

**THE RELATIONSHIP BETWEEN
DEMERIT POINTS ACCRUAL
AND CRASH INVOLVEMENT**

by

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Abstract

The objective of this study was to consider whether a driver's prior demerit points data (or their offence data used in other ways) could be used (in combination with other variables) to improve the prediction of the driver's subsequent crashes. To achieve this aim, multivariate statistical models were developed to represent drivers' crash involvements during 1993-1994 as a function of potential predictor variables measured during 1991-1992.

The initial multivariate model fitted included all available driver and licence variables (ie. driver age, driver sex, driver location and endorsement of licence) as well as the driver's reported casualty crash and serious injury involvements, and total traffic convictions during 1991-1992. Adding a driver's prior offences (whether as demerit point levels or categories of offence) into this model produced the two models with the best predictive ability in identifying drivers with future crash-involvements. For both these models, the proportion of drivers amongst the 500 highest scoring drivers who were subsequently involved in 1993-1994 crashes was 12.4%, ie. considerably greater than the 7.3% crash-involvement rate for the top 500 drivers identified by the initial model which did not use prior offence data. The corresponding crash-involvement rate for all drivers in the database was 0.76%.

The research on the relationship between demerit points accrual and subsequent crash-involvement has shown that inclusion of a driver's prior offences (whether as demerit point levels or categories of offence) in a multivariate model adds to the predictive ability of that model in identifying drivers with subsequent crash-involvements. The more efficient model uses a driver's prior offences classified into demerit point levels. Demerit points alone can be used to predict a driver's subsequent crash involvement, but an even better model can be produced by including prior casualty crash involvements as well.

Key Words: (IRRD except when marked*)

demerit points, crash involvement, traffic offences, driver's prior crashes, efficiency, multivariate model, relative risk, correct positives

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EXECUTIVE SUMMARY

The Victorian Parliamentary Road Safety Committee recommended that an analysis be undertaken of the VicRoads driver and accident databases to determine the relationship between driver accident involvement, demerit points accrual and other relevant factors as a means of identifying groups that have a significantly higher than average accident potential. The Monash University Accident Research Centre (MUARC) was contracted by VicRoads to determine both the nature and strength of the relationship between prior offence history and subsequent road accident involvement of drivers in Victoria. While the focus of the Parliamentary Committee's recommendation was on the relationship between demerit points and subsequent crashes, the study considered all available potential predictor variables such as the full range of offence information available, prior crash involvements, and driver characteristics such as age, sex, residential postcode and licence type.

The main objective of the study was to consider whether a driver's prior demerit points data (or their offence data used in other ways) could be used (in combination with other variables) to improve the prediction of the driver's subsequent crashes. To achieve this aim, multivariate statistical models were developed to represent drivers' crash involvements during 1993-1994 as a function of potential predictor variables measured during 1991-1992.

The initial multivariate model fitted was the *base* model (Model 1). This model included all available driver and licence variables (driver age, driver sex, driver location and endorsement of licence) as well as the driver's reported casualty crash and serious injury involvements, and total traffic convictions* during 1991-1992. To this model the driver's prior offence** data (in various forms) was added with the aim of finding a model which best predicted the driver's crash involvements during 1993-1994. Addition of the offence data resulted in the estimation of the following models:

- *Model 2*: base model + total number of offences during 1991-1992;
- *Model 3*: base model + number of offences during 1991-1992 by category of offence;
- *Model 4*: base model + number of offences during 1991-1992 by demerit point level of offence;
- *Model 5*: base model + total number of demerit points incurred during 1991-1992.

The above models were all superior to the base model with high statistical significance ($p < 0.0001$). Hence, addition of a driver's prior offence data (in some form) adds to the ability of a model in predicting subsequent casualty crash-involvements.

The two models which included offence categories that reflected their relative importance in predicting drivers' crash involvements during 1993-1994 (ie. Model 3, the "category of offence" model, and Model 4, the "demerit point level of offence" model) were the best fitting of the five models. Both these models were significantly superior to both the "total offences" and "total demerit points" models ($p < 0.0004$).

* A traffic conviction is defined to be a licence cancellation, licence suspension or licence disqualification.

** Offences are only those that incur demerit points (eg. exceeding speed limit, running a red-light), and do not include other offences such as drink-driving offences.

In addition to the above models, another model was fitted to the data in which the driver's prior casualty crash and serious injury involvements were omitted. This was found to be a less informative model in terms of predicting subsequent crash-involvements. Thus, although delays occur in obtaining crash data for each driver in Victoria, the ability of the models to predict subsequent crash involvements would be enhanced if such data could be included.

For the best fitting model (ie. Model 4, the "demerit point level of offence" model), the groups with the highest estimated probability of being represented in 1993-1994 crashes were:

- young drivers;
- male drivers;
- drivers endorsed with a truck licence;
- Melbourne residents;
- drivers with casualty crash and serious injury involvements in 1991-1992;
- drivers who had incurred licence convictions in 1991-1992;
- drivers with 'four demerit points', 'three demerit points', 'one demerit point', 'six demerit points', and/or 'two demerit points' offences (in that order) in 1991-1992.

The efficiency of the models was measured in terms of their ability to identify the drivers with the highest "accident potential". Each model's efficiency was compared by estimating the *relative risk* of casualty crash-involvement of the highest scoring drivers to that of all drivers in the database, and by estimating the proportion of "*correct positives*" (ie. drivers with high scores who were subsequently involved in crashes).

The risk of 1993-1994 crash involvement of the highest scoring 1% of drivers relative to all drivers in the database was greatest (and very similar) for the "category of offence" and "demerit point level of offence" models. For both these models, the highest scoring 1% of drivers had an estimated risk of crash-involvement 4.4 times that of all crashed drivers.

Amongst the 500 highest scoring drivers, the "category of offence" and "demerit point level of offence" models were equally efficient in identifying the crash-involved drivers. For both these models, the proportion of drivers amongst the 500 highest scoring drivers who were subsequently involved in 1993-1994 crashes was 12.4%, ie. considerably greater than the 7.3% crash-involvement rate for the top 500 drivers identified by the base model which did not use prior offence data. The corresponding crash-involvement rate for all drivers in the database was 0.76%.

This research on the relationship between demerit points accrual and subsequent crash-involvement has shown that inclusion of a driver's prior offences (whether as demerit point levels or categories of offence) in a multivariate model adds to the predictive ability of that model in identifying drivers with subsequent crash-involvements. The more efficient model uses a driver's prior offences classified into demerit point levels. Demerit points alone can be used to predict a driver's subsequent crash involvement, but an even better model can be produced by including prior casualty crash involvements as well.

1. INTRODUCTION

The Victorian Parliamentary Road Safety Committee recommended that an analysis be undertaken of the VicRoads driver and accident databases to determine the relationship between driver accident involvement, demerit points accrual and other relevant factors as a means of identifying groups that have a significantly higher than average accident potential.

The Monash University Accident Research Centre (MUARC) was contracted by VicRoads to determine both the nature and strength of the relationship between prior offence history and subsequent road accident involvement of drivers in Victoria.

1.1 DATA SOURCES

To perform the analysis the following two data files were created and supplied to MUARC by VicRoads:

1. a data file combining licence details (including traffic offence details) with driver crash history as recorded on the Police-reported Victorian road accident database;
2. a data file containing the same licence details and traffic offence details of drivers who have not been involved in a casualty crash.

The two files were selected according to the following criteria:

FILE 1: *Crashed Drivers*

- 56,855 drivers involved in one (or more) casualty crashes in the period 1991 to 1994 inclusive (including unlicensed drivers);

FILE 2: *Non-Crashed Drivers*

- 67,745 drivers randomly sampled from the remaining driver records on the Licence Database in late 1995 (at a rate of 1 in every 50 driver licence records).

These files contain records of four types:

1. Offence details (including offence type and demerit points assigned);
2. Conviction details (including dates between which the driver was banned from driving);
3. Driver details (including driver age, sex and postcode);
4. Crash details (not applicable to drivers in the second data file).

1.2 STATISTICAL METHODS AND MODELS

While the focus of the Parliamentary Committee's recommendation is on the relationship between demerit points and subsequent crashes, the study will consider all available potential predictor variables such as the full range of offence information available, prior crash involvements, and driver characteristics such as age, sex, residential postcode and licence type. The study will consider whether the prior demerit points data (or the offence data used in other ways) can improve the efficiency of a statistical model derived to predict the subsequent crashes. Multivariate statistical models will be developed which aim to represent drivers' crash involvements during 1993-1994 as functions of potential predictor variables measured during 1991-1992.

1.2.1 Literature Review

There is a clear need for a multivariate model of statistical analysis which can be used to develop a mathematical model of crash involvement. The method should be capable of easily including and excluding relevant predictor variables so their influence can be seen. A number of previous researchers have examined relationships between offences, other predictors and subsequent crashes, and their statistical methods are outlined below.

Stewart and Campbell (1972) crosstabulated the number of accidents each North Carolina driver sustained in a two year period with (a) the number of traffic violations in the previous two year period, and (b) the number of accidents in the same previous period. This method was not able to consider both prior violations and prior accidents (nor any other factors) simultaneously as combined potential predictors.

Peck and Kuan (1983) used stepwise multiple regression to model each California driver's total number of accidents in a three year period as a function of total numbers of traffic citations and prior accidents (both in the previous three year period), age, sex, licence type, area of residence, and traffic density of the county. The Biomedical Statistical Package BMDP was used. The form of multiple regression used assumed that the accident frequencies had a Normal distribution, which is likely to be a good approximation only in cases of high frequencies.

Hauer et al (1991) also used multiple regression to model each Ontario driver's accidents in a two year period as functions of prior accidents, traffic convictions (total; 14 different types separately; and demerit-point weighted), age and sex. "At-fault" and "not-at-fault" accidents were considered separately, but the "at-fault" accidents provided no greater predictive power than total accidents. Hauer et al assumed a more appropriate distribution for accident frequencies (the Negative Binomial) and used the statistical package GLIM to fit the models. They showed that details of the prior offences can be used to achieve greater predictive power than simply the demerit points count, and that prior accidents improved the prediction substantially. A subsequent study on the same data showed that models taking into account whether

the driver was licensed to drive a truck further increased the predictive power (Smiley et al, 1992), apparently due to the greater crash exposure of truck drivers.

Chen et al (1995) used logistic regression to model the proportion of British Columbia drivers with “at-fault” accident involvements during a two year period as a function of numbers of traffic convictions in 15 categories and prior “at-fault” accident involvements, each during the prior three year period. They chose to ignore a number of available potential predictor variables (such as age, sex, residence and “not-at-fault” accident involvements) for equity reasons. The statistical software was not specified in the paper. Logistic regression does not involve any assumptions about the statistical distribution of individual drivers’ accident frequencies; it analyses only whether the driver was crash-involved or not-involved during the period.

Most of the above studies included a preliminary examination of each potential predictor variable separately, in comparison with the subsequent accident involvements. This type of univariate analysis was also carried out in this study prior to the multivariate analysis; the univariate results are presented in Chapter 3.

1.2.2 Multivariate Method used in this Study

The multivariate analysis used logistic regression to model the proportion of drivers in the database who were crash-involved during 1993-1994 as functions of potential predictor variables. Based on the findings of Hauer et al (1991), the approach of Chen et al (1995), which attempted to define a sub-set of “at-fault” casualty crash involvement for use as either predictor or predicted crashes was not followed. The results of the multivariate analysis are presented and discussed in Chapter 4.

Before commencing the main analysis, issues concerning the quality of the two data files were investigated. The findings of the data vetting are summarised in the following chapter. A more detailed discussion of the data vetting is given in an interim report of this study by Dyte et al (1996).

2. DATA VETTING RESULTS

The driver records were used to create separate files of each of the four types (offence, conviction, driver and crash details) resulting in the creation of seven files (four files for crashed drivers and three files for non-crashed drivers). These files were subsequently vetted to ensure the reliability of the data provided, and its suitability for analysis.

Frequency tables were generated for all variables that would be involved in the main analysis. There were no apparent problems with the offence variables or the crash variables. The majority of the remaining data (conviction variables and driver variables) appeared almost complete and able to support the proposed univariate and multivariate analyses.

The most serious problems concerned the variables involving the end date of the driver's ban period. Over half the data for the end year of the ban period was missing (data was missing for 56% of non-crashed drivers and 53% for crashed drivers). This was partially, but not entirely, accounted for by disqualifications. A method was attempted to provide a proxy variable for the missing end ban dates. For those convictions where the end ban date was known, the ban time in months was tabulated by the variable "Ban Type". It was hoped that this would point to a ban length that was clearly most common for each particular ban type. This, however, was clearly not the case, with a wide variation in ban times. Therefore good proxy data could not be generated.

Other than driver age, there were three variables that could have been used as possible indicators of driving experience.

1. "Licence Proficiency": This variable was sampled at the time the data was extracted (ie. late 1995) rather than January 1993 therefore the probationary periods on many licences would have expired in the interim. Furthermore the proportions of each licence type in the sample do not match the proportions in the total licence database in either 1993 or 1995. This is probably because the sampling of 1 driver in 50 did not produce a truly random sample. The licences were in date of issue order when the sample was taken and since the learner permits, the probationary licences and the full licences for new residents are more recent and hence grouped towards the end of the file they were undersampled. Thus, for the data used in this study, the "licence proficiency" variable cannot provide a reliable distribution measure of driving experience on a Victorian drivers licence.
2. "Expiry date of licence": This variable could not be used because the duration of a licence has varied over time (3, 6 or 10 years duration). Since dual licensing began in 1987 it is possible to be issued with a full licence after passing the driving test for a car licence if the person has ridden a motorcycle on a probationary licence for 3 years (and vice versa). First time full Victorian licences are also issued to qualified drivers from other states and other countries.

3. “Time licence was held”: This variable contains a large proportion of missing values (over 50% in each data set). When the licence information was computerised in 1984 the issue data was not recorded. Therefore, it can be assumed that the licences with no original ‘issue date’ were those current in 1984 and only renewed after 1984. This variable has been included in the univariate analysis, but not in the multivariate analysis because of the possibility of the missing values also containing a proportion of unknowns.

3. UNIVARIATE ANALYSIS

The main objective of the study was to consider whether a driver's prior demerit points data (or their offence data used in other ways) could be used (in combination with other variables) to predict the driver's subsequent crashes. To achieve this aim, a multivariate model will be developed which aims to represent drivers' crash involvements during 1993-1994 as a function of potential predictor variables measured during 1991-1992. There was a clear need to undertake a multivariate method of statistical analysis which could be used to develop a mathematical model of crash involvement. The method needed to be capable of easily including and excluding relevant predictor variables so their influence could be seen.

However, prior to developing a multivariate model, a preliminary univariate examination of each potential predictor variable, in comparison with the subsequent accident involvements was undertaken.

3.1 METHODOLOGY

The number of drivers involved in 0, 1, 2 or 3 reported casualty crashes during 1993-1994 were crosstabulated against each of the potential predictor variables available in the data file. The list of available predictor variables was:

Driver/Licence Variables

- driver sex;
- driver age at 1 January 1993;
- driver postcode (categorised as Melbourne and country Victoria);
- proficiency of licence as of late 1995 when the data was extracted;
- endorsement of licence as of late 1995 when the data was extracted;
- time licence was held at 1 January 1993;
- expiry date of licence.

It should be noted that the months licensed during 1991-1992 and 1993-1994 were not reliable because of the reasons mentioned in Chapter 2. In addition more than half of the issue dates for the first Victorian licence were missing in the "time licence was held" variable. The missing values could be assumed to be for licences issued before 1984 when the computerised database was first set up, however they were not used for the reasons stated in Chapter 2.

Offence Variables

- total number of offences during 1991-1992;
- number of offences by category of offence;
- number of offences by demerit point level of offence;
- total number of demerit point incurred during 1991-1992;
- total demerit points accumulated.

Conviction Variables

- total number of convictions during 1991-1992;
- number of convictions by type of ban.

It should be noted that due to the unreliability of the “end of ban” date, the number of convictions by length of ban were not analysed (and subsequently not used in the multivariate analysis).

Crash Variables

- total reported casualty crash involvements during 1991-1992;
- crash involvements in which the specific driver was seriously injured during 1991-1992;
- crash involvements in which the specific driver was killed.

The original data files, containing crashed and non-crashed drivers, were added together and merged with the other files using the licence number. From this merged file (containing offence, conviction, crash and driver details), information on drivers involved and not involved in casualty crashes during 1991-1994 were extracted. For the four-year period, a total of 124,383¹ drivers were considered. Of these drivers, 68,774 (55.3%) were not crash-involved during 1991-94. Because these drivers were randomly sampled from the driver records on the Licence database at a rate of 1 in every 50 driver licence records, they were accordingly weighted by a factor of 50 to represent the population of non-crashed drivers in Victoria. This resulted in an estimated population of 3,438,700 drivers who were not involved in a casualty crash during 1991-1994. An additional 55,609 were crash-involved, making an estimated total of 3,494,309 drivers in the population.

