road transport injury compensation. For each claimant, up to five injuries were recorded, as well as length of stay in hospital and total payments made by the TAC for treatment and loss of income. Details of the vehicle occupied were added from the VIC ROADS registration system.

TAC claims from drivers of cars and station wagons manufactured after 1981 who were involved in crashes in the period 1983 to 1990, and whose medical expenses exceeded a threshold which was indexed from year to year (\$317 in 1989), were matched with Police accident reports. The Police reports were on all drivers involved in accidents, no matter whether the Police officer recorded the person as injured or uninjured (this procedure was followed because it was possible for an injury claim to be made in circumstances where injury was not apparent at the time of the accident). Accidents are reported to the Police in Victoria if a person was killed or injured, if property was damaged but names and addresses were not exchanged, or if a possible breach of the Road Traffic Regulations has occurred (Green 1990).

The merged file covered 15876 drivers of 1982-90 model cars and station wagons crashing during 1983-90. Of these drivers involved in reported crashes, 12867 (81%) were injured (ie. TAC claimants), and 3158 (24.5%) of the injured were killed or hospitalised.

2.2 New South Wales Crashes

The NSW Roads and Traffic Authority (RTA) supplied a file covering 75860 light passenger vehicles involved in Police reported crashes during 1989-90 which resulted in death or injury or a vehicle being towed away. The NRMA had added the make, model and year of manufacture to these vehicles after matching with the NSW vehicle register via registration number and then decoding the chassis number obtained from that source. The file supplied covered only 1982-90 models (as determined by NRMA), but also covered four-wheel drive vehicles, passenger vans, light trucks and other commercial vehicles (these could be identified by their model) as well as cars and station wagons.

The vehicle file (which also contained driver age and sex) was merged with files supplied by NSW RTA covering details of the person casualties (killed and injured persons) and the reported crashes for the same years. Each vehicle/driver matched uniquely with the corresponding crash information, but only injured drivers could match with persons in the casualty file. A driver who did not match was considered to be uninjured. When the unoccupied vehicles were excluded, the injury details of 73399 drivers involved in crashes were available. According to the data supplied about these drivers, 10097 (13.8%) were injured and 2045 (20.3%) of the injured were killed or hospitalised.

The presence of uninjured drivers in the merged data file meant that it was suitable for measuring the risk of driver injury (in cars sufficiently damaged to require towing). This contrasted with the Victorian data file, which could not be used to measure injury risk directly because not all uninjured drivers were included.

3.0 DERIVATION OF MODELS OF CARS

The Victorian vehicle register provided the make and year of manufacture of the crashed vehicle but not the model. Model was initially derived for 1982-88 model cars using logic developed and supplied by the Royal Automobile Club of Victoria (RACV) based on the make, year and power-mass units. Power-mass units (PMU) are the sum of RAC horsepower units (PU) and the vehicle mass in units of 50 Kg (MU). Refined logic was developed by MUARC based on make, year, PMU, PU, MU and bodytype, and extended to cover 1989-90 models. The MUARC logic was applied to the combined Victorian data in conjunction with the RACV logic to derive passenger car models for the model years 1982-90.

In developing the MUARC logic, attention was paid to matching the range of models available in the NSW vehicle file. MUARC logic was developed for all models with more than 50 crash involvements in NSW during 1989-90, wherever possible.

The NRMA had decoded the chassis number (obtained from the NSW vehicle register) to determine the models of light passenger vehicles. The decoding identified some light truck and other commercial models which were not considered further. In addition, because the Victorian data was limited to cars and station wagons, the four-wheel drive and passenger van models in the NSW data were analysed separately.

All but 8% of the NSW vehicles had a model identified; in these cases the make of the vehicle was used as the model in both States' data. Comparison between makes which contain more than one model should be made with care and may not be legitimate, because some manufacturers have a broad span of masses in their model range.

Advice was provided by the VIC ROADS Vehicle Safety Branch regarding the models, years and bodytypes which needed to be kept separate, or could be aggregated, because of dissimilarity/similarity of crashworthiness aspects. They advised of a need to separate:

- . Ford Falcon/Fairmont XD, XE and XF series from the EA and EB series
- . Ford Falcon/Fairmont station wagons from sedans in the above series
- . Holden Commodore VH, VK and VL series from the VN series
- . Toyota Camry pre-1989 models from the 1989-90 models.

In addition, there is a need to note that some models have undergone substantial change during 1982-90 and that their aggregate rating for all the year models released in this period needs to be interpreted with caution.

The Vehicle Safety Branch also advised that the following models could be combined because of their similarity to maximize the number of cars on which the crashworthiness rating is based:

- . Holden Commodore VN and Toyota Lexcen
- . Ford Fairlane Z series and LTD F series
- . Ford Fairlane N series and LTD D series
- . Toyota Camry (1989-90 models) and Holden Apollo
- . Ford Telstar and Mazda 626
- . Toyota Corolla and Holden Nova

- . Holden Astra and Nissan Pulsar
- . Holden Barina and Suzuki Swift.

4.0 MEASURES TO RATE CRASHWORTHINESS

4.1 Overview

Crashworthiness ratings measure the risk of serious injury to the drivers of each specific model car when it is involved in a crash. This risk can be measured in two components:

- . risk of injury for drivers involved in crashes ("**injury risk**"), and
- . risk of serious injury for drivers who are injured ("**injury severity**").

Following the method used by Folksam Insurance in Sweden (Gustafsson et al 1989), it is then possible to calculate an overall crashworthiness rating, defined as:

$$\text{Combined Rate} = \text{Injury Severity} \times \text{Injury Risk.}$$

The combined rate defined in this way can be interpreted as measuring the risk of serious injury to drivers involved in a crash. Serious injury can be variously defined, but in this study, serious injury was taken as death, or injury requiring hospital admission.

Aldman et al (1984) recommended that "*when individual car models are studied the possible influence of the age of the driver, speed limit at the scene of the accident, belt usage rate, weight of the struck car, (and) impact direction ... must be taken into account*". Major differences in crash patterns between models of cars have the potential to hide any effects of the vehicle design on injury risk or injury severity. It is necessary to take these differences into account if valid comparisons of the crashworthiness of cars are to be made.

The variables in the data files which described the crash patterns included speed zone, crash type, point of impact on the car, car mass, and restraint use. The driver age and sex are related to injury susceptibility. The first question was whether any of these variables had a significant relationship with the injury severity and injury risk measures selected for rating crashworthiness. The second question was whether the significant variable differed enough between makes/models for this to make a substantial difference to the rating scores. These questions were investigated separately for each measure (Cameron et al 1992) and the findings are summarized in the following sections.

4.2 Injury Severity of Injured Drivers

The injury outcome of the 12867 injured drivers from Victoria (ie. TAC claimants who matched with Police accident reports) was categorised as:

- . Killed
- . Admitted to hospital for more than 6 days
- . Admitted to hospital for up to 6 days
- . Injured but not admitted to hospital.

Of the Victorian drivers injured in crashes, 3148 (or 24.5%) were killed or hospitalised.

The injury outcome of the 10097 injured drivers from NSW was categorised as:

- . Fatality (died within 30 days of the accident)
- . Admitted to hospital
- . Treated injury
- . Non-treated injury.

Of these injured NSW drivers, 2045 (or 20.3%) were killed or hospitalised.

The data on injured drivers from Victoria and NSW was pooled to measure injury severity by model of car, ie. to provide the first component of the combined rate. In the pooled data, 5193 of the 22964 injured drivers were killed or hospitalised, representing an injury severity of 22.6 per 100 injured drivers. This was considered sufficiently similar to the separate injury severities from Victoria and NSW to justify combining the two States' data. The standard deviation of the pooled injury severity (0.27) was substantially lower than that for either State alone. Thus the pooled data has greater sensitivity and reliability than the separate data sets.