Amongst this ‘weighted’ population of drivers, 27,872 (0.80%) were involved in at least one casualty crash during 1993-1994. The majority of the crash-involved drivers (27,513) were in *one* casualty crash during 1993-1994. Only 1.3% were involved in two or more casualty crashes.

3.2 DRIVER AND LICENCE VARIABLES

3.2.1 Driver Sex

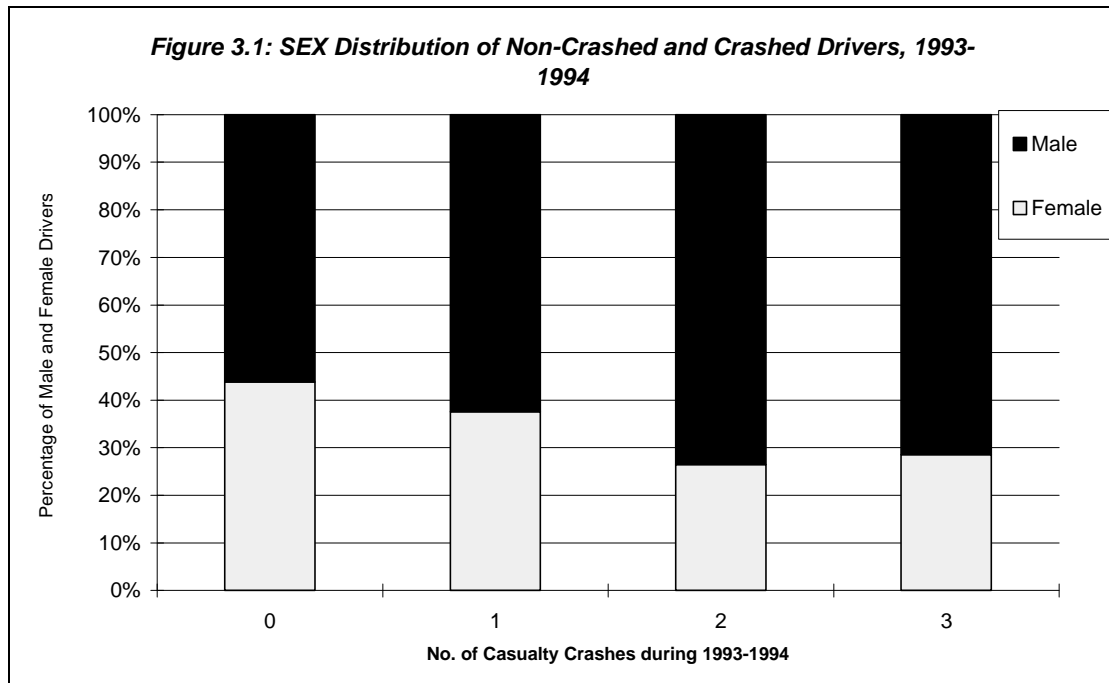
Table 3.1 gives the casualty crash involvement for male and female drivers during 1993-1994. A greater proportion of males were crash-involved than females (0.89% and 0.68%, respectively).

¹ This total is less than the total number of drivers given in Section 1.1 (ie. 124,600) because of the exclusion of 217 drivers who were killed in a crash during 1991-1992 and therefore could not have crashed during 1993-1994.

Table 3.1: Casualty Crash Involvement of MALE and FEMALE Drivers during 1993-1994

| No. of Casualty Crashes during 1993-1994 | Unknown | Female | Male | Total |
|--|--------------|--------------|--------------|--------------|
| 0 | 251 | 1,517,512 | 1,948,674 | 3,466,437 |
| 1 | 1 | 10,339 | 17,173 | 27,513 |
| 2 | | 93 | 259 | 352 |
| 3 | | 2 | 5 | 7 |
| Total | 252 | 1,527,946 | 1,966,111 | 3,494,309 |
| <i>%crash-involved drivers</i> | <i>0.40%</i> | <i>0.68%</i> | <i>0.89%</i> | <i>0.80%</i> |

Figure 3.1 gives the percentage of male and female drivers involved in 0, 1, 2 or 3 casualty crashes. Amongst the crashed drivers, 63% were male compared with 56% of non-crashed drivers.



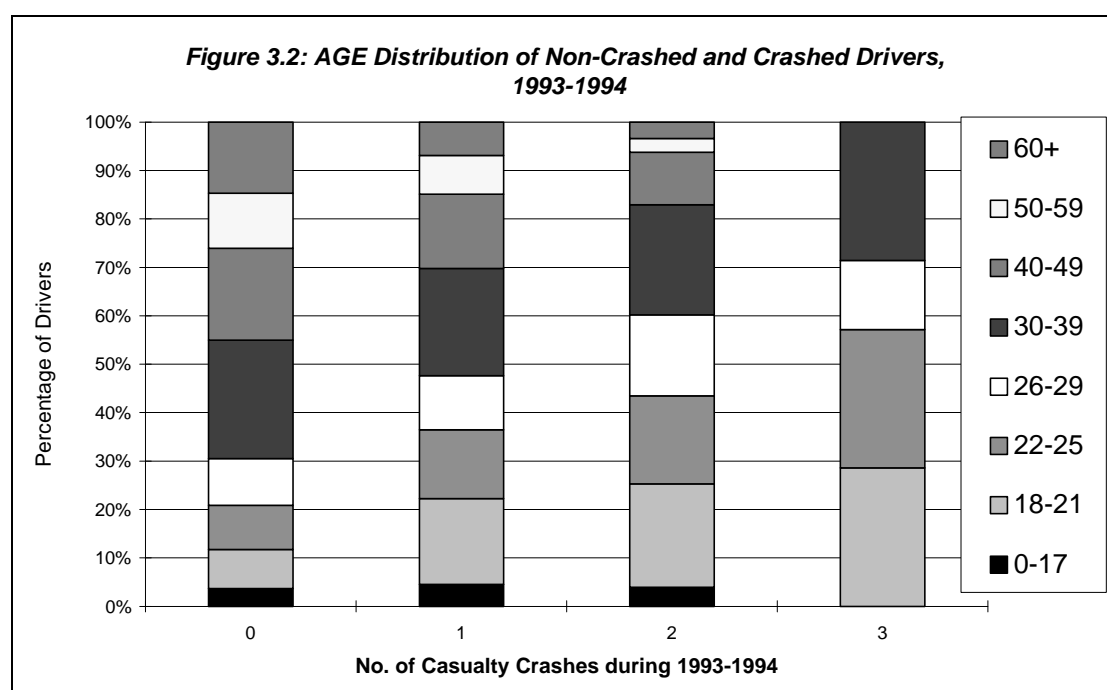
3.2.2 Driver Age

Table 3.2 and Figure 3.2 give the casualty crash involvement of drivers during 1993-1994 as a function of their age at 1 January 1993. Generally crashed drivers tend to be younger than non-crashed drivers; 55% of non-crashed drivers were aged under 40 whilst of the drivers involved in *one* casualty crash in 1993-1994, 70% were aged under 40. Further, all 7 drivers involved in three crashes during the two-year period were aged between 18-40. A total of 1,262 crash-involved drivers were aged under 18 at the beginning of 1993, and 14 of these were involved in two casualty crashes during 1993-1994.

Younger drivers were more likely to be crash-involved than older drivers. The groups with the greatest crash-involvement were drivers aged 18-21 and drivers aged 22-25, with respective crash-involvement rates of 1.75% and 1.24%, whereas only 0.56% of drivers aged 50-59 and 0.37% of drivers aged 60+ were crash-involved during 1993-1994.

Table 3.2: Casualty Crash Involvement of Drivers during 1993-1994 by DRIVER AGE

| Driver Age (yrs) | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|------------------|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0-17 | 126,850 | 1,248 | 14 | | 128,112 | 0.99% |
| 18-21 | 279,127 | 4,888 | 75 | 2 | 284,092 | 1.75% |
| 22-25 | 316,820 | 3,903 | 64 | 2 | 320,789 | 1.24% |
| 26-29 | 335,378 | 3,068 | 59 | 1 | 338,506 | 0.92% |
| 30-39 | 847,575 | 6,088 | 80 | 2 | 853,745 | 0.72% |
| 40-49 | 658,525 | 4,218 | 38 | | 662,781 | 0.64% |
| 50-59 | 391,868 | 2,206 | 10 | | 394,084 | 0.56% |
| 60+ | 510,294 | 1,894 | 12 | | 512,200 | 0.37% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |



3.2.3 Driver Postcode

Table 3.3 gives the casualty crash involvement of drivers during 1993-1994 as a function of location. Location is defined as the driver's resident postcode (at the time of the crash) and not the location of the crash. Postcodes were categorised as either metropolitan or country postcode areas.

In the Melbourne group of drivers, 0.84% were crash-involved compared with 0.69% of country Victoria residents. Further *all* drivers involved in *three* casualty crashes during 1993-1994 were from Melbourne.

Of the crash-involved drivers, 74% were resident in the metropolitan area compared with 70% of the non-crash involved drivers. A small proportion of the drivers in the database were apparently non-Victorian residents (1.3%); these may also include Victorian postcodes which were incorrectly coded.

Table 3.3: Casualty Crash Involvement of Drivers during 1993-1994 by LOCATION

| No. of Casualty Crashes during 1993-1994 | LOCATION | | | |
|--|------------------------|------------------|---------------------|--------------|
| | Metropolitan Melbourne | Country Victoria | Other than Victoria | Total |
| 0 | 2,429,479 | 993,288 | 43,670 | 3,466,437 |
| 1 | 20,389 | 6,871 | 253 | 27,513 |
| 2 | 276 | 71 | 5 | 352 |
| 3 | 7 | | | 7 |
| Total | 2,450,151 | 1,000,230 | 43,928 | 3,494,309 |
| <i>%crash-involved drivers</i> | <i>0.84%</i> | <i>0.69%</i> | <i>0.59%</i> | <i>0.80%</i> |

3.2.4 Proficiency of Licence

Table 3.4 gives the casualty crash involvement of drivers during 1993-1994 according to their licence proficiency at the time the data was extracted (ie. late 1995). There was an increasing trend of crash-involvement for less experienced drivers; 0.78% of drivers with full licences were involved in at least one casualty crash during 1993-1994, compared with 0.90% and 3.58% of probationary and learner drivers, respectively.

Table 3.4: Casualty Crash Involvement of Drivers during 1993-1994 by LICENCE PROFICIENCY

| No. of casualty crashes during 1993-1994 | LICENCE PROFICIENCY | | | | |
|--|---------------------|--------------|--------------|--------------|--------------|
| | Unknown | Full | Probationary | Learner | Total |
| 0 | 2,115 | 3,269,800 | 184,555 | 9,967 | 3,466,437 |
| 1 | 112 | 25,388 | 1,653 | 360 | 27,513 |
| 2 | 3 | 315 | 24 | 10 | 352 |
| 3 | | 7 | | | 7 |
| Total | 2,230 | 3,295,510 | 186,232 | 10,337 | 3,494,309 |
| <i>%crash-involved drivers</i> | <i>5.16%</i> | <i>0.78%</i> | <i>0.90%</i> | <i>3.58%</i> | <i>0.80%</i> |

Ninety-four percent of non-crashed drivers had a full licence whilst 5% were probationary drivers. Of those drivers involved in one or more casualty crashes, 92% were full licence holders and 6% were probationary licence holders. It should be noted that only 0.3% of all drivers in the 'weighted' population were learners, and 5% were probationary drivers. These proportions are less than the figures for all licensed

drivers in Victoria of which 7.8% were probationary drivers and 4.6% were learner drivers at 31 December 1995. There was, however, an undersampling of inexperienced drivers from the licence database and the apparent crash involvement percentages for these groups should be treated with caution.

It is worth noting that the composition of the 10 learners who were involved in more than one casualty crash during 1993-1994 was:

- all motorcycle riders
- 8 males; 2 females
- 3 aged 0-17; 3 aged 18-21; 3 aged 22-25; 1 aged 60+
- 5 metropolitan residents; 5 rural residents.

3.2.5 Endorsement of Licence

Table 3.5 gives the casualty crash involvement of drivers during 1993-1994 according to the type of licence endorsement needed to drive a particular type of motor vehicle. The motor vehicle categories (other than cars and motorcycles) are:

- “*Light rigid vehicle*” which is a rigid vehicle that has a maximum loaded mass exceeding 4.5 tonnes but not exceeding 8 tonnes, or seats more than 12 adults (including the driver) and does not exceed 8 tonnes maximum loaded mass);
- “*Medium rigid vehicle*” which is a rigid vehicle exceeding 8 tonnes maximum loaded mass that has 2 axles;
- “*Heavy rigid vehicle*” which is a rigid vehicle exceeding 8 tonnes maximum loaded mass that has 3 or more axles;
- “*Heavy combination vehicle*” which is a prime mover to which is attached a single semi-trailer exceeding 9 tonnes maximum loaded mass, or a rigid vehicle to which is attached a trailer exceeding 9 tonnes maximum loaded mass;
- “*Multi-combination vehicle*” which is a heavy combination vehicle to which is attached one or more additional trailers, each of which exceeds 9 tonnes maximum loaded mass.

The licence endorsement groups most likely to be involved in at least one casualty crash during 1993-1994 were drivers endorsed to drive a multi-combination vehicle (1.73% were crash-involved) and those endorsed to drive a heavy combination vehicle (1.20%). These compare with a crash-involvement rate of 0.77% for car drivers.

Table 3.5: Casualty Crash Involvement of Drivers & Riders during 1993-1994 by LICENCE ENDORSEMENT Category

| Motor Vehicle Category for Licence Endorsement | No. of casualty crashes during 1993-1994 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| Unknown | 101 | 2 | | | 103 | 1.94% |
| Motorcycle | 260,984 | 2,103 | 43 | 1 | 263,131 | 0.82% |
| Car | 2,850,637 | 21,869 | 242 | 6 | 2,872,754 | 0.77% |
| Heavy combination vehicle | 154,522 | 1,840 | 35 | | 156,397 | 1.20% |
| Heavy rigid vehicle | 134,278 | 1,066 | 19 | | 135,363 | 0.80% |
| Medium rigid vehicle | 54,731 | 514 | 10 | | 55,255 | 0.95% |
| Light rigid vehicle | 8,226 | 67 | 3 | | 8,296 | 0.84% |
| Multi-combination vehicle | 2,958 | 52 | | | 3,010 | 1.73% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

Drivers endorsed to ride a motorcycle comprised 7.7% of crashed and 7.5% of non-crashed drivers. Similar proportions of car endorsed drivers occurred in the non-crashed and crashed groups (79% of crashed, and 82% of non-crashed). It should be noted that 19% of drivers involved in *two* casualty crashes were endorsed to drive some type of “truck” (ie. light, heavy, medium or multi rigid vehicle), compared with 10% of non-crashed drivers.

3.2.6 Time Licence was held at 1/1/1993

Table 3.6 gives the number of casualty crashes in which drivers were involved during 1993-1994 as a function of the number of years they had held their licence at 1 January 1993.

Since 372,579 drivers apparently had their licence issued during or after 1993, they should have been either learner or probationary drivers, dual full licence holders or qualified newly resident drivers from other states or countries during 1993-1994. However, from Table 3.4, only 196,569 learner or probationary drivers were in the database. The discrepancy may be due to the undersampling of inexperienced drivers in the database.

The proportion of drivers involved in at least one casualty crash during 1993-1994 was greater for less experienced drivers. ie: 1.44% of drivers who had apparently held their licence for one year or less were crash-involved compared with 0.96% of those who had apparently held their licence for more than 10 years.

However, the time a driver’s licence was held was missing amongst 64% of the non-crashed drivers, and amongst 51% of the crashed drivers. This is because licences issued before 1984 were not put on the computerised database unless they were entered later for some particular reason. Further, only 4,133 and 40 of the respective non-crashed and crashed drivers were recorded as having held their licence for more than 10 years, suggesting that a large proportion of the unknowns may have been more experienced drivers. However, because of the possibility that the missing values could

also contain a proportion of unknowns, it was decided not to use this variable in the multivariate analysis.

It is further worth noting that six of the drivers involved in three casualty crashes during 1993-1994 had held their licence for less than five years.

Table 3.6: Casualty Crash Involvement of Drivers during 1993-1994 as a function of TIME LICENCE was held

| Time Licence Held at 1/1/1993 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|-------------------------------|--|---------------|------------|----------|------------------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| Issued in 1993 or later | 368,715 | 3,810 | 53 | 1 | 372,579 | 1.04% |
| up to 1 year | 98,644 | 1,421 | 22 | 1 | 100,088 | 1.44% |
| up to 2 years | 123,603 | 1,570 | 21 | | 125,194 | 1.27% |
| up to 3 years | 120,658 | 1,434 | 23 | 2 | 122,117 | 1.19% |
| up to 5 years | 235,079 | 2,442 | 34 | 2 | 237,557 | 1.04% |
| up to 10 years | 292,378 | 2,728 | 37 | | 295,143 | 0.94% |
| assumed pre-1984 | 2,227,360 | 14,108 | 162 | 1 | 2,241,631 | 0.64% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.3 OFFENCE VARIABLES

Offences presented in the following tables are only those that incur demerit points, and do not include offences such as drink-driving offences. However, the conviction variables (presented later in section 3.4) do include drink-driving offences, but it was not known specifically what each conviction was due to.

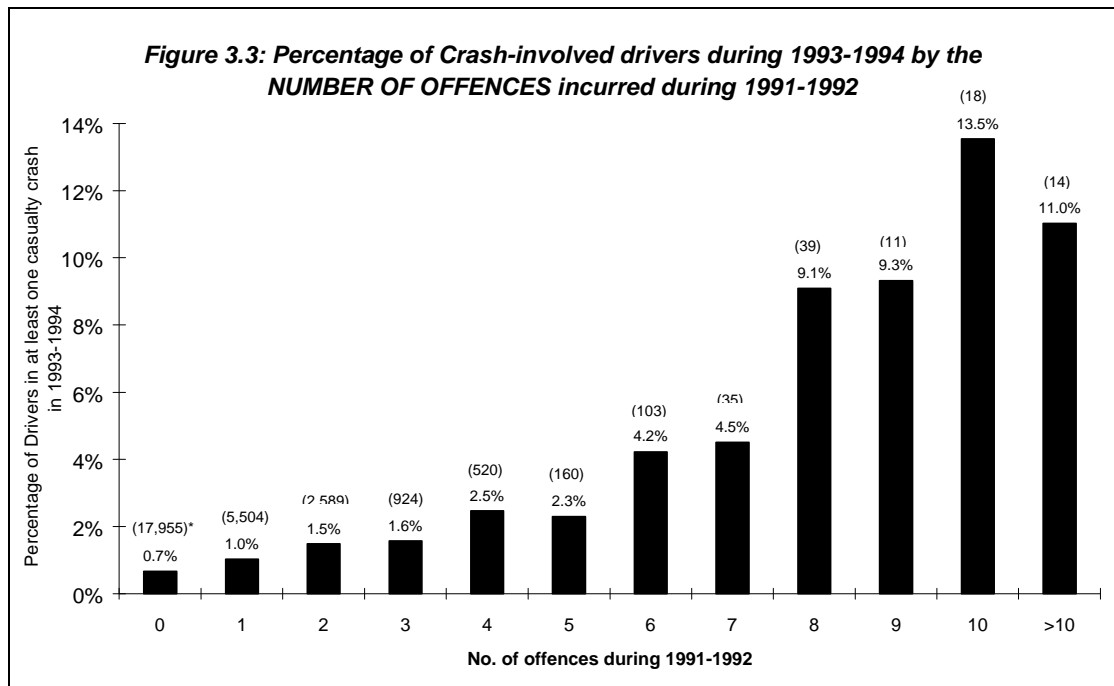
3.3.1 Number of Offences Incurred During 1991-1992

Table 3.8 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of offences incurred in the prior two-year period of 1991-1992. The proportion of drivers involved in at least one casualty crash during 1993-1994 generally increased with increasing number of offences incurred during 1991-1992 as shown in Figure 3.3.

For example, 0.67% of drivers with no offences during 1991-1992 were crash-involved in 1993-1994, whereas 11% of drivers with more than 10 offences during 1991-1992 were crash-involved two years later. It is worth noting that three of the drivers who had not incurred any offences during 1991-1992 were each involved in three casualty crashes during 1993-1994.

Table 3.8: Casualty Crash Involvement of Drivers during 1993-1994 as a function of the number of OFFENCES incurred during 1991-1992

| #Offences during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|----------------------------|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 2,675,505 | 17,750 | 202 | 3 | 2,693,460 | 0.67% |
| 1 | 530,345 | 5,463 | 40 | 1 | 535,849 | 1.0% |
| 2 | 171,562 | 2,527 | 62 | | 174,151 | 1.5% |
| 3 | 57,897 | 914 | 10 | | 58,821 | 1.6% |
| 4 | 20,537 | 499 | 21 | | 21,057 | 2.5% |
| 5 | 6,790 | 157 | 3 | | 6,950 | 2.3% |
| 6 | 2,334 | 94 | 7 | 2 | 2,437 | 4.2% |
| 7 | 742 | 34 | 1 | | 777 | 4.5% |
| 8 | 390 | 35 | 3 | 1 | 429 | 9.1% |
| 9 | 107 | 10 | 1 | | 118 | 9.3% |
| 10 | 115 | 17 | 1 | | 133 | 13.5% |
| 11 | 2 | 2 | | | 4 | 50.0% |
| 12 | 53 | 3 | | | 56 | 5.4% |
| 13 | 2 | 1 | | | 3 | 33.3% |
| 14 | 52 | 3 | | | 55 | 5.5% |
| 16 | 2 | | | | 2 | 0.0% |
| 17 | | 1 | | | 1 | 100% |
| 18 | | 2 | | | 2 | 100% |
| 20 | 2 | | | | 2 | 0.0% |
| 22 | | 1 | | | 1 | 100% |
| 28 | | | 1 | | 1 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |



*Figures in brackets refer to the number of crash-involved drivers during 1993-1994

The offences presented in Table 3.8 were grouped into the following categories of offences:

- i. Offences in which the speed limit was exceeded by under 30 km/h
 - incur the loss of one demerit point if exceed limit by 15 km/h or less;
 - incur the loss of three demerit points if exceed speed limit by more than 15 km/h but less than 30 km/h .
- ii. Offences in which the speed limit was exceeded by at least 30 km/h
 - incur the loss of four demerit points if exceed limit by at least 30 km/h but less than 45 km/h;
 - incur the loss of six demerit points if exceed limit by at least 45 km/h.
- iii. Stop and Give Way Offences
 - include failing to give way, failing to stop, risk colliding with alighting or boarding tram passengers;
 - incur the loss of three demerit points.
- iv. Unsafe Action Offences
 - driving on wrong side of double lines/divided highway (loss of three demerit points);
 - careless/negligent driving (loss of 3 demerit points);
 - improper over-taking (loss of 2 demerit points);
 - turning/stopping without signalling (loss of 2 demerit points);
 - failing to keep left (loss of 2 demerit points);
 - following too closely (loss of 1 demerit point).
- v. Headlight and Defect Notice Offences
 - driving contrary to defect notice (loss of 3 demerit points);
 - failure to dip head-lights (loss of 1 demerit point);
 - driving at night without head-lights on (loss of 1 demerit point).
- vi. Restraint or Helmet Offences
 - driving with unrestrained passengers under legal age (loss of 3 demerit points);
 - driving without a seat belt (loss of 3 demerit points);
 - riding a motorcycle without a helmet (loss of 3 demerit points).
- vii. Signal Offences
 - disobeying a traffic control signal (loss of 3 demerit points);
 - disobeying a traffic control sign or Police directing traffic (loss of 3 demerit points).

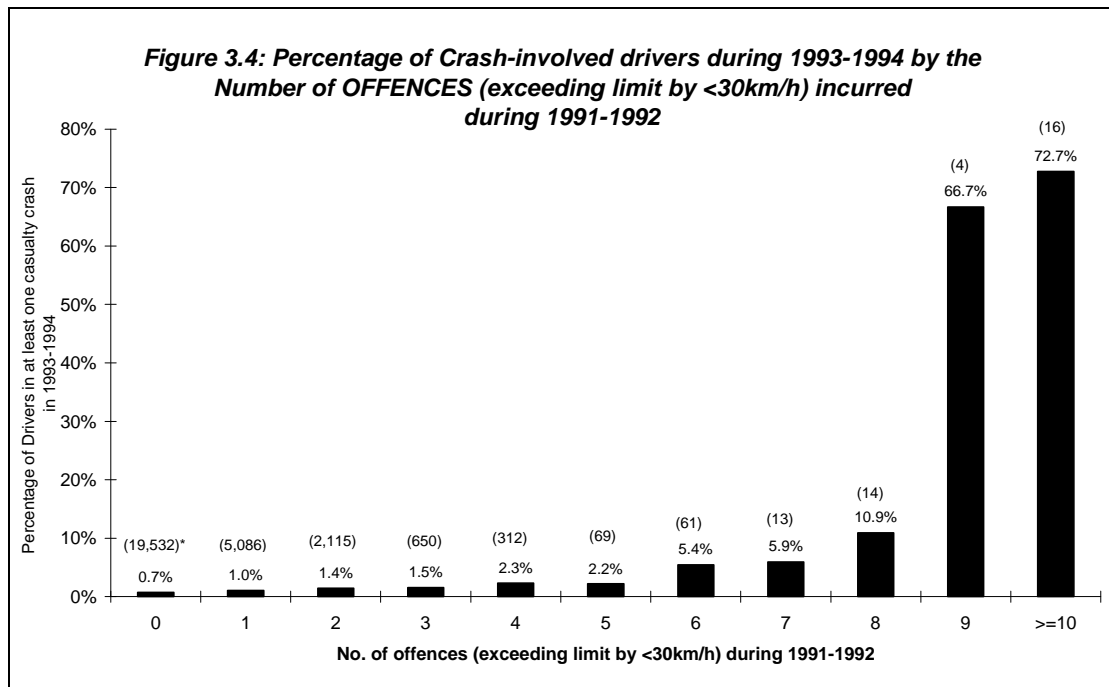
3.3.2 Offences Exceeding Speed Limit by Under 30 km/h

Table 3.9 presents the casualty crash involvement of drivers during 1993-1994 as a function of the number of offences incurred during 1991-1992 in which the speed limit was exceeded by less than 30 km/h.

Table 3.9: Casualty Crash Involvement of Drivers during 1993-1994 as a function of SPEEDING OFFENCES (exceeding limit by <30 km/h) incurred during 1991-1992

| #Offences exceeding speed limit by <30 km/h in 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 2,778,687 | 19,305 | 224 | 3 | 2,798,219 | 0.70% |
| 1 | 483,618 | 5,044 | 41 | 1 | 488,704 | 1.0% |
| 2 | 144,379 | 2,052 | 63 | | 146,494 | 1.4% |
| 3 | 41,950 | 644 | 5 | 1 | 42,600 | 1.5% |
| 4 | 13,322 | 304 | 8 | | 13,634 | 2.3% |
| 5 | 3,088 | 68 | 1 | | 3,157 | 2.2% |
| 6 | 1,064 | 52 | 7 | 2 | 1,125 | 5.4% |
| 7 | 207 | 13 | | | 220 | 5.9% |
| 8 | 114 | 14 | | | 128 | 10.9% |
| 9 | 2 | 3 | 1 | | 6 | 66.7% |
| 10 | 1 | 10 | 1 | | 12 | 91.7% |
| 11 | 2 | | | | 2 | 0.0% |
| 12 | | 4 | | | 4 | 100% |
| 14 | 3 | | | | 3 | 0.0% |
| 20 | | | 1 | | 1 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

Generally the more offences incurred during 1991-1992 in which the speed limit was exceeded by no more than 30 km/h, the greater the percentage of drivers involved in casualty crashes two years later. For example, 0.70% of drivers who did not incur any speeding offences (exceeding limit by <30 km/h) in 1991-1992 were crash-involved in 1993-1994. This compares with 5.4% of drivers who had incurred 6 such speeding offences and 72.7% who had incurred at least 10 offences in the prior crash period (Figure 3.4).



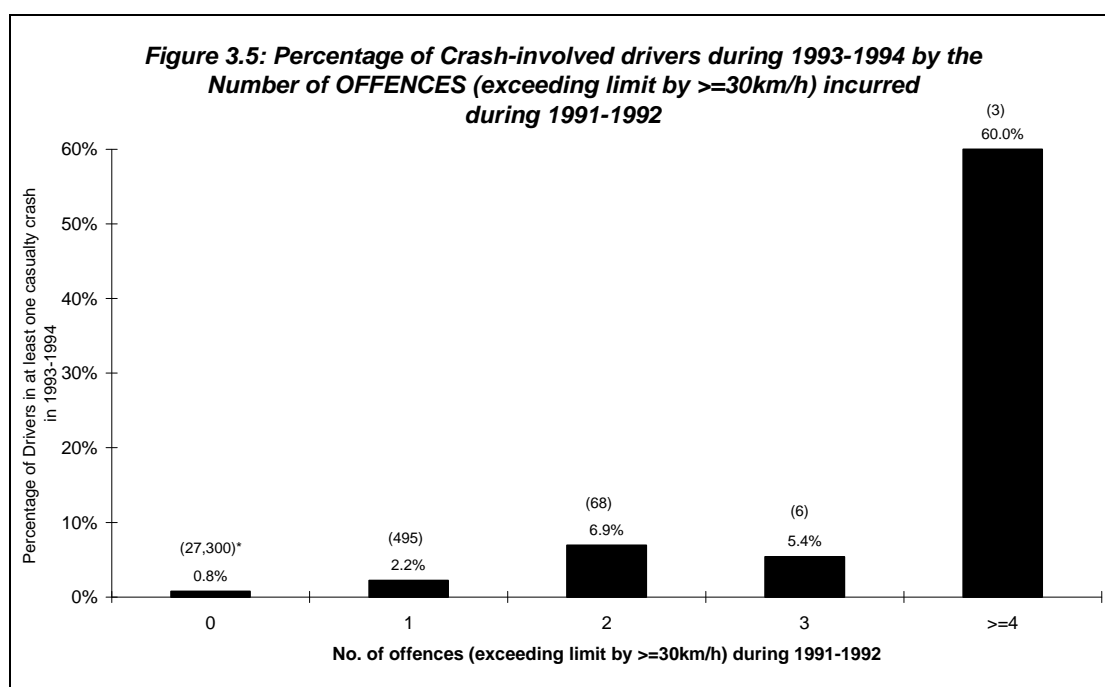
*Figures in brackets refer to the *number* of crash-involved drivers during 1993-1994

3.3.3 Offences Exceeding Speed Limit by at least 30 km/h

Table 3.10 presents the casualty crash involvement of drivers during 1993-1994 as a function of the number of offences incurred during 1991-1992 in which the speed limit was exceeded by at least 30 km/h. Generally, the percentage of crash-involved drivers during 1993-1994 increased as the number of speeding offences incurred two years prior (in which the speed limit was exceeded by at least 30 km/h) increased (Figure 3.5). Three of the five drivers who had incurred at least four offences during 1991-1992 in which the speed limit was exceeded by at least 30 km/h were crash-involved two years later, (but it is difficult to draw conclusions from such small numbers), whereas only 0.79% of drivers with no such speeding offences were crash-involved during 1993-1994. It is worth noting that all seven drivers who were involved in three casualty crashes each during 1993-1994 did not incur any speeding offences (exceeding limit by ≥ 30 km/h) during 1991-1992.

Table 3.10: Casualty Crash Involvement of Drivers during 1993-1994 as a function of SPEEDING OFFENCES (exceeding limit by ≥ 30 km/h) incurred during 1991-1992

| #Offences exceeding speed limit by ≥ 30 km/h in 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,443,419 | 26,955 | 338 | 7 | 3,470,719 | 0.79% |
| 1 | 21,998 | 487 | 8 | | 22,493 | 2.2% |
| 2 | 913 | 62 | 6 | | 981 | 6.9% |
| 3 | 105 | 6 | | | 111 | 5.4% |
| 4 | 1 | 2 | | | 3 | 66.7% |
| 5 | 1 | | | | 1 | 0.0% |
| 8 | | 1 | | | 1 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |



*Figures in brackets refer to the number of crash-involved drivers during 1993-1994

3.3.4 Stop and Give Way Offences

Table 3.11 presents the casualty crash involvement of drivers during 1993-1994 as a function of the number of stop and give way offences incurred two years prior. The percentage of crash-involved drivers during 1993-1994 was greater for those who had incurred one stop or give way offence during 1991-1992 than for those who did not incur any such offences (1.3% and 0.8%, respectively). Further, 39.4% of drivers who had incurred two stop/give offences during 1991-1992 were crash-involved two years later.