In both the Victorian and NSW data files on injured drivers, it was found that the driver sex and the speed zone at the crash location (in two categories: up to 75 km/h; 80 km/h and above) were both strongly related to injury severity and they varied substantially across makes and models of crash involved cars. Other factors influencing injury severity were either associated with speed zone or, like driver age above 60, varied so little across models that their overall effect was relatively small compared with driver sex and speed zone.

The differences in driver sex and speed zone between models of cars were taken account by normalisation, a method used by HLDI (1991) following Armitage (1971). This was achieved by calculating the injury severity for drivers within each of the four categories of sex by speed zone, then combining the four figures using a constant mix of these categories for each model (the mix was in fact the average mix for all models combined). Thus every model was treated as if it had the same mix of male and female drivers and crashes in the high and low speed zones. This was essential to allow comparisons which related to vehicle differences rather than to injury susceptibility and other differences in the crash circumstances.

In the pooled data from the two States, 22626 (or 98.5%) of the injured drivers had known sex and speed zone. This data was the basis for calculating the normalised injury severity for each car model.

4.3 Injury Risk of Drivers Involved in Crashes

Because the Victorian data file did not include all uninjured drivers involved in crashes, it was not used to calculate injury risk for the main results. The file of 73399 drivers of 1982-90 model cars crashing in NSW during 1989-90 included 63302 who were not recorded as injured on the Police report. Some of their crashes may have been reported due to other persons being injured, but most would have been reported because a vehicle was towed away. This means that the injury rate is essentially an unbiased measure of the driver's injury risk in tow-away crashes. Thus the driver injury rate was used for the second component of the combined rate. The overall injury rate of the NSW drivers was 13.8 per 100 involved drivers with a standard deviation of 0.13.

The influence of crash patterns and driver characteristics on the comparisons of injury rates between models of cars was also investigated. Like injury severity, it was found that the driver sex and the speed zone were each strongly related to injury rate (and each varied substantially across makes and models of crash involved cars). Other factors had relatively small effects. Accordingly, the driver injury rate for each model car was normalised by driver sex and speed zone in a similar way as the driver injury severity described above.

Among the crash involved drivers from NSW, 70916 (or 96.6%) had known sex and speed zone. This data was the basis for calculating the normalised injury rate for each car model.

4.4 Combined Rate

The combined rate for each model was calculated by multiplying the driver injury severity (based on Victorian and NSW data) by the driver injury rate (based on NSW data). Thus the combined rate was normalised by driver sex and speed zone, because each of its components was separately normalised. The two components, respectively, measure:

- . the risk of death or hospitalisation for drivers who were injured in a crash, and
- . the risk of injury for drivers involved in crashes.

The combined rate can thus be interpreted as measuring the risk of death or hospitalisation for drivers involved in crashes. The overall combined rate was 3.14 per 100 involved drivers with a standard deviation of 0.05.

5.0 CRASHWORTHINESS RATINGS BY MODEL OF VEHICLE

5.1 Overview

Crashworthiness ratings based on the combined rate defined in Section 4.4 were calculated for each model of passenger car and station wagon, where there was sufficient data to calculate each normalised component of the combined rate. These calculations made use of data from Victoria and NSW crashes.

Separate ratings were calculated for four-wheel drive vehicles and passenger vans because the models of these types of vehicles were available only in the NSW data. The raw figures were not directly comparable with those for cars and station wagons, because the overall combined rate based on NSW data alone was only 2.80 per 100 involved drivers. To facilitate a direct comparison, the combined rates for the four-wheel drive and passenger van models were rescaled (by the ratio 3.14/2.80).