Table 3.11: Casualty Crash Involvement of drivers during 1993-1994 as a function of STOP/GIVE OFFENCES incurred during 1991-1992

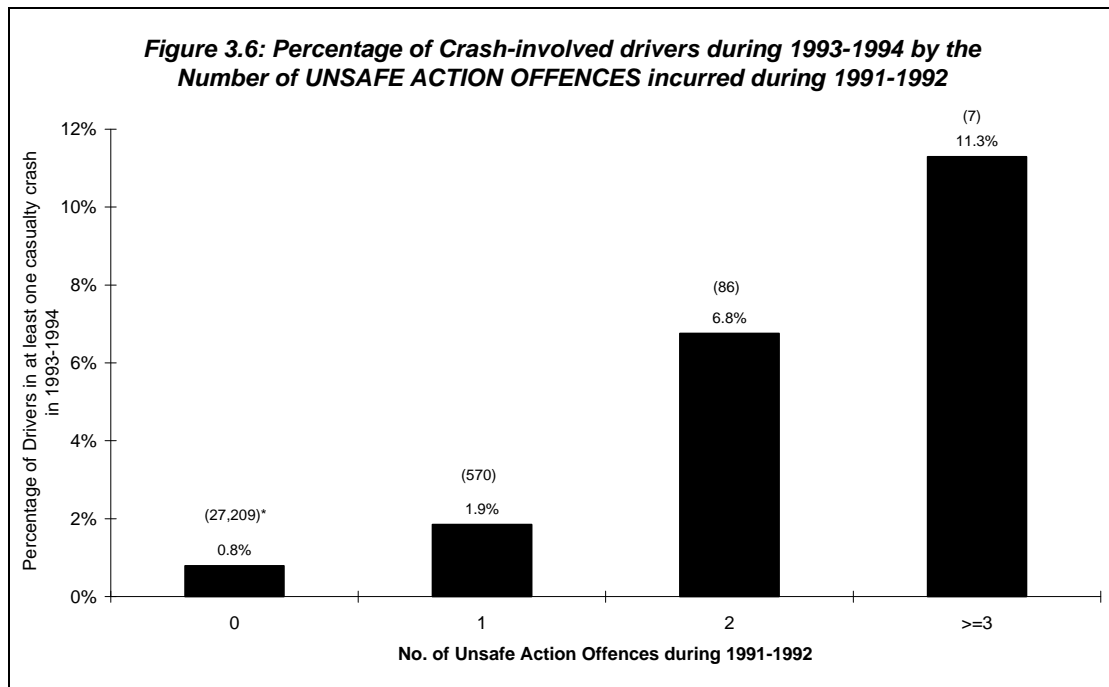
| #Stop/Give Way Offences during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|--|--|---------------|------------|----------|------------------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,455,303 | 27,352 | 352 | 7 | 3,483,014 | 0.80% |
| 1 | 11,113 | 148 | | | 11,261 | 1.3% |
| 2 | 20 | 13 | | | 33 | 39.4% |
| 4 | 1 | | | | 1 | 0.0% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.3.5 Unsafe Action Offences

Table 3.12 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of unsafe action offences incurred during 1991-1992. An increasing trend occurred in the proportion of drivers involved in crashes during 1993-1994 with increasing number of unsafe action offences incurred during 1991-1992 (Figure 3.6). Approximately 11% percent of drivers who had incurred at least three unsafe action offences during 1991-1992 were crash-involved two years later, compared with 0.79% of drivers who did not incur any unsafe action offences.

Table 3.12: Casualty Crash Involvement of Drivers during 1993-1994 as a function of UNSAFE ACTION OFFENCES incurred during 1991-1992

| #Unsafe Action Offences incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|---|--|---------------|------------|----------|------------------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,434,955 | 26,864 | 338 | 7 | 3,462,164 | 0.79% |
| 1 | 30,240 | 562 | 8 | | 30,810 | 1.9% |
| 2 | 1,187 | 80 | 6 | | 1,273 | 6.8% |
| 3 | 3 | 3 | | | 6 | 50.0% |
| 4 | 2 | 4 | | | 6 | 66.7% |
| 5 | 50 | | | | 50 | 0.0% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |



*Figures in brackets refer to the *number* of crash-involved drivers during 1993-1994

3.3.6 Headlight or Defect Notice Offences

Table 3.13 presents the casualty crash involvement of drivers during 1993-1994 as a function of the number of headlight and defect notice offences incurred during 1991-1992. Generally the percentage of crash-involved drivers in 1993-1994 increased with increasing number of headlight/defect notice offences incurred during 1991-1992. Forty percent of drivers who had incurred at least 3 headlight/defect notice offences in 1991-1992 were crash-involved two years later, compared with 0.79% of drivers who did not incur any such offences.

Table 3.13: Casualty Crash Involvement of Drivers during 1993-1994 as a function of HEADLIGHT/DEFECT NOTICE OFFENCES incurred during 1991-1992

| #Headlight/Defect Notice Offences incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|---|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,459,168 | 27,331 | 350 | 6 | 3,486,855 | 0.79% |
| 1 | 7,195 | 170 | 1 | | 7,366 | 2.3% |
| 2 | 71 | 11 | 1 | | 83 | 14.5% |
| 3 | 2 | 1 | | 1 | 4 | 50.0% |
| 4 | 1 | | | | 1 | 0.0% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.3.7 Restraint and Helmet Offences

Table 3.14 gives the casualty crash involvement of drivers and motorcycle riders during 1993-1994 as a function of the number of restraint and helmet offences incurred during 1991-1992. With the exception of drivers and riders who had incurred 3 restraint/helmet offences during 1991-1992, there was an increasing trend in the percentage of crash-involved drivers and riders during 1993-1994 with increasing number of restraint/helmet offences incurred two years prior. Eleven percent of drivers and riders who had incurred *at least four* restraint or helmet offences during 1991-1992 were crash-involved two years later.

Table 3.14: Casualty Crash Involvement of Drivers/Rider during 1993-1994 as a function of RESTRAINT/HELMET OFFENCES incurred during 1991-1992

| #Restraint/Helmet offences incurred during 1991-1992 | No. of Casualty Crashes during 1991-1992 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,404,698 | 26,460 | 334 | 6 | 3,431,498 | 0.78% |
| 1 | 56,251 | 875 | 10 | | 57,136 | 1.55% |
| 2 | 4,912 | 159 | 7 | 1 | 5,079 | 3.3% |
| 3 | 470 | 7 | | | 477 | 1.47% |
| 4 | 105 | 10 | | | 115 | 8.7% |
| 5 | 1 | 1 | | | 2 | 50.0% |
| 6 | | 1 | | | 1 | 100% |
| 8 | | | 1 | | 1 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.3.8 Signal Offences

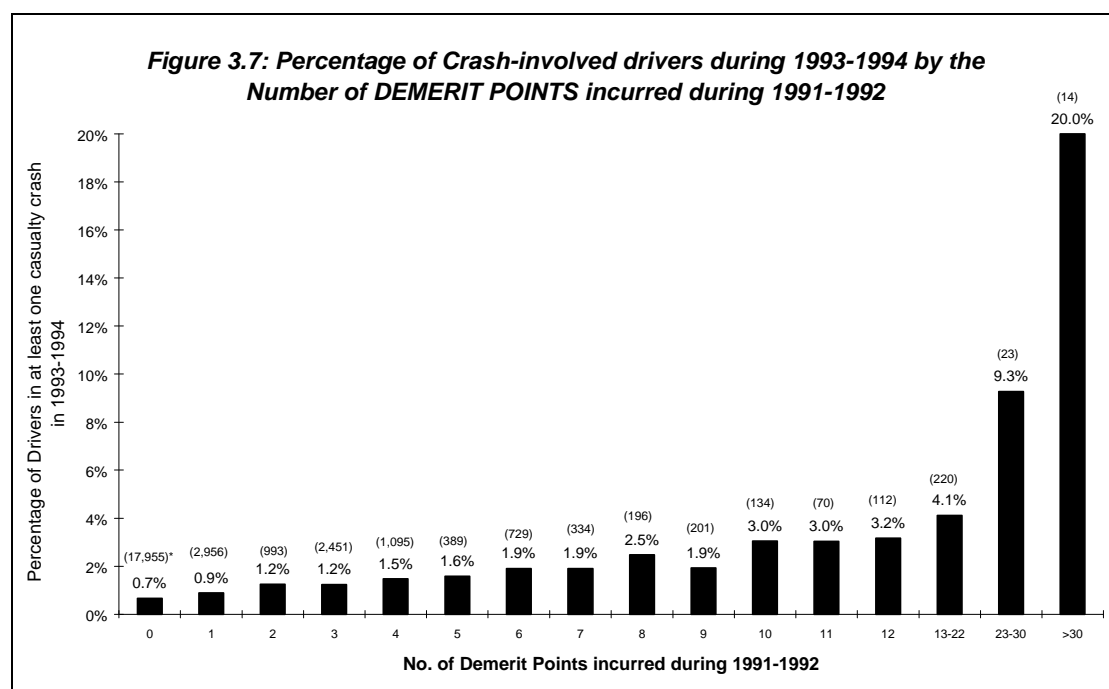
Table 3.15 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of signal offences incurred two years prior. The greater the number of signal offences incurred during 1991-1992 the higher the proportion of crash-involved drivers during 1993-1994. Only 0.78% of drivers who did not incur any signal offences during 1991-1992 were crash-involved two years later, compared with 56% of those who had incurred *at least 4* signal offences during 1991-1992.

Table 3.15: Casualty Crash Involvement of Drivers during 1993-1994 as a function of SIGNAL OFFENCES incurred during 1991-1992

| #Signal Offences incurred during 1991-1992 | No. of Casualty Crashes during 1991-1992 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,399,541 | 26,454 | 330 | 7 | 3,426,332 | 0.78% |
| 1 | 64,128 | 933 | 12 | | 65,073 | 1.5% |
| 2 | 2,504 | 105 | 7 | | 2,616 | 4.3% |
| 3 | 257 | 13 | 2 | | 272 | 5.5% |
| 4 | 5 | 6 | | | 11 | 54.5% |
| 6 | 2 | 2 | 1 | | 5 | 60.0% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.3.9 Demerit Points incurred during 1991-1992

Figure 3.7 and Table 3.16 give the casualty crash-involvement of drivers during 1993-1994 as a function of the total number of demerit points incurred during 1991-1992. From Figure 3.7, it can be seen that the proportion of crash-involved drivers during 1993-1994 generally increases with increasing demerit point accumulation two years prior. For example, 0.67% of drivers who did not incur any demerit points during 1991-1992 were involved in at least one casualty crash during 1993-1994. The corresponding crash-involvement proportion for drivers who had incurred 12 demerit points during 1991-1992 was 3.2% and for those who had incurred over 30 demerit points it was 20%. It is worth noting that both drivers who had incurred the most demerit points (64 points) during 1991-1992 were crash-involved two years later.



*Figures in brackets refer to the number of crash-involved drivers during 1993-1994

Table 3.16: Casualty Crash Involvement of Drivers during 1993-1994 as a function of the TOTAL NUMBER OF DEMERIT POINTS incurred during 1991-1992

| #Demerit Points incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash- involved drivers |
|---|---|---------------|------------|----------|------------------|--------------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 2,675,505 | 17,750 | 202 | 3 | 2,693,460 | 0.67% |
| 1 | 330,662 | 2,935 | 21 | | 333,618 | 0.89% |
| 2 | 78,477 | 964 | 29 | | 79,470 | 1.25% |
| 3 | 195,953 | 2,431 | 19 | 1 | 198,404 | 1.24% |
| 4 | 73,354 | 1,081 | 14 | | 74,449 | 1.47% |
| 5 | 24,190 | 384 | 5 | | 24,579 | 1.58% |
| 6 | 37,710 | 709 | 20 | | 38,439 | 1.90% |
| 7 | 17,291 | 332 | 2 | | 17,625 | 1.90% |
| 8 | 7,734 | 190 | 6 | | 7,930 | 2.47% |
| 9 | 10,236 | 194 | 7 | | 10,437 | 1.93% |
| 10 | 4,266 | 130 | 4 | | 4,400 | 3.05% |
| 11 | 2,233 | 65 | 5 | | 2,303 | 3.04% |
| 12 | 3,412 | 107 | 4 | 1 | 3,524 | 3.18% |
| 13 | 1,471 | 45 | 1 | | 1,517 | 3.03% |
| 14 | 1,102 | 41 | 2 | | 1,145 | 3.76% |
| 15 | 689 | 33 | 1 | | 723 | 4.70% |
| 16 | 546 | 15 | 2 | | 563 | 3.02% |
| 17 | 464 | 12 | | | 476 | 2.52% |
| 18 | 273 | 23 | 4 | 1 | 301 | 9.30% |
| 19 | 307 | 8 | | | 315 | 2.54% |
| 20 | 15 | 14 | 2 | 1 | 32 | 53.1% |
| 21 | 9 | 4 | | | 13 | 30.8% |
| 22 | 257 | 10 | 1 | | 268 | 4.10% |
| 23 | 2 | 4 | | | 6 | 66.7% |
| 24 | 5 | 4 | | | 9 | 44.4% |
| 25 | 53 | 2 | | | 55 | 3.64% |
| 26 | 52 | 6 | | | 58 | 10.34% |
| 27 | 52 | 2 | | | 54 | 3.70% |
| 28 | 55 | 1 | | | 56 | 1.79% |
| 29 | 1 | | | | 1 | 0.0% |
| 30 | 5 | 4 | | | 9 | 44.44% |
| 31 | | 1 | | | 1 | 100% |
| 32 | 50 | 3 | | | 53 | 5.66% |
| 33 | 1 | | | | 1 | 0.00% |
| 36 | 1 | 1 | | | 2 | 50.0% |
| 37 | | 1 | | | 1 | 100% |
| 38 | 1 | 1 | | | 2 | 50.0% |
| 39 | | 1 | | | 1 | 100% |
| 40 | | 1 | | | 1 | 100% |
| 42 | | 1 | | | 1 | 100% |
| 46 | 1 | | | | 1 | 0.00% |
| 50 | 1 | 1 | | | 2 | 50.0% |
| 51 | | 1 | | | 1 | 100% |
| 63 | 1 | | | | 1 | 0.00% |
| 64 | | 1 | 1 | | 2 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.3.10 Total Demerit Points Accumulated Throughout Driver's Driving History

Table 3.17 gives the total number of demerit points accumulated throughout the driver's driving history and the corresponding casualty crash-involvement during 1993-1994. Only 0.5% of drivers who had never incurred a demerit point whilst on the road were crash-involved during 1993-1994, whilst almost 52% of those who had incurred more than 55 demerit points throughout their driving history were involved in at least one casualty crash during 1991-1992. It is worth noting that six of the seven drivers involved in *three* casualty crashes during 1993-1994 had obtained at least one demerit point throughout their driving history.

Table 3.17: Casualty Crash Involvement of Drivers during 1993-1994 as a function of TOTAL DEMERIT POINTS incurred throughout driving history

| Total Demerit Points accumulated during driving history | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|---|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 1,742,758 | 8,673 | 86 | 1 | 1,751,518 | 0.50% |
| 1-5 | 1,238,779 | 11,136 | 123 | 2 | 1,250,040 | 0.90% |
| 6-10 | 331,934 | 4,529 | 74 | 1 | 336,538 | 1.37% |
| 11-15 | 99,631 | 1,756 | 38 | 1 | 101,426 | 1.77% |
| 16-20 | 33,914 | 673 | 15 | | 34,602 | 1.99% |
| 21-25 | 10,224 | 291 | 3 | 1 | 10,519 | 2.80% |
| 26-30 | 4,902 | 134 | 4 | 1 | 5,041 | 2.76% |
| 31-35 | 2,178 | 59 | 4 | | 2,241 | 2.81% |
| 36-40 | 1,242 | 26 | 3 | | 1,271 | 2.28% |
| 41-45 | 412 | 15 | | | 427 | 3.51% |
| 46-50 | 109 | 11 | | | 120 | 9.17% |
| 51-55 | 161 | 6 | | | 167 | 3.59% |
| >55 | 193 | 204 | 2 | | 399 | 51.6% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.3.11 Offences by Demerit Point Level of Offence

The following section will examine the casualty crash involvement of drivers during 1993-1994 according to the levels of demerit point offences incurred during 1991-1992. Five levels were considered - those offences in which one, two, three, four or six demerit points were incurred.

One Demerit Point Offences

Offences in which one demerit point is incurred include failing to dip headlights, driving at night without headlights on, exceeding a speed limit by 15 km/h or less and following too closely.

Table 3.18 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of offences in which one demerit point was incurred during 1991-1992. The greater the number of “one” demerit points incurred during 1991-1992, the greater the proportion of crash-involved drivers two years later. Only 0.74% of drivers who had not incurred any “one” demerit point offences during 1991-1992 were involved in at least one casualty crash during 1993-1994, compared with 72% of drivers who had incurred at least seven “one” demerit point offences during 1991-1992.

Table 3.18: Casualty Crash Involvement of drivers during 1993-1994 as a function of “ONE” DEMERIT POINT OFFENCES incurred during 1991-1992

| #One demerit point offences incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|---|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 2,925,771 | 21,426 | 262 | 5 | 2,947,464 | 0.74% |
| 1 | 417,550 | 4,308 | 39 | | 421,897 | 1.0% |
| 2 | 96,921 | 1,334 | 37 | 1 | 98,293 | 1.4% |
| 3 | 20,623 | 263 | 1 | 1 | 20,888 | 1.3% |
| 4 | 4,582 | 128 | 9 | | 4,719 | 2.9% |
| 5 | 671 | 21 | | | 692 | 3.0% |
| 6 | 314 | 22 | 2 | | 338 | 7.1% |
| 7 | | 4 | | | 4 | 100% |
| 8 | 3 | 6 | 1 | | 10 | 70.0% |
| 10 | 1 | 1 | 1 | | 3 | 66.7% |
| 12 | 1 | | | | 1 | 0.00% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

Two Demerit Points Offences

Offences in which two demerit points are incurred include improper overtaking or passing, turning or stopping without signalling, turning improperly or failing to keep left.

Table 3.19 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of offences in which two demerit points were incurred during 1991-1992. The greater the number of offences in which two demerit points were incurred during 1991-1992, the greater the proportion of crash-involved drivers two years later, with 9% of drivers who had incurred at least three “two” demerit points offences being crash-involved during 1993-1994.

Table 3.19: Casualty Crash Involvement of drivers during 1993-1994 as a function of “TWO” DEMERIT POINTS OFFENCES incurred during 1991-1992

| #Two demerit points offences incurred during 1991-1992 | No. of casualty crashes during 1993-1994 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,443,382 | 27,039 | 341 | 7 | 3,470,769 | 0.79% |
| 1 | 22,497 | 426 | 7 | | 22,930 | 1.9% |
| 2 | 506 | 43 | 4 | | 553 | 8.5% |
| 3 | 1 | 2 | | | 3 | 66.7% |
| 4 | 1 | 3 | | | 4 | 75.0% |
| 5 | 50 | | | | 50 | 0.0% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

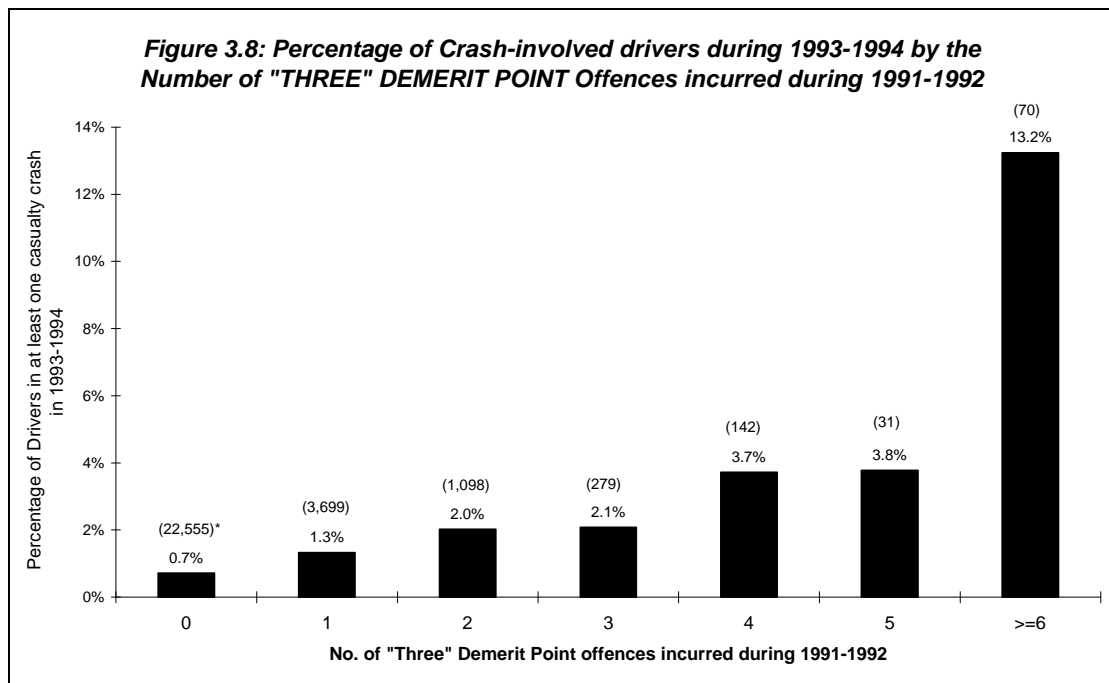
Three Demerit Points Offences

Offences in which three demerit points are incurred include exceeding a speed limit by more than 15 km/h but less than 30 km/h; disobeying a traffic control signal; failing to give way; driving without a seat belt; riding without a helmet; driving on wrong side of double lines or divided highway; risk colliding with alighting, boarding or waiting tram passengers; careless or negligent driving or failing to stop and/or give way at pedestrian, school or level crossing.

Table 3.20 and Figure 3.8 give the casualty crash involvement of drivers during 1993-1994 as a function of the number of offences in which three demerit points were incurred during 1991-1992. The greater the number of “three” demerit points offences incurred during 1991-1992, the greater the proportion of crash-involved drivers two years later. For example, 0.72% of drivers who did not incur any “three” demerit points offences during 1991-1992 were crash-involved in 1993-1994, compared with 13.2% of drivers who had incurred *at least six* “three” demerit points offences during 1991-1992.

Table 3.20: Casualty Crash Involvement of drivers during 1993-1994 as a function of "THREE" DEMERIT POINTS OFFENCES incurred during 1991-1992

| #Three demerit points offences incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,120,370 | 22,289 | 263 | 3 | 3,149,925 | 0.72% |
| 1 | 275,000 | 3,663 | 35 | 1 | 278,699 | 1.3% |
| 2 | 53,096 | 1,063 | 35 | | 54,194 | 2.0% |
| 3 | 13,046 | 269 | 7 | 1 | 13,323 | 2.1% |
| 4 | 3,677 | 135 | 7 | | 3,819 | 3.7% |
| 5 | 789 | 30 | 1 | | 820 | 3.8% |
| 6 | 240 | 39 | 3 | 2 | 284 | 15.5% |
| 7 | 108 | 6 | | | 114 | 5.3% |
| 8 | 54 | 8 | | | 62 | 12.9% |
| 9 | 52 | 4 | | | 56 | 7.1% |
| 10 | 3 | 2 | | | 5 | 40.0% |
| 11 | | 1 | | | 1 | 100% |
| 12 | | 3 | | | 3 | 100% |
| 13 | 2 | | | | 2 | 0.0% |
| 16 | | 1 | | | 1 | 100% |
| 18 | | | 1 | | 1 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |



*Figures in brackets refer to the number of crash-involved drivers during 1993-1994

Four Demerit Points Offences

Four demerit points are incurred by a driver when the speed limit is exceeded by at least 30 km/h but less than 45 km/h.

Table 3.21 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of offences in which four demerit points were incurred during 1991-1992. Only 0.79% of drivers who did not incur any “four” demerit points offences during 1991-1992 were involved in at least one casualty crash during 1993-1994, whereas 11.1% of drivers who had incurred *at least three* “four” demerit points offences during 1991-1992 were crash-involved two years later.

Table 3.21: Casualty Crash Involvement of drivers during 1993-1994 as a function of “FOUR” DEMERIT POINTS OFFENCES incurred during 1991-1992

| #Four demerit points offences incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|---|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,445,324 | 27,011 | 340 | 7 | 3,472,682 | 0.79% |
| 1 | 20,452 | 438 | 8 | | 20,898 | 2.1% |
| 2 | 605 | 57 | 4 | | 666 | 9.2% |
| 3 | 53 | 5 | | | 58 | 8.6% |
| 4 | 3 | 1 | | | 4 | 25.0% |
| 6 | | 1 | | | 1 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

Six Demerit Points Offences

Six demerit points are the maximum number of points incurred for a single offence by a driver - the offence being exceeding the speed limit by 45 km/h or more. Table 3.22 gives the casualty crash involvement of drivers during 1993-1994 by the number of offences in which six demerit points were incurred during 1991-1992. Only 0.8% of drivers who did not incur any “six” demerit points offences during 1991-1992 were involved in at least one casualty crash during 1993-1994. The corresponding crash percentages for drivers who had incurred *one and two* “six” demerit points offences during 1991-1994 were 2.5% and 5.1%, respectively. However, it should be noted, that all drivers who had exceeded the speed limit by at least 45 km/h *three times* during 1991-1992 were *not* crash-involved two years later.

Table 3.22: Casualty Crash Involvement of drivers during 1993-1994 as a function of “SIX” DEMERIT POINTS OFFENCES incurred during 1991-1992

| #Six demerit points offences incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,462,178 | 27,404 | 349 | 7 | 3,489,938 | 0.80% |
| 1 | 4,004 | 100 | 1 | | 4,105 | 2.5% |
| 2 | 204 | 9 | 2 | | 215 | 5.1% |
| 3 | 51 | | | | 51 | 0.0% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.4 CONVICTION VARIABLES

Convictions are given as the total number incurred during 1991-1992, and were not available as a specific type of conviction (such as the number of drink-driving convictions). However the convictions data will be presented as a function of the following “ban” types:

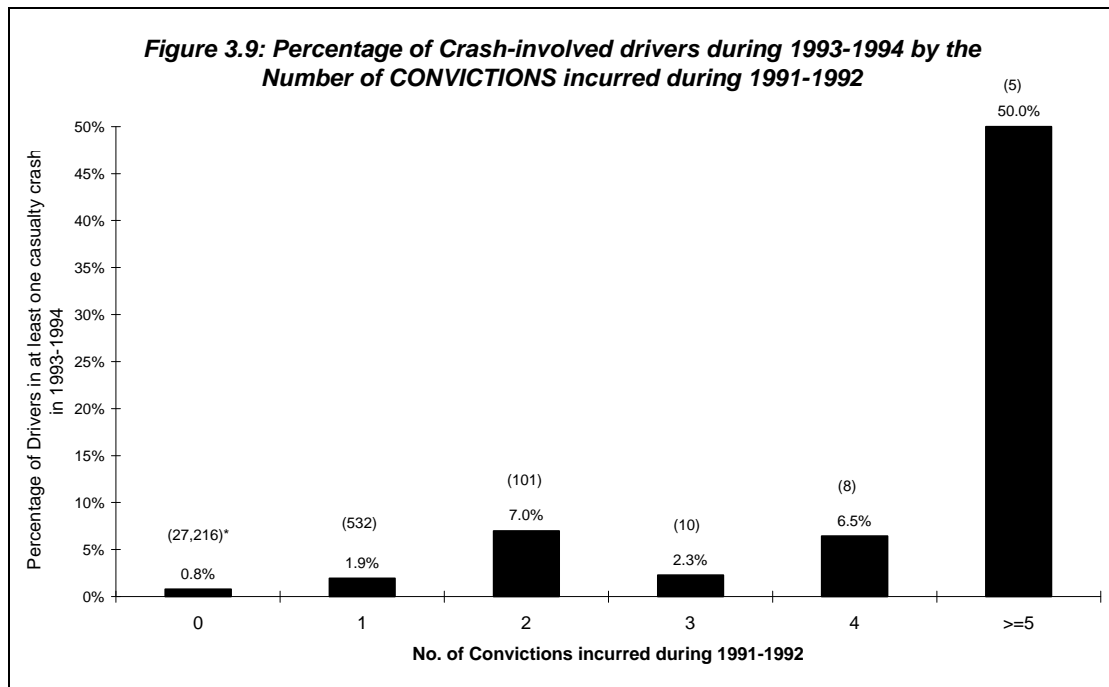
- licence suspensions (ie. licence is returned at end of suspension period) ;
- licence cancellations (ie. licence ceases to exist and the person has to apply for another one);
- licence disqualifications (ie. the person is disqualified from obtaining a licence until the period of disqualification has expired).

3.4.1 Number of Convictions Incurred During 1991-1992

Table 3.23 and Figure 3.9 give the casualty crash involvement of drivers during 1993-1994 as a function of the number of convictions incurred during the prior two-year period. Five of the ten drivers who had at least five convictions during 1991-1992 were crash-involved during 1993-1994, compared with 0.79% of drivers who had no convictions during 1991-1992. It is worth noting that all drivers involved in three casualty crashes during 1993-1994 did not have any convictions during the prior two-year period, however the driver with the most convictions during 1991-1992 (eight convictions) was involved in two casualty crashes in the following two years.

Table 3.23: Casualty Crash Involvement of drivers during 1993-1994 as a function of the NUMBER OF CONVICTIONS incurred during 1991-1992

| No. of Convictions incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash- involved drivers |
|--|---|--------|-----|---|-----------|--------------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,437,417 | 26,870 | 339 | 7 | 3,464,633 | 0.79% |
| 1 | 27,128 | 525 | 7 | | 27,660 | 1.9% |
| 2 | 1,344 | 97 | 4 | | 1,445 | 7.0% |
| 3 | 427 | 10 | | | 437 | 2.3% |
| 4 | 116 | 7 | 1 | | 124 | 6.5% |
| 5 | 4 | 1 | | | 5 | 20.0% |
| 6 | 1 | 2 | | | 3 | 66.7% |
| 7 | | 1 | | | 1 | 100% |
| 8 | | | 1 | | 1 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |



*Figures in brackets refer to the *number* of crash-involved drivers during 1993-1994

3.4.2 Number of Licence Suspensions Incurred During 1991-1992

Table 3.24 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of licence suspensions incurred during the prior two-year period. Only 0.79% of drivers who did not have any licence suspensions during 1991-1992 were crash-involved two years later. This proportion had increased to 8.9% for those drivers who had incurred two suspensions during 1991-1992. However only 3.9% of drivers who had at least three suspensions during 1991-1992 were crash-involved two years later. It is worth noting that both drivers who had incurred the highest number of suspensions during 1991-1992 (six suspensions) were involved in one casualty crash in the following two years.

Table 3.24: Casualty Crash Involvement of drivers during 1993-1994 as a function of the NUMBER OF LICENCE SUSPENSIONS incurred during 1991-1992

| No. of Suspensions incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|--|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,446,045 | 27,021 | 344 | 7 | 3,473,417 | 0.79% |
| 1 | 19,304 | 408 | 4 | | 19,716 | 2.1% |
| 2 | 763 | 71 | 4 | | 838 | 8.9% |
| 3 | 315 | 5 | | | 320 | 1.6% |
| 4 | 9 | 6 | | | 15 | 40.0% |
| 5 | 1 | | | | 1 | 0.0% |
| 6 | | 2 | | | 2 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.4.3 Number of Licence Cancellations Incurred During 1991-1992

Table 3.25 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of licence cancellations incurred during the prior two-year period. Almost 5% of drivers who had incurred two licence cancellations during 1991-1992 were crash-involved two years later. However all the drivers who had incurred the highest number of cancellations during 1991-1992 (3 or 4 cancellations) were *not* crash-involved during 1993-1994.

Table 3.25: Casualty Crash Involvement of drivers during 1993-1994 as a function of the NUMBER OF LICENCE CANCELLATIONS incurred during 1991-1992

| No. of Cancellations incurred during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash- involved drivers |
|--|---|--------|-----|---|-----------|--------------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,461,682 | 27,440 | 352 | 7 | 3,489,481 | 0.80% |
| 1 | 4,493 | 65 | | | 4,558 | 1.4% |
| 2 | 159 | 8 | | | 167 | 4.8% |
| 3 | 52 | | | | 52 | 0.0% |
| 4 | 51 | | | | 51 | 0.0% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

3.4.4 Number of Licence Disqualifications Incurred During 1991-1992

Table 3.26 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of licence disqualifications incurred during the prior two-year period. The proportions of crash-involved drivers during 1993-1994 who were disqualified once (1.5%) or twice (7.1%) in the prior two-year period, were greater than the corresponding proportion for drivers who were not disqualified (0.8%). Further, five of the 13 drivers who were disqualified *at least four* times during 1991-1992 were involved in at least one casualty crash two years later. It is worth noting that the driver with the highest number of disqualifications incurred during 1991-1992 (eight disqualifications) was involved in two casualty crashes during 1993-1994.

Table 3.26: Casualty Crash Involvement of drivers during 1993-1994 as a function of the NUMBER OF LICENCE DISQUALIFICATIONS incurred during 1991-1992

| No. of Disqualifications during 1991-1992 | No. of Casualty Crashes during 1993-1994 | | | | | %crash-involved drivers |
|---|--|--------|-----|---|-----------|-------------------------|
| | 0 | 1 | 2 | 3 | Total | |
| 0 | 3,462,193 | 27,432 | 347 | 7 | 3,489,979 | 0.80% |
| 1 | 3,967 | 57 | 3 | | 4,027 | 1.5% |
| 2 | 210 | 16 | | | 226 | 7.1% |
| 3 | 59 | 5 | | | 64 | 7.8% |
| 4 | 5 | 2 | 1 | | 8 | 37.5% |
| 5 | 2 | | | | 2 | 0.0% |
| 6 | 1 | | | | 1 | 0.0% |
| 7 | | 1 | | | 1 | 100% |
| 8 | | | 1 | | 1 | 100% |
| Total | 3,466,437 | 27,513 | 352 | 7 | 3,494,309 | 0.80% |

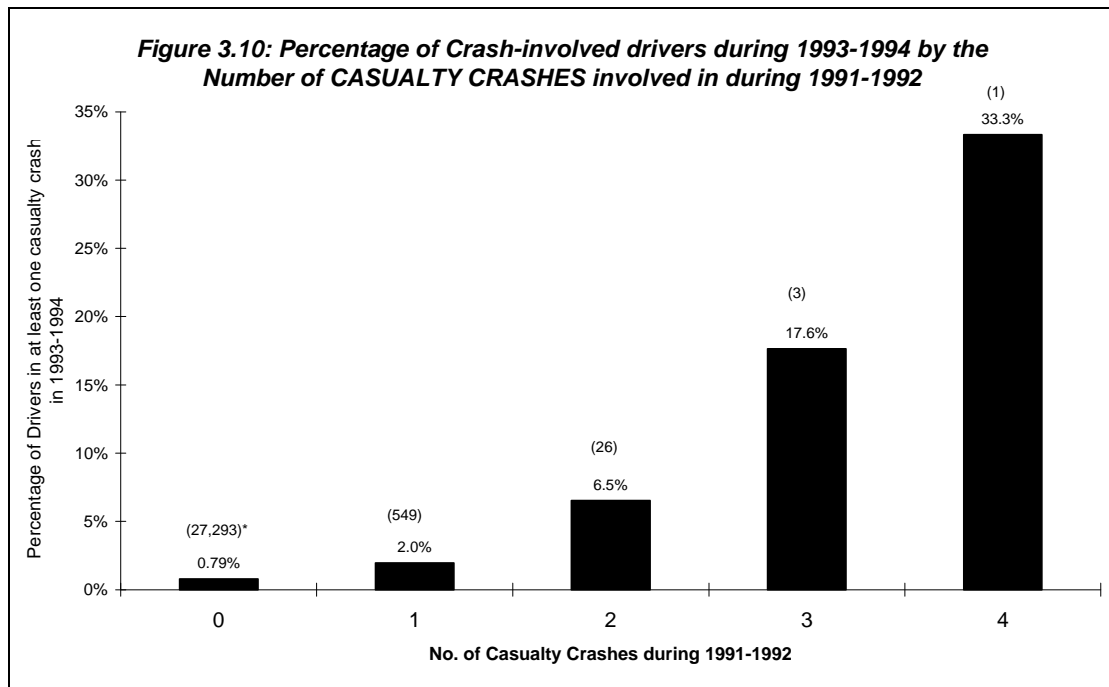
3.5 CRASH VARIABLES

3.5.1 Casualty Crash Involvements During 1991-1992

Table 3.27 and Figure 3.10 give the casualty crash involvement of drivers during 1993-1994 as a function of the number of casualty crashes in which they were involved as a driver during the prior two-year period. The proportion of drivers involved in at least one casualty crash during 1993-1994 increased with increasing crash involvement during the prior two-year period. For example, 0.79% of drivers with no crash history during 1991-1992 were crash-involved two years later, whereas 2% and 6.5% of drivers who were involved in *one* and *two* casualty crashes during 1991-1992, respectively, were crash-involved during 1993-1994.