5.2 Rating Scores

The crashworthiness rating score for each model of car, station wagon, four-wheel drive vehicle and passenger van is presented in Table 1 (in bold type), sorted in ascending order within market group. These groups provided by the NRMA reflect the general market categories within which consumers typically make a decision about which model to purchase. The rating scores for the makes which were not separated into models (see Section 3.0) are presented in Table 2.

TABLE 1: CRASHWORTHINESS RATINGS OF 1982-90 MODEL VEHICLES INVOLVED IN CRASHES

MAKE	MODEL OF CAR	YEARS OF MANUFACTURE INVOLVED IN CRASHES	RISK OF DEATH OR HOSPITALISATION FOR DRIVERS INVOLVED IN CRASHES			DEVIATION OF RATING FROM ALL MODEL AVE.	
			Rating Per 100 Drivers	Standard Deviation	Coeff. of Variation	Per 100 Drivers	Std. Dev. Units
All Make/Model Average			3.14	0.05	1.51%		
LARGE CARS							
Ford	FALCON E SEDAN	1988-90	1.85	0.45	24.16%	-1.29	-2.88
Holden	COMMODORE VN	1988-90	2.39	0.41	17.18%	-0.75	-1.83
Toyota	LEXCEN	1988-90					
Mitsubishi	MAGNA	1984-90	2.40	0.25	10.26%	-0.74	-3.02
Nissan	SKYLINE	1982-90	2.62	0.48	18.35%	-0.52	-1.09
Ford	FALCON X SEDAN	1982-88	2.65	0.16	5.85%	-0.48	-3.12
Ford	FALCON X WAGON	1982-88	2.75	0.31	11.40%	-0.39	-1.25
Ford	FALCON E WAGON	1988-90	2.75	0.93	33.74%	-0.39	-0.42
Holden	COMMODORE VH-VL	1982-88	2.99	0.16	5.40%	-0.14	-0.89
Large Car Average			2.69				
MEDIUM CARS							
Holden	APOLLO	1989-90	2.55	0.66	25.74%	-0.58	-0.89
Toyota	CAMRY (89-90)	1989-90					
Nissan	PINTARA	1986-90	2.71	0.56	20.83%	-0.43	-0.77
Toyota	CAMRY (83-88)	1983-88	2.97	0.43	14.48%	-0.17	-0.39
Toyota	CORONA	1982-87	3.16	0.30	9.51%	0.03	0.09
Mitsubishi	SIGMA/SCORPION	1982-87	3.25	0.28	8.47%	0.11	0.40
Nissan	BLUEBIRD	1982-86	3.28	0.31	9.45%	0.14	0.47
Mazda	MAZDA 626	1982-90	3.37	0.25	7.52%	0.23	0.90
Ford	TELSTAR	1983-90					
Holden	CAMIRA	1982-89	3.53	0.25	7.15%	0.39	1.56
Mitsubishi	NIMBUS	1984-90	3.73	1.34	36.04%	0.59	0.44
Nissan	GAZELLE	1983-86	4.11	1.35	32.84%	0.97	0.72
Medium Car Average			3.27				
SMALL CARS							
Mitsubishi	LANCER	1988-90	2.18	0.91	41.92%	-0.96	-1.05
Toyota	COROLLA	1982-90	3.38	0.23	6.81%	0.24	1.05
Holden	NOVA	1989-90					
Mazda	MAZDA 323	1982-90	3.39	0.46	13.66%	0.25	0.54
Ford	METEOR/LASER	1982-90	3.46	0.20	5.67%	0.32	1.65
Holden	ASTRA	1984-89	3.52	0.28	8.06%	0.38	1.34
Nissan	VECTOR/PULSAR	1982-90					
Mitsubishi	COLT	1982-90	3.53	0.42	11.81%	0.39	0.94
Mitsubishi	CORDIA	1982-88	4.05	0.89	22.06%	0.91	1.02
Honda	CIVIC	1982-90	4.08	0.67	16.40%	0.94	1.41
Holden	GEMINI	1982-88	4.21	0.41	9.77%	1.07	2.60
Hyundai	EXCEL	1986-90	4.27	0.90	21.05%	1.13	1.26
Holden	BARINA	1984-90	4.52	0.73	16.23%	1.38	1.88
Suzuki	SWIFT	1984-90					
Daihatsu	CHARADE	1982-90	4.69	0.82	17.42%	1.55	1.90
Small Car Average			3.57				

TABLE 1: CRASHWORTHINESS RATINGS OF 1982-90 MODEL VEHICLES INVOLVED IN CRASHES

MAKE	MODEL OF CAR	YEARS OF MANUFACTURE INVOLVED IN CRASHES	RISK OF DEATH OR HOSPITALISATION FOR DRIVERS INVOLVED IN CRASHES			DEVIATION OF RATING FROM ALL MODEL AVE.	
			Rating Per 100 Drivers	Standard Deviation	Coeff. of Variation	Per 100 Drivers	Std. Dev. Units
All Make/Model Average			3.14	0.05	1.51%		
LUXURY CARS							
Volvo	VOLVO 700 SERIES	1984-88	1.31	0.76	58.19%	-1.83	-2.40
Holden	STATESMAN	1982-86	1.51	0.52	34.39%	-1.63	-3.15
Ford	FAIRLANE N & LTD D	1988-90	2.05	0.85	41.20%	-1.09	-1.28
Honda	ACCORD	1982-90	2.58	0.68	26.33%	-0.55	-0.81
Honda	PRELUDE	1982-90	2.63	0.77	29.41%	-0.51	-0.66
Toyota	CRESSIDA/CROWN	1982-90	2.70	0.59	21.73%	-0.43	-0.74
Volvo	VOLVO 200 SERIES	1982-90	2.88	0.75	26.07%	-0.26	-0.35
Ford	FAIRLANE Z & LTD F	1982-87	3.13	0.50	15.89%	0.00	-0.01
Mazda	MAZDA 929	1982-90	3.56	0.72	20.25%	0.42	0.58
Luxury Car Average			2.49				
SPORTS CARS							
Toyota	CELICA	1982-90	3.03	0.66	21.76%	-0.11	-0.17
Mazda	RX7	1982-90	3.72	1.01	27.10%	0.58	0.58
Sports Car Average			3.24				
4 WHEEL DRIVE VEHICLES							
Nissan	PATROL/PATHFINDER	1982-90	1.98	0.75	37.97%	-1.16	-1.55
Holden	JACKAROO	1983-90	2.08	0.72	34.88%	-1.07	-1.47
Daihatsu	ROCKY	1984-90	2.15	1.46	68.06%	-1.00	-0.68
Toyota	4RUNNER/LAND CRUISER	1982-90	2.70	0.60	22.31%	-0.44	-0.73
Mitsubishi	PAJERO	1983-90	3.03	1.24	41.02%	-0.11	-0.09
Nissan	NAVARA	1984-90	4.17	1.38	33.13%	1.03	0.74
Suzuki	SIERRA	1982-90	4.85	1.37	28.24%	1.70	1.24
4 Wheel Drive Average			2.63				
PASSENGER VANS							
Toyota	HILUX/HI & LITEACE	1982-90	3.42	0.54	15.79%	0.27	0.50
Ford	COURIER	1982-89	3.90	1.04	26.69%	0.76	0.73
Mitsubishi	MITSUBISHI VANS	1982-90	3.96	0.80	20.27%	0.82	1.02
Toyota	TARAGO	1983-85	4.10	1.40	34.06%	0.95	0.68
Passenger Van Average			3.67				