Table 3.27: Casualty Crash Involvement of drivers during 1993-1994 as a function of the NUMBER OF CASUALTY CRASHES involved in during 1991-1992

| #Casualty Crashes during 1993-1994 | Casualty Crash involvement during 1991-1992 | | | | | |
|---|---|--------|------|-------|-------|-----------|
| | 0 | 1 | 2 | 3 | 4 | Total |
| 0 | 3,438,700 | 27,349 | 372 | 14 | 2 | 3,466,437 |
| 1 | 26,950 | 536 | 23 | 3 | 1 | 27,513 |
| 2 | 337 | 13 | 2 | | | 352 |
| 3 | 6 | | 1 | | | 7 |
| Total | 3,465,993 | 27,898 | 398 | 17 | 3 | 3,494,309 |
| <i>%crash-involved drivers during 1993-1994</i> | 0.79% | 2.0% | 6.5% | 17.6% | 33.3% | 0.80% |



*Figures in brackets refer to the *number* of crash-involved drivers during 1993-1994

3.5.2 Crashes in which the driver was Seriously Injured during 1991-1992

Table 3.28 gives the casualty crash involvement of drivers during 1993-1994 as a function of the number of casualty crashes during 1991-1992 in which the specific driver was seriously injured. In the sample of drivers, 4,164 (or 0.12%) had sustained at least one serious injury whilst in a crash during 1991-1992. Of these, 4,051 were not involved in a casualty crash during 1993-1994. Only 113 (or 2.7%) seriously injured drivers were crash-involved during 1993-1994. However, this proportion is larger than the corresponding crash-involved proportion for drivers who were not seriously injured during 1991-1992 (0.8%).

Table 3.28: Casualty Crash Involvement of drivers during 1993-1994 as a function of the Number of Casualty Crashes in which they were SERIOUSLY INJURED during 1991-1992

| #Casualty Crashes during 1993-1994 | Number of Casualty Crashes in which driver was seriously injured during 1991-1992 | | | | |
|---|---|-------------|--------------|-------------|--------------|
| | 0 | 1 | 2 | 3 | Total |
| 0 | 3,462,386 | 4,039 | 11 | 1 | 3,466,437 |
| 1 | 27,402 | 107 | 4 | | 27,513 |
| 2 | 351 | 1 | | | 352 |
| 3 | 6 | | 1 | | 7 |
| Total | 3,490,145 | 4,147 | 16 | 1 | 3,494,309 |
| <i>%crash-involved drivers during 1993-1994</i> | <i>0.80%</i> | <i>2.6%</i> | <i>31.3%</i> | <i>0.0%</i> | <i>0.80%</i> |

3.5.3 Crashes in which the specific driver was killed

In the sample of drivers, there were 453 fatalities. Of these 217 were killed before 1993 so were omitted from the previous tables (and from the subsequent multivariate analysis) as they could not have crashed during 1993-1994. Of the remaining fatalities, 235 were involved in one casualty crash during 1993-1994 (presumably the crash which resulted in the driver's death). There was also one killed driver who was involved in two casualty crashes during 1993-1994.

4. MULTIVARIATE ANALYSIS

The preliminary univariate analysis revealed that very few drivers (1.3% of crashed drivers) had more than one casualty crash involvement during 1993-1994. Thus most of the information regarding driver's crash involvements was captured in whether they had *any* casualty crashes during 1993-1994. The method of multivariate analysis used was logistic regression, described in detail in Hosmer and Lemeshow (1989). For this analysis, logistic regression models the proportion of drivers in the data set who were casualty crash-involved during 1993-1994 as functions of the potential predictor variables outlined in Chapter 3.

4.1 THE LOGISTIC REGRESSION MODEL

The multivariate logistic regression model was estimated using the GENMOD procedure in the statistical package, SAS (SAS Institute Inc., 1993). To build the model, a forward stepwise selection procedure was used. This procedure allowed for the inclusion and/or exclusion of significant predictor variables during the model building process.

To set up the design matrix of predictor or explanatory effects, "reference cell" parameterisation was used. This type of design allows the effects in question to be estimated relative to a reference level. For example, in the case of driver gender, females were estimated relative to males, and for location, rural residents were estimated relative to Melbourne residents.

To estimate the probability of crash-involvement during 1993-1994 from p independent predictor variables the following logistic regression model was used:

$$Prob(\text{crash-involvement during 1993-1994}) = \frac{1}{1 + e^{-Z}}$$

where Z is the linear combination of predictor variables

$$Z = B_0 + B_1 X_1 + B_2 X_2 + \dots + B_p X_p$$

and B_0, B_1, \dots, B_p are coefficients estimated from the data; X_1, X_2, \dots, X_p are the independent predictor variables, and e is the base of the natural logarithms, approximately 2.718.

From this model, odds ratios were also estimated. An odds ratio is a measure of association which estimates how much more likely (or unlikely) it is for the outcome (in this case, crash occurrence in 1993-1994) to be present amongst a particular category (eg. female drivers) relative to the reference category (eg. male drivers).

Calculation of the i -th odds ratio, y_i , was determined as follows:

$$y_i = e^{B_i}, \quad i=1,2,\dots,p,$$

with 95% confidence limits for the odds ratio given by,

$$\exp[B_i \pm 1.96 * S.E.(B_i)]$$

where $S.E.(B_i)$ is the standard error of the i -th coefficient and was estimated from the data.

4.2 ISSUES RELATING TO “PROBLEM” VARIABLES

Time on Road

It was decided not to specifically attempt to adjust for time spent on the roads in 1991-1992. Convictions and serious injury involvement were included instead in the statistical models. This provides a more exact measure than the crude estimates of road time that would otherwise be necessary, which in any case cannot take account of factors such as drivers remaining on the road despite a conviction. In regard to time missed in 1993-1994 due to serious injury or fatality, it was considered that it would be an error if time on the roads were adjusted for these factors. In such cases the subject is already in the “involved” category and this would merely have the effect of unduly weighting such cases according to the time during 1993-1994 that they were involved. The intention of the model is to predict crash involvement in the two-year period, not earliness of crash involvement.

Exclusion Criteria

In order to attempt to choose drivers who were on the road for as much of 1991-1992 as possible, drivers aged under 20 at the beginning of 1993 were excluded. It is believed that a substantial proportion of such drivers were not on the road for all of 1991-1992. Also, those with a licence issue date after 1992 were excluded, although this group almost entirely coincided with those excluded by the criterion of age. Drivers with unknown age were also excluded as these drivers had all crashed during 1991-1994, and would thus bias the results.

Convictions Incurred during 1991-1992

Convictions were not correlated with offences. For example, convictions relating to drink-driving offences were not part of the offence data since the offence data relates only to demerit point offences. These convictions may be an important behavioural indicator and should be included in the analysis in some way.

Since the data did not allow the ready calculation of “time spent on the road”, convictions and serious injury involvement during 1991-1992 were included as a

proxy for this effect. This also reduces the considerable error associated with miscalculating time missed due to these factors, which would likely be considerable.

4.3 PREDICTOR OR EXPLANATORY VARIABLES

In view of the above problems with some of the data, the following explanatory variables were used to predict a driver's casualty crash involvement during 1993-1994 and were categorised as follows:

4.3.1 Categorical Variables

The variable categories with a code of "1" are the reference groups, that is male drivers, aged 20-21, who are Melbourne residents, who have a car licence, and who were not involved in a casualty crash during 1991-1992 and were not seriously injured in a crash during 1991-1992.

Driver Information

1. Age

1 = 20-21 yrs; 2 = 22-25 yrs; 3 = 26-29 yrs; 4 = 30-39 yrs; 5 = 40-49 yrs;
6 = 50-59 yrs; 7 = 60+ yrs

2. Sex

1 = male; 2 = female; 3 = unknown

3. Residential Location of Driver

1 = metropolitan Melbourne; 2 = rural Victoria; 3 = non-Victorian

4. Endorsement of Licence

1 = car; 2 = truck²; 3 = motorcycle

Prior Crash Information

1. Number of Casualty Crashes during 1991-1992

1 = no prior crashes; 2 = 1 prior crash; 3 = at least 2 prior crashes

2. Number of Serious Injuries incurred by driver in a crash during 1991-1992

1 = no serious injuries; 2 = at least one serious injury

² 'Truck' refers to drivers with a licence endorsed to drive either a heavy combination, a heavy rigid, a medium rigid, a light rigid or a multi-combination vehicle.

4.3.2 Non-Categorical Variables

The following offence and conviction variables were not grouped into categories, but were modelled as the actual frequency incurred by the driver.

Offence Variables

1. Total number of offences incurred during 1991-1992
2. Number of offences incurred during 1991-1992 due to :
 - the speed limit being exceeded by under 30 km/h (OFFENCE TYPE 1)
 - the speed limit being exceeded by at least 30 km/h (OFFENCE TYPE 2)
 - the driver failing to stop or give way (OFFENCE TYPE 3)
 - an unsafe driving action (OFFENCE TYPE 4)
 - headlight or defect notice offence (OFFENCE TYPE 5)
 - the driver/rider not wearing a restraint/helmet (OFFENCE TYPE 6)
 - the driver disobeying a traffic control signal or sign (OFFENCE TYPE 7).
3. Total number of demerit points incurred during 1991-1992 (DEMERITS)
4. Number of offences incurred during 1991-1992 by demerit point level:
 - one demerit point offence (DEMERIT 1)
 - two demerit points offence (DEMERIT 2)
 - three demerit points offence (DEMERIT 3)
 - four demerit points offence (DEMERIT 4)
 - six demerit points offence (DEMERIT 6).

Conviction Variables

1. Total number of convictions incurred during 1991-1992 (CONVICTIONS)
2. Number of licence suspensions incurred during 1991-1992 (SUSPENSIONS)
3. Number of licence cancellations incurred during 1991-1992 (CANCELLATIONS)
4. Number of licence disqualifications incurred during 1991-1992 (DISQUALIFICATIONS).

4.4 MODEL FITTING

The *initial or base* model (Model 1) fitted included all available and reliable driver and licence variables (driver age, driver sex, driver location and endorsement of licence). This model also included the driver's reported casualty crash involvement during 1991-1992, as well as their total number of convictions incurred during 1991-1992. Since "time on the road" could not readily be calculated from the data, the number of casualty crashes in which the driver was seriously injured during 1991-1992 was included as a proxy for this effect in the initial model.

To this model other predictor variables were added to predict drivers' crash involvements during 1993-1994, resulting in the estimation of the following four models:

- *Model 2*: base model + total number of offences during 1991-1992;
- *Model 3*: base model + number of offences during 1991-1992 by category of offence;
- *Model 4*: base model + number of offences during 1991-1992 by demerit point level of offence;
- *Model 5*: base model + total number of demerit points incurred during 1991-1992.

It should be mentioned that offences are those in which demerit points were incurred by the driver, whereas convictions are those which stemmed from all type of traffic offences including drink-driving and not just offences which incur demerit points.

The improvements in the fit of these models, relative to the base model, was used to measure the contribution of offence data to the prediction, and to judge the relative efficiency of representing the offences in the four ways indicated.

For the best of these models, another model was fitted (Model 6) in which the prior crash and prior serious injury involvements were ignored. Given the delays in obtaining crash data for each driver in Victoria, knowledge of the importance of this model in predicting subsequent crash involvements provides useful additional information.

4.4.1 The Base Model

The forward stepwise selection procedure used to model the data found that all variables fitted in the base model were statistically significant in predicting drivers' crash involvement during 1993-1994.

Goodness-of-fit

To assess how effective the estimated logistic regression model is in predicting a driver's crash involvement during 1993-1994, a "goodness-of-fit" statistic was used. The criteria for assessing the goodness-of-fit of the model is to divide the deviance of the fitted model (a function of the difference between the observed and fitted values of the data) by its degrees of freedom. If the deviance is small relative to its degrees of freedom (or the ratio is approximately equal to one) then this is a possible indication of a good model fit (SAS Inc, 1993).

For the base model, a goodness-of-fit ratio of 2.4494 was produced. Table 4.1 presents the estimated results from fitting the base logistic regression model.

It should be noted that the number of convictions incurred during 1991-1992 by a driver was not grouped into categories and fitted as a categorical variable like the

other variables in the base model. Instead the conviction data was fitted to the model as the *actual number* of convictions incurred by each driver. The interpretation of its coefficient estimate is somewhat different in that it is not referenced to other levels. For instance, the estimated coefficient of 0.4662 given in Table 4.1 produces an estimated odds ratio of 1.59. This odds ratio has been estimated for a driver with one conviction. For an increasing number of convictions incurred by the driver, the odds ratio also increases. For example the estimated odds for three convictions incurred during 1991-1992 is $exp(3 \times 0.4662)$ or 4.05. This indicates that with each increase in the number of convictions, the likelihood of crash-involvement increases accordingly.

The offence and demerit points data fitted in the subsequent models were also not grouped into categories but were fitted as actual numbers of offences or demerit points. Hence their coefficients should be interpreted similarly to the “convictions” coefficient estimate.

Table 4.1: Coefficient Estimates, Odds Ratios and 95% Confidence Limits for each Predictor in the Base Model (Model 1)

| Predictor | Predictor Levels | Coefficient Estimate, B_i * | Standard Error | p-value | odds ratio* | 95% confidence interval for odds |
|-----------------------------------|--------------------|-------------------------------|----------------|---------|-------------|----------------------------------|
| Constant term | | -3.9952 | 0.0225 | 0.0001 | | |
| No. of crashes in 1991-1992 | None (reference) | 0 | 0 | | 1.00 | |
| | One | 0.6746 | 0.0502 | 0.0001 | 1.96 | 1.78 - 2.17 |
| | > One | 1.7398 | 0.2092 | 0.0001 | 5.70 | 3.78 - 8.58 |
| Age of Driver (yrs) | 20-21 (reference) | 0 | 0 | | 1.00 | |
| | 22-25 | -0.2620 | 0.0266 | 0.0001 | 0.77 | 0.73 - 0.81 |
| | 26-29 | -0.5689 | 0.0279 | 0.0001 | 0.57 | 0.54 - 0.60 |
| | 30-39 | -0.8043 | 0.0250 | 0.0001 | 0.45 | 0.43 - 0.47 |
| | 40-49 | -0.9428 | 0.0263 | 0.0001 | 0.39 | 0.37 - 0.41 |
| | 50-59 | -1.0806 | 0.0302 | 0.0001 | 0.34 | 0.32 - 0.36 |
| | 60+ | -1.4751 | 0.0313 | 0.0001 | 0.23 | 0.22 - 0.24 |
| Serious Injuries in 1991-1992 | None (reference) | 0 | 0 | | 1.00 | |
| | ≥ One | 0.2961 | 0.1119 | 0.0082 | 1.35 | 1.08 - 1.67 |
| Residential Location | Metro. (reference) | 0 | 0 | | 1.00 | |
| | Rural | -0.2400 | 0.0156 | 0.0001 | 0.79 | 0.76 - 0.81 |
| | Non-Victoria | -0.4011 | 0.0692 | 0.0001 | 0.67 | 0.59 - 0.77 |
| Sex of Driver | Male (reference) | 0 | 0 | | 1.00 | |
| | Female | -0.2037 | 0.0145 | 0.0001 | 0.82 | 0.79 - 0.84 |
| | Unknown | -0.3250 | 1.0022 | 0.7457 | 0.72 | 0.10 - 5.15 |
| Licence Endorsement | Car (reference) | 0 | 0 | | 1.00 | |
| | Truck | 0.3354 | 0.0199 | 0.0001 | 1.40 | 1.35 - 1.45 |
| | Motorcycle | -0.0479 | 0.0264 | 0.0693 | 0.95 | 0.91 - 1.00 |
| Convictions incurred in 1991-1992 | | 0.4662 | 0.0330 | 0.0001 | 1.59 | 1.49 - 1.70 |

*Odds and coefficient estimates are relative to the reference group of male car drivers aged 20-21 resident in Melbourne, who were not involved in a prior crash or were not seriously injured in 1991-1992, and who did not incur any convictions during 1991-1992.