TABLE 2: CRASHWORTHINESS RATINGS OF 1982-90 MODEL VEHICLES INVOLVED IN CRASHES

MAKE	MODEL OF CAR	YEARS OF MANUFACTURE INVOLVED IN CRASHES	RISK OF DEATH OR HOSPITALISATION FOR DRIVERS INVOLVED IN CRASHES			DEVIATION OF RATING FROM ALL MODEL AVE.	
			Rating Per 100 Drivers	Standard Deviation	Coeff. of Variation	Per 100 Drivers	Std. Dev. Units
All Make/Model Average			3.14	0.05	1.51%		
CARS BY MAKE ONLY							
SAAB		1982-90	1.77	0.68	38.39%	-1.37	-2.03
Rover		1982-89	1.78	0.73	40.82%	-1.35	-1.86
B M W		1982-90	1.93	0.49	25.60%	-1.21	-2.44
Mercedes		1982-90	2.07	0.52	24.97%	-1.07	-2.06
Renault		1982-89	2.39	1.07	44.69%	-0.75	-0.70
Fiat		1982-89	2.70	1.30	48.15%	-0.44	-0.34
Alfa Romeo		1982-90	2.80	0.74	26.45%	-0.34	-0.46
Peugeot		1982-90	2.94	1.00	34.06%	-0.20	-0.20
Subaru		1982-90	3.40	0.41	12.09%	0.26	0.63
Range Rover		1982-89	3.45	1.25	36.36%	0.31	0.25

Note: The results in this table, which represent several different models of different mass, are not directly comparable with those in Table 1, for a single make/model

The rating score for each pair of models which could be aggregated (because the models are believed to be essentially the same so far as crashworthiness aspects are concerned; see Section 3.0) is their aggregate rating, ie. the same value is assigned to each of the models (in no case was there a statistically significant difference between their individual rating scores).

The standard deviation is a measure of the reliability of the rating score in estimating the crashworthiness of a specific model car. The standard deviation is a function of the number of involved and injured drivers in the data files. The true risk of driver death or hospitalisation in a crash could be expected to be within two standard deviations of the rating score with approximately 95% confidence. Thus each rating score can be considered to have error limits spanning two standard deviations on each side of the score.

It was decided that the rating score should not be reported if it does not provide a reliable estimate of the crashworthiness of the specific model car (or aggregate of two models). The results in Tables 1 and 2 exclude those makes and models where:

- . there were insufficient involved or injured drivers to calculate both of the components of the rating score (ie. combined rate) for the specific model,
- . the standard deviation of the rating score exceeded 1.5, or
- . the coefficient of variation (ie. standard deviation divided by the estimate) of the rating score exceeded 70%
 - this criterion was also necessary because small standard deviations tended to occur for the lower rating scores, but the standard deviations were relatively high in proportionate terms.

5.3 Deviations from the All Make/Model Average

The standard deviation can also be used to judge whether the rating score is sufficiently different from the all make/model average (3.14 per 100 involved drivers) for this to be unlikely to be due to chance. Tables 1 and 2 show the deviation of each make or model from the average in absolute terms (per 100 involved drivers) and also in units of the standard deviation for the make or model. A deviation of 1.96 standard deviations or more could occur by chance only about 5% of the time.

Such deviations below the average are indicative of superior crashworthiness, whereas those above the average suggest inferior crashworthiness. Of the 62 makes and models for which the rating score could be calculated reliably, eight displayed a score significantly below average and one displayed a score significantly greater than average. However, it should be noted that 5% of the 62 models (ie. about three) could be expected to deviate by chance from the all make/model average by more than 1.96 standard deviations.

6.0 DISCUSSION

The rating scores given in Tables 1 and 2 measure the risk of death or hospitalisation of drivers of specific makes and models of vehicles involved in crashes. The question is whether the figures represent the crashworthiness of the vehicle alone, or whether they also

reflect other differences between vehicles related to the crashes in which they were involved or to physiological and other characteristics of the driver.

The analysis has recognised that a number of factors available in the data could affect the rating scores. The most important of these factors were the driver sex and speed zone, and the variations in these factors between makes and models were taken into account. Other factors which were strongly associated with the high speed zones (eg. single-vehicle crashes, fixed object collisions, and rollovers) were also taken into account with speed zone due to the strong association. Driver age, which could be expected to affect injury susceptibility, did not appear to vary sufficiently between models of cars to have a substantial effect on the rating scores.

However the analysis was not able to take into account other potentially important factors which were not measured in the data, eg. the crash speed of the vehicle (to the extent that variations in this factor were not reflected in the speed zone at the crash location). The absence of such information from Police accident reports and injury compensation claim records is a limitation of this type of data. However, the large number of cases available in these files provide the opportunity to measure the risks of serious injury to crash involved drivers reliably.

The crashworthiness of vehicles sold and crashing in Victoria and NSW would not be expected to differ between the States. The technical report demonstrated a statistically significant correlation between the rating scores derived for the two States independently (even though they used different methods of analysis for a component of the figures, ie. driver injury risk) (Cameron et al 1992). As the vehicles were the only common factor between the two States, the presence of a correlation suggests that both sets of rating scores are measuring the same thing, ie. the crashworthiness of the vehicles alone.

It follows that the rating scores based on both States' data combined are also likely to measure crashworthiness alone, and presumably more reliably. Regarding reliability, the rating scores in Tables 1 and 2 have been selected for presentation on the basis of relatively liberal standards for the error of estimation (see Section 5.4). A more reliable set of rating scores could be chosen if more conservative standards were set, but of course the rating scores would then cover a smaller number of makes and models. The reliability of the current rating scores is indicated by the standard deviations in Tables 1 and 2.

Comparison of the rating scores can be made for each pair of models, within the limits of their individual levels of reliability. The most reliable comparisons are for those pairs of models where the error limits (two standard deviations on either side of the rating score) do not overlap. The limited reliability of the relative comparisons is obvious when the general width of the error limits is examined.

7.0 CONCLUSIONS

1. The rating scores in Tables 1 and 2 measure the crashworthiness of the makes and models of vehicles, free from the effects of driver sex and speed zone differences between models. The analysis suggests that the different rating scores were predominantly due to vehicle factors alone.

2. Each rating score is reliable in indicating the crashworthiness of the vehicle specified to the extent indicated by error limits of two standard deviations on either side of the score.
3. The rating scores can be used to make reliable comparisons of the crashworthiness of pairs of models when the error limits do not overlap.

8.0 ASSUMPTIONS AND QUALIFICATIONS

The results and conclusions presented in this report are based on a number of assumptions and warrant a number of qualifications which the reader should note. These are listed in the following sections.

8.1 Assumptions

It has been assumed that:

- . TAC claims records and NSW Police accident reports accurately recorded driver injury, hospitalisation and death.
- . There was no bias in the merging of TAC claims and Victorian Police accident reports related to crash exposure factors and model of car.
- . Crashed vehicle registration numbers were recorded accurately on Police accident reports and that they correctly identified the crashed vehicles in the Victorian and NSW vehicle registers.
- . The adjustment for driver sex and speed zone was sufficient to remove the influences of the main factors available in the data which affected crash severity and injury susceptibility. (Other factors examined had smaller effects on injury severity or injury risk, and/or varied by relatively small amounts between models.)

8.2 Qualifications

The results and conclusions warrant at least the following qualifications:

- . Only driver crash involvements and injuries have been considered. Passengers occupying the same model cars may have had different injury outcomes which may have suggested a different assessment of the crashworthiness of the cars in terms of protecting all their occupants from injury.
- . The makes of cars which could not be disaggregated into models may include a range of models with a broad span of masses or other factors affecting crashworthiness. The rating score calculated for these makes should not be interpreted as applying to each model of these manufacturers.
- . Some models with the same name through the 1982-90 years of manufacture varied substantially in their construction and mass. The rating score calculated for these models may give a misleading impression and should be interpreted with caution.

Other factors not collected in the data (eg. crash speed) may differ between the makes and models and may affect the results.

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