To estimate the probability of casualty crash involvement during 1993-1994 for a linear combination of predictor variables, the formulation given in section 4.1 was used. For the reference group of drivers in the base model, this probability was estimated to be:

$$\begin{aligned}
& \text{Prob}(\text{crash in 1993-1994/reference group}) \\
& = 1/[1+e^{(-3.9952)}] \\
& = 0.0181.
\end{aligned}$$

This means that the chance of being casualty crash-involved during 1993-1994, given you are a 20-21 year-old male car driver residing in Melbourne who did not have any crash or serious injury involvements or convictions two years prior was estimated to be 1.81%. The sign (and magnitude) of the estimated coefficients in Table 4.1 indicates whether a particular level of a predictor has a larger or smaller probability of crash involvement relative to the reference group. A positive sign indicates a higher chance of crash involvement whereas a negative sign indicates a lower chance.

Driver Age

All age-groups above 21 years had negative coefficients (and the coefficients become more negative with increasing age), indicating a decreasing probability of crash involvement with increasing driver age. For instance,

$$\begin{aligned}
& \text{Prob}(\text{crash in 1993-1994/male car driver residing in Melbourne aged 40-49,} \\
& \text{with no crashes, serious injuries or convictions in 1991-1992}) \\
& = 1/[1+e^{(-3.9952-0.9428)}] \\
& = 0.0071.
\end{aligned}$$

Thus male car drivers residing in Melbourne aged 40-49 had a smaller chance (ie. 0.71%) of crash involvement in 1993-1994 relative to the reference group of drivers aged 20-21.

All age levels above age 21 had odds ratios below unity and the corresponding 95% confidence intervals did not contain unity. This indicates a statistically significant over-representation of the youngest age group in 1993-1994 casualty crashes. For example, occurrence of a 1993-1994 crash was estimated to be 0.39 times as likely amongst 40-49 drivers as those aged 20-21.

The driver age trends produced from the multivariate modelling correspond with the univariate trends shown in Table 3.2 in which the percentage of crash-involved drivers in 1993-1994 increased with decreasing driver age.

Driver Sex

Female drivers were significantly under-represented in 1993-1994 crashes when compared to male drivers. That is, the occurrence of a 1993-1994 crash was 0.82 times as likely amongst female than male drivers and the probability of crash involvement was:

$$\begin{aligned}
& \text{Prob}(\text{crash in 1993-1994/female car driver residing in Melbourne aged 20-} \\
& \text{21, with no crashes, serious injuries or convictions in 1991-1992}) \\
& = 1/[1+e^{(-3.9952-2.037)}] \\
& = 0.0148.
\end{aligned}$$

It should be noted that in the univariate analysis in Table 3.1, female drivers were also under-represented in 1993-1994 casualty crashes when compared to males.

Residential Location

Melbourne residents were significantly over-represented in 1993-1994 crashes when compared to rural Victorian (and non-Victorian) residents. This finding agrees with the trend shown in Table 3.3 in the univariate analysis.

The occurrence of a 1993-1994 crash was 0.79 times as likely amongst rural compared with Melbourne residents and the probability of crash involvement was:

$$\begin{aligned} & \text{Prob}(\text{crash in 1993-1994/male car driver residing in rural Victoria aged 20-} \\ & \text{21, with no crashes, serious injuries or convictions in 1991-1992}) \\ & = 1/[1+e^{-(3.9952-0.2400)}] \\ & = 0.0143. \end{aligned}$$

Thus for the reference group of drivers, rural residents have a 1.43% chance of crash involvement in 1993-1994, compared with a 1.81% chance for Melbourne residents.

Licence Endorsement

Drivers endorsed to drive a truck were significantly over-represented in 1993-1994 crashes compared to car drivers, whereas motorcycle riders were under-represented (although no statistically significant difference between car drivers and motorcycle riders was found). The occurrence of a 1993-1994 crash was 1.4 times as likely amongst truck drivers than car drivers and the probability of crash involvement was:

$$\begin{aligned} & \text{Prob}(\text{crash in 1993-1994/male truck driver residing in Melbourne aged 20-} \\ & \text{21, with no crashes, serious injuries or convictions in 1991-1992}) \\ & = 1/[1+e^{-(3.9952+0.3354)}] \\ & = 0.0253. \end{aligned}$$

Crash Involvement during 1991-1992

Drivers who were casualty crash-involved in 1991-1992 were significantly over-represented in 1993-1994 crashes; drivers involved in *one or more than one* casualty crash in 1991-1992 had odds ratios of 1.96 and 5.70, respectively.

For the reference group of drivers, the probability of crash-involvement in 1993-1994 given *one* crash two years prior was:

$$\begin{aligned} & \text{Prob}(\text{crash in 1993-1994/male car driver residing in Melbourne aged 20-21,} \\ & \text{with one prior crash and no serious injuries or convictions in 1991-1992}) \\ & = 1/[1+e^{-(3.9952+0.6746)}] \\ & = 0.0349. \end{aligned}$$

For drivers who were involved in *more than one* casualty crash in 1991-1992, the probability of crash-involvement in 1993-1994 was considerably greater at 9.49%.

When comparing drivers with one prior crash to those who had more than one prior crash, the occurrence of a 1993-1994 crash was 2.9 (95% limits in the range 1.9 - 4.4) times more likely amongst drivers who had multiple crashes in 1991-1992 than those with one prior crash.

Serious Injury Involvement during 1991-1992

Drivers who were involved in at least one casualty crash in which they were seriously injured during 1991-1992 were significantly over-represented in 1993-1994 crashes. For male car drivers resident in Melbourne, aged 20-21 who were involved in one prior crash, the occurrence of a 1993-1994 crash was 1.35 times as likely amongst drivers who had been seriously injured two years prior than those who had not, and the corresponding predicted probability was:

$$\begin{aligned} & \text{Prob}(\text{crash in 1993-1994/male car driver residing in Melbourne aged 20-21,} \\ & \text{with **one prior** crash involvement who was **seriously injured** with no} \\ & \text{convictions in 1991-1992)} \\ & = 1/[1+e^{(-3.9952+0.6746+0.2961)}] \\ & = 0.0463. \end{aligned}$$

Convictions incurred during 1991-1992

For the reference group of drivers, incurring one conviction in 1991-1992 increased the probability of crash-involvement in 1993-1994 from 1.81% to 2.85%, that is:

$$\begin{aligned} & \text{Prob}(\text{crash in 1993-1994/male car driver residing in Melbourne aged 20-21,} \\ & \text{with no crashes or serious injuries but with one conviction in 1991-1992)} \\ & = 1/[1+e^{(-3.9952+0.4662)}] \\ & = 0.0285. \end{aligned}$$

Because of the positive coefficient of the estimate, this probability increased with increasing number of convictions incurred by the driver. For example incurring *four* convictions in 1991-1992 resulted in a chance of crash-involvement two years later of 10.6%.

In general for the base model, the groups most likely to be represented in 1993-1994 crashes were young males; drivers endorsed with a truck licence; Melbourne residents; drivers with casualty crash-involvements and serious injuries during 1991-1992; and drivers who had incurred convictions during 1991-1992. These findings coincided with those found in the univariate analysis.

Highest Risk Groups:

As estimated by the base model, some of the driver groups with the highest risk of casualty crash involvement were:

- Male drivers *aged 20-21*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred one conviction during 1991-1992. The probability of crash-involvement during 1993-1994 for this group was *23.9%*, with a corresponding odds ratio of *17.1* relative to the reference group of drivers.
- Male drivers *aged 22-25*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred one conviction during 1991-1992. The probability of crash-involvement during 1993-1994 for this group was *19.5%*, with a corresponding odds ratio of *13.1* relative to the reference group of drivers.

For these high risk groups (and for all driver groups in general), the estimated probability of crash-involvement further increased with increasing number of convictions incurred during 1991-1992.

It should be mentioned that the conviction data was also considered as three conviction categories (ie. suspensions, disqualifications and cancellations) rather than as total convictions. However, because the inclusion of total convictions produced a sparser model than the model containing the conviction categories, it was decided to use total convictions in the base model.

4.4.2 Total Offences Model

To Model 1 (the base model) the total number of offences accrued by the driver during 1991-1992 were added to produce Model 2. The forward stepwise selection procedure used to select important variables in the fitted model, found that all variables included in Model 2 (ie. total offences incurred during 1991-1992 by a driver, as well as the variables included in the base model) were statistically significant in predicting a driver’s casualty crash involvement during 1993-1994.

The reduction in deviance between this model and the base model (ie. 1,758.83) was tested as chi-square with 1 degree of freedom. The chi-square test was statistically significant ($p < 0.0001$) indicating that Model 2 was superior to the base model. Thus inclusion of the total offences incurred by the driver during 1991-1992 to the base model provides better information about his or her future crash involvement than omitting these prior offences.

For model 2 a goodness-of-fit ratio of 2.4336 was produced. This is smaller than the corresponding goodness-of-fit ratio estimated from the base model (ie. 2.4494) indicating the addition of offence data to the model improves the fit.

Table 4.2 presents the results obtained from fitting the multivariate model which includes the total number of offences incurred by the driver during 1991-1992.

For model 2, the odds ratios and estimated coefficients presented in Table 4.2 are referenced to male car drivers aged 20-21 years residing in Melbourne with no casualty crash involvement or serious injuries during 1991-1992 and no offences or convictions during 1991-1992.

For this reference group of drivers the probability of crash involvement during 1993-1994 was estimated to be:

$$\begin{aligned} & \text{Prob}(\text{crash in 1993-1994/reference group}) \\ &= 1/[1+e^{-(4.2074)}] \\ &= 0.0147. \end{aligned}$$

In other words, male car drivers aged 20-21 years, resident in Melbourne with no prior crash or serious injury involvements during 1991-1992, and with no prior offences or convictions during 1991-1992 had a 1.47% chance of being crash-involved during 1993-1994.

Table 4.2: Coefficient Estimates, Odds Ratios and 95% Confidence Limits for each Predictor in the “Total Offences” Model (Model 2)

| Predictor | Predictor Levels | Coefficient Estimate, B_i^* | Standard Error | p-value | odds ratio* | 95% confidence interval for odds |
|-----------------------------------|--------------------|-------------------------------|----------------|---------|-------------|----------------------------------|
| Constant term | | -4.2074 | 0.0233 | 0.0001 | | |
| No. of crashes in 1991-1992 | None (reference) | 0 | 0 | | 1.00 | |
| | One | 0.5590 | 0.0506 | 0.0001 | 1.75 | 1.58 - 1.93 |
| | > One | 1.2583 | 0.2208 | 0.0001 | 3.52 | 2.28 - 5.43 |
| Age of Driver (yrs) | 20-21 (reference) | 0 | 0 | | 1.00 | |
| | 22-25 | -0.2843 | 0.0266 | 0.0001 | 0.75 | 0.71 - 0.79 |
| | 26-29 | -0.5558 | 0.0280 | 0.0001 | 0.57 | 0.54 - 0.61 |
| | 30-39 | -0.7638 | 0.0251 | 0.0001 | 0.47 | 0.44 - 0.49 |
| | 40-49 | -0.8948 | 0.0264 | 0.0001 | 0.41 | 0.39 - 0.43 |
| | 50-59 | -1.0155 | 0.0303 | 0.0001 | 0.36 | 0.34 - 0.38 |
| | 60+ | -1.3551 | 0.0315 | 0.0001 | 0.26 | 0.24 - 0.27 |
| Serious Injuries in 1991-1992 | None (reference) | 0 | 0 | | 1.00 | |
| | ≥ One | 0.2900 | 0.1129 | 0.0102 | 1.34 | 1.07 - 1.67 |
| Residential Location | Metro. (reference) | 0 | 0 | | 1.00 | |
| | Rural | -0.1911 | 0.0156 | 0.0001 | 0.83 | 0.80 - 0.85 |
| | Non-Victoria | -0.3066 | 0.0692 | 0.0001 | 0.74 | 0.64 - 0.84 |
| Sex of Driver | Male (reference) | 0 | 0 | | 1.00 | |
| | Female | -0.1287 | 0.0147 | 0.0001 | 0.88 | 0.85 - 0.91 |
| | Unknown | -0.3801 | 1.0023 | 0.7045 | 0.68 | 0.10 - 4.88 |
| Licence Endorsement | Car (reference) | 0 | 0 | | 1.00 | |
| | Truck | 0.3327 | 0.0199 | 0.0001 | 1.40 | 1.34 - 1.45 |
| | Motorcycle | -0.0294 | 0.0264 | 0.2655 | 0.97 | 0.92 - 1.02 |
| Convictions incurred in 1991-1992 | | 0.3238 | 0.0352 | 0.0001 | 1.38 | 1.29 - 1.48 |
| Offences incurred in 1991-1992 | | 0.2530 | 0.0054 | 0.0001 | 1.29 | 1.27 - 1.30 |

*Coefficient estimates and odds are relative to the reference group of male car drivers aged 20-21 resident in Melbourne, who were not involved in a prior crash or were not seriously injured in 1991-1992, and who did not incur any offences or convictions in 1991-1992.

For the same variables fitted in this model as were fitted in the base model, similar trends were produced. For instance,

- Male drivers were significantly more likely to be crash-involved during 1993-1994 than females;
- Drivers aged 20-21 were significantly more likely to be crash-involved during 1993-1994 than older drivers (ie. all age groups above 21 years had negative coefficients and odds ratios below unity relative to the reference group, with the coefficient becoming more negative with increasing driver age. Thus the probability of crash-involvement during 1993-1994 decreased with increasing driver age);
- Drivers endorsed to drive a truck were significantly more likely to be crash-involved during 1993-1994 than car drivers or motorcycle riders (there were no statistically significant differences between car drivers and motorcycle riders, however).
- Drivers residing in metropolitan areas were significantly more likely to be crash-involved during 1993-1994 than drivers living in rural Victoria;
- Drivers involved in one or more than one casualty crash during 1991-1992 were significantly more likely to be involved in a crash two years later than those with no prior crashes. Further, occurrence of a 1993-1994 casualty crash was *twice* as likely amongst drivers who were involved in *more than one crash* during 1991-1992 than those involved in one prior crash;
- Drivers who were seriously injured in a casualty crash during 1991-1992 were significantly more likely to be crash-involved during 1993-1994 than those not seriously injured;
- Occurrence of a 1993-1994 crash was 1.38 times more likely amongst drivers who had incurred a licence conviction during 1991-1992 than those who had not (p=0.0001). This likelihood increased with increasing number of convictions.

Offences incurred during 1991-1992

The variable added to the base model to produce Model 2 was the total number of offences incurred by a driver during 1991-1992. This variable was statistically significant in predicting a driver's future crash involvement.

For the reference group of drivers, incurring one offence during 1991-1992 was estimated to increase the probability of crash-involvement from 1.47% to 1.88%, that is:

$$\begin{aligned}
 & \text{Prob}(\text{crash in 1993-1994/male car driver residing in Melbourne aged 20-21,} \\
 & \text{with no crashes, serious injuries or convictions but with one offence during} \\
 & \text{1991-1992}) \\
 & = 1/[1+e^{-(4.2074+0.2530)}] \\
 & = 0.0188.
 \end{aligned}$$

Because of the positive coefficient of the estimate, this probability increased with increasing number of offences accrued by the driver (as did the corresponding odds ratio). This can be seen in the following table:

Table 4.3: Number of offences incurred during 1991-1992 and corresponding probability of crash involvement and odds of crash occurrence during 1993-1994*

| Offences | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 |
|-------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Probability | 0.0188 | 0.0241 | 0.0308 | 0.0393 | 0.0501 | 0.0636 | 0.0804 | 0.1013 | 0.1267 | 0.1574 | 0.7011 |
| Odds | 1.29 | 1.66 | 2.14 | 2.75 | 3.54 | 4.56 | 5.88 | 7.57 | 9.75 | 12.55 | 157.6 |

*Probability and odds are referenced relative to male car drivers aged 20-21, resident in Melbourne, with no crash or serious injury involvements during 1991-1992, and no licence convictions.

For model 2 (base model plus total offences accrued by the driver in 1991-1992) the groups most represented in 1993-1994 crashes were young drivers; male drivers; drivers endorsed with a truck licence; Melbourne residents; drivers with casualty crash-involvements and serious injuries during 1991-1992; drivers who had incurred licence convictions during 1991-1992; and drivers with offences during 1991-1992.

Highest Risk Groups

For model 2, some of the driver groups with the highest risk of casualty crash involvement during 1993-1994 included:

- Male drivers, *aged 20-21*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992, who had incurred *one conviction* and *one offence* during 1991-1992. The probability of crash-involvement for this group was *14.8%*, with a corresponding odds ratio of *11.7* relative to the reference group.
- Male drivers, *aged 22-25*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred *one conviction* and *one offence* during 1991-1992. The probability of crash-involvement for this group was *11.6%*, with a corresponding odds ratio of *8.8* relative to the reference group of drivers.

Both these high risk groups, had higher probabilities of crash-involvements during 1993-1994 the greater the number of offences and/or convictions that were incurred during 1991-1992. For example:

- Male drivers, *aged 20-21*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992, and who had incurred *two convictions* and *five offences* during 1991-1992 had a probability of crash-involvement of *39.8%*. The corresponding odds ratio was *44.4*.
- Male drivers, *aged 22-25*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred *two convictions* and *five offences* during 1991-1992 had a probability of crash-involvement of *33.2%*. The corresponding odds ratio was *33.4*.

4.4.3 Category of Offence Model

Rather than adding the *total* offences incurred by the driver during 1991-1992 to the base model as was done in Model 2, the offence data was divided into the seven offence categories listed in Section 3.3.1 and the number of offences in each category was added as a separate variable. Each of these categories of offences were added to the base model to give Model 3.

The forward stepwise selection procedure used to select important variables in the multivariate model, found that all variables included in Model 3 (ie. all seven offence categories, as well as the variables included in the base model) were statistically significant in predicting a driver's casualty crash involvement during 1993-1994.

Model 3 was significantly superior to the base model ($p < 0.0001$). The reduction in deviance (ie. 1,784.04) was tested as chi-square with 7 degrees of freedom. Model 3 was also significantly superior to Model 2 ($p = 0.0003$) which contained the offence data uncategorised into type of offence. The reduction in deviance between Model 2 and Model 3 was 25.22 and was tested as chi-square with 6 degrees of freedom. Hence inclusion of a driver's prior offences in various categories of offence provides better information about his or her future casualty crash-involvement than does the inclusion of the offence data as total offences only.

For Model 3 a goodness-of-fit ratio of 2.4335 was produced which was almost identical to that of Model 2.

Table 4.4 gives the results obtained from fitting the logistic regression model containing a driver's prior offences categorised into type of offence. For this model, the odds ratios and estimated coefficients presented in Table 4.4 are referenced to male car drivers, aged 20-21 years, residing in Melbourne with no casualty crash or serious injuries during 1991-1992, and with no convictions or offences in any category incurred during 1991-1992.

For this reference group of drivers the probability of crash involvement during 1993-1994 was estimated to be:

$$\begin{aligned} & \text{Prob}(\text{crash in 1993-1994/reference group}) \\ &= 1/[1+e^{-(4.2099)}] \\ &= 0.0146. \end{aligned}$$

Thus, male car drivers, resident in Melbourne, aged 20-21, with no casualty crash or serious injury involvement during 1991-1992, and with no licence cancellations or offences during 1991-1992, were estimated to have had a 1.46% chance of being in a casualty crash during 1993-1994.

Apart from the offence types, the estimated coefficients fitted in this model were similar to those fitted in the base model and in Model 2.

Table 4.4: Coefficient Estimates, Odds Ratios and 95% Confidence Limits for each Predictor in the “Category of Offence” Model (Model 3)

| Predictor | Predictor Levels | Coefficient Estimate, B_i^* | Standard Error | p-value | odds ratio * | 95% confidence interval for odds |
|-----------------------------------|--------------------|-------------------------------|----------------|---------|--------------|----------------------------------|
| Constant term | | -4.2099 | 0.0233 | 0.0001 | | |
| No. of crashes in 1991-1992 | None (reference) | 0 | 0 | | 1.000 | |
| | One | 0.5545 | 0.0507 | 0.0001 | 1.74 | 1.58 - 1.92 |
| | > One | 1.2379 | 0.2230 | 0.0001 | 3.45 | 2.23 - 5.34 |
| Age of Driver (yrs) | 20-21 (reference) | 0 | 0 | | 1.00 | |
| | 22-25 | -0.2824 | 0.0267 | 0.0001 | 0.75 | 0.72 - 0.79 |
| | 26-29 | -0.5522 | 0.0281 | 0.0001 | 0.58 | 0.55 - 0.61 |
| | 30-39 | -0.7590 | 0.0252 | 0.0001 | 0.47 | 0.45 - 0.49 |
| | 40-49 | -0.8887 | 0.0265 | 0.0001 | 0.41 | 0.39 - 0.43 |
| | 50-59 | -1.0094 | 0.0303 | 0.0001 | 0.36 | 0.34 - 0.39 |
| | 60+ | -1.3508 | 0.0316 | 0.0001 | 0.26 | 0.24 - 0.28 |
| Serious Injuries in 1991-1992 | None (reference) | 0 | 0 | | 1.00 | |
| | ≥ One | 0.2861 | 0.1132 | 0.0115 | 1.33 | 1.07 - 1.66 |
| Residential Location | Metro. (reference) | 0 | 0 | | 1.00 | |
| | Rural | -0.1917 | 0.0156 | 0.0001 | 0.83 | 0.80 - 0.85 |
| | Non-Victoria | -0.3080 | 0.0692 | 0.0001 | 0.74 | 0.64 - 0.84 |
| Sex of Driver | Male (reference) | 0 | 0 | | 1.00 | |
| | Female | -0.1259 | 0.0147 | 0.0001 | 0.88 | 0.86 - 0.91 |
| | Unknown | -0.3698 | 1.0023 | 0.7122 | 0.69 | 0.10 - 4.93 |
| Licence Endorsement | Car (reference) | 0 | 0 | | 1.00 | |
| | Truck | 0.3324 | 0.0199 | 0.0001 | 1.39 | 1.34 - 1.45 |
| | Motorcycle | -0.0302 | 0.0264 | 0.2524 | 0.97 | 0.92 - 1.02 |
| Convictions incurred in 1991-1992 | | 0.2791 | 0.0393 | 0.0001 | 1.32 | 1.22 - 1.43 |
| Exceed Speed Limit <30km/h | Offence Type 1 | 0.2364 | 0.0070 | 0.0001 | 1.27 | 1.25 - 1.28 |
| Exceed Speed Limit ≥30 km/h | Offence Type 2 | 0.3738 | 0.0439 | 0.0001 | 1.45 | 1.33 - 1.58 |
| Stop/Give Way Offences | Offence Type 3 | 0.2963 | 0.0796 | 0.0001 | 1.34 | 1.15 - 1.57 |
| Unsafe Driving Action Offences | Offence Type 4 | 0.2478 | 0.0349 | 0.0001 | 1.28 | 1.20 - 1.37 |
| Headlight/Defect Notice Offences | Offence Type 5 | 0.4688 | 0.0763 | 0.0001 | 1.60 | 1.38 - 1.86 |
| Restraint/Helmet Offences | Offence Type 6 | 0.2927 | 0.0258 | 0.0001 | 1.34 | 1.27 - 1.41 |
| Disobey Traffic Signal or Sign | Offence Type 7 | 0.2955 | 0.0285 | 0.0001 | 1.34 | 1.27 - 1.42 |

*Coefficient estimates and odds are relative to the reference group of male car drivers, aged 20-21, resident in Melbourne, who were not involved in a prior crash or were not seriously injured in 1991-1992, and who did not incur any offences in any category or any convictions in 1991-1992.

Offences incurred during 1991-1992 by category of offence

The set of variables containing the offence categories were added to the base model to produce Model 3. Each of the seven offence categories proved to be statistically significant in predicting a driver’s future crash involvement. The offence category with the largest odds ratio was ‘offence type 5’ which includes headlight offences and

offences incurred whilst driving contrary to a defect notice. Relative to the reference group, the occurrence of a 1993-1994 crash was 1.6 times as likely amongst drivers who had incurred a headlight/defect notice offence two years earlier than those who had not.

All category of offence variables had positive coefficients and odds ratios above unity, thus the probability of crash involvement increased with increasing number of offences (of any type).

Type 2 offences (those in which the speed limit was exceeded by ≥ 30 km/h) were significantly different from Type 1 offences (those in which the speed limit was exceeded by < 30 km/h). In terms of crash-involvement drivers in the reference group who had incurred a type 2 offence during 1991-1992 had a probability of being involved in a 1993-1994 crash of 0.0211, whereas those with a type 1 offence had a significantly lower probability of 0.0185.

Type 5 offences (headlight offences and offences incurred whilst driving contrary to a defect notice) were significantly different from Type 4 (unsafe driving action offences) and Type 1 offences. The probability of 1993-1994 crash-involvement for reference group drivers who had incurred a Type 5 offence during 1991-1992 was 0.0232 whereas the corresponding probabilities for drivers who had incurred a Type 4 and a Type 1 offence were significantly lower at 0.0187 and 0.0185, respectively.

Type 3 (stop/give way offences), Type 6 (restraint/helmet offences) and Type 7 offences (offences in which a traffic signal/sign was disobeyed) were not significantly different from any other offence types.

For model 3 (base model plus total offences by category of offence accrued by the driver in 1991-1992) the groups most represented in 1993-1994 crashes were young drivers; male drivers; drivers endorsed with a truck licence; Melbourne residents; drivers with casualty crash-involvements and serious injuries during 1991-1992; drivers who had incurred licence convictions during 1991-1992; and drivers with Type 5, Type 2, Type 3, Type 6, Type 7, Type 4 and/or Type 1 offences (in that order) during 1991-1992.

Highest Risk Groups

Some of the driver groups with the highest risk of casualty crash involvement during 1993-1994 obtained from Model 3 included:

- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992, who had incurred *one conviction* and *one offence* of *each* type during 1991-1992. The estimated probability of crash-involvement for this group was 53.4%, with a corresponding odds ratio of 77.2 relative to the reference group of drivers.
- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred *one conviction* and

one offence of Type 5 (headlight/defect notice) during 1991-1992. The estimated probability of crash-involvement for this group was 16.7% , with a corresponding odds ratio of 13.5 relative to the reference group of drivers.

- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred *one conviction* and *one offence of Type 2* (offences in which the speed limit was exceeded by ≥ 30 km/h) during 1991-1992. The estimated probability of crash-involvement for this group was 15.4% , with a corresponding odds ratio of 12.3 relative to the reference group of drivers.

For these high risk groups (and for all driver groups in general) the estimated probability of 1993-1994 casualty crash-involvement increased with increasing number of offences of each type and/or increasing number of convictions incurred during 1991-1992.

4.4.4 Demerit Point Level of Offence Model

The total number of offences accrued by a driver during 1991-1992 was next categorised into the demerit point level of each offence. Five categories were used corresponding to the number of demerit points incurred by a driver for a particular offence. For an offence a driver can incur one, two, three, four or six demerit points - the greater the weighting the more 'serious' the offence is deemed to be. The type of offences that comprise each demerit point level category are given in Section 3.3.11. To the base model, the offence data was thus added as five separate demerit point level variables to produce Model 4.

The forward stepwise selection procedure used to select important variables in the model found that all variables included in Model 4 (ie. all five demerit point level variables as well as the variables included in the base model) were statistically significant in predicting a driver's future casualty crash involvement.

Model 4 was significantly superior to the base model ($p < 0.0001$). The reduction in deviance (ie. 1,784.04) was tested as chi-square with 5 degrees of freedom. Model 4 was also significantly superior to Model 2, the model containing the offence data uncategorised ($p < 0.0001$) with a reduction in deviance of 25.61 on 4 degrees of freedom. Therefore, inclusion of a driver's prior offence data into demerit level of offence categories provides more information about his or her future casualty crash involvement than including the offence data uncategorised.

Whether the total offences should be categorised into the seven offence type categories (as in Model 3) or the five demerit point level categories (as in Model 4) is debatable since both Model 3 and Model 4 were significantly superior to Model 2 (the total offences model). Further, for Model 4 a goodness-of-fit ratio of 2.4335 was produced. This ratio was identical to that for Model 3. In addition the reduction in deviance between these two models (ie. 0.3966) tested as chi-square with 2 degrees of freedom was not statistically significant ($p = 0.8201$).

Table 4.5 presents the results from fitting the multivariate model which contains the offence data as demerit point levels of offence. For this model, the odds ratios and estimated coefficients are referenced to male car drivers, aged 20-21 years, residing in Melbourne with no casualty crash or serious injury involvement during 1991-1992, and with no convictions or demerit points incurred during 1991-1992

Table 4.5: Coefficient Estimates, Odds Ratios and 95% Confidence Limits for each Predictor in the “Demerit Point Level of Offence” Model (Model 4)

| Predictor | Predictor Levels | Coefficient Estimate, B_i^* | Standard Error | p-value | odds ratio* | 95% confidence interval for odds |
|---|--------------------|-------------------------------|----------------|---------|-------------|----------------------------------|
| Constant term | | -4.2071 | 0.0233 | 0.0001 | | |
| No. of crashes in 1991-1992 | None (reference) | 0 | 0 | | 1.000 | |
| | One | 0.5532 | 0.0507 | 0.0001 | 1.74 | 1.57 - 1.92 |
| | > One | 1.2415 | 0.2222 | 0.0001 | 3.46 | 2.24 - 5.35 |
| Age of Driver (yrs) | 20-21 (reference) | 0 | 0 | | 1.00 | |
| | 22-25 | -0.2885 | 0.0267 | 0.0001 | 0.75 | 0.71 - 0.79 |
| | 26-29 | -0.5569 | 0.0280 | 0.0001 | 0.57 | 0.54 - 0.61 |
| | 30-39 | -0.7629 | 0.0251 | 0.0001 | 0.47 | 0.44 - 0.49 |
| | 40-49 | -0.8912 | 0.0265 | 0.0001 | 0.41 | 0.39 - 0.43 |
| | 50-59 | -1.0113 | 0.0303 | 0.0001 | 0.36 | 0.34 - 0.39 |
| | 60+ | -1.3528 | 0.0316 | 0.0001 | 0.26 | 0.24 - 0.28 |
| Serious Injuries in 1991-1992 | None (reference) | 0 | 0 | | 1.00 | |
| | \geq One | 0.2866 | 0.1131 | 0.0113 | 1.33 | 1.07 - 1.66 |
| Residential Location | Metro. (reference) | 0 | 0 | | 1.00 | |
| | Rural | -0.1917 | 0.0156 | 0.0001 | 0.83 | 0.80 - 0.85 |
| | Non-Victoria | -0.3086 | 0.0693 | 0.0001 | 0.73 | 0.64 - 0.84 |
| Sex of Driver | Male (reference) | 0 | 0 | | 1.00 | |
| | Female | -0.1243 | 0.0147 | 0.0001 | 0.88 | 0.86 - 0.91 |
| | Unknown | -0.3613 | 1.0023 | 0.7185 | 0.70 | 0.10 - 4.97 |
| Licence Endorsement | Car (reference) | 0 | 0 | | 1.00 | |
| | Truck | 0.3313 | 0.0199 | 0.0001 | 1.39 | 1.34 - 1.45 |
| | Motorcycle | -0.0306 | 0.0264 | 0.2463 | 0.97 | 0.92 - 1.02 |
| Convictions incurred in 1991-1992 | | 0.2779 | 0.0391 | 0.0001 | 1.32 | 1.22 - 1.43 |
| One Demerit Point Offence in 1991-1992 | | 0.2252 | 0.0094 | 0.0001 | 1.253 | 1.230 - 1.276 |
| Two Demerit Points Offence in 1991-1992 | | 0.1980 | 0.0400 | 0.0001 | 1.219 | 1.127 - 1.318 |
| Three Demerit Points Offence in 1991-1992 | | 0.2786 | 0.0094 | 0.0001 | 1.321 | 1.297 - 1.346 |
| Four Demerit Points Offence in 1991-1992 | | 0.3897 | 0.0465 | 0.0001 | 1.477 | 1.348 - 1.617 |
| Six Demerit Points Offence in 1991-1992 | | 0.2217 | 0.0926 | 0.0167 | 1.248 | 1.041 - 1.497 |

*Coefficient estimates and odds are relative to the reference group of male car drivers aged 20-21 resident in Melbourne, who were not involved in a prior crash or were not seriously injured in 1991-1992, and who did not incur any demerit points or any convictions in 1991-1992.

For this reference group of drivers the probability of casualty crash-involvement during 1993-1994 was estimated to be:

$$\begin{aligned}
 & \text{Prob}(\text{crash in 1993-1994/reference group}) \\
 & = 1/[1+e^{-(4.2071)}] \\
 & = 0.0147.
 \end{aligned}$$

Hence from Model 4, a male car driver, aged 20-21, residing in Melbourne, with no prior crash-involvement, serious injuries, convictions or demerit points was estimated to have a 1.47% chance of being involved in a casualty crash during 1993-1994.

Apart from the demerit point level categories, the estimated coefficients fitted in this model were similar to those fitted in the base model and in Model 2.

Offences accrued during 1991-1992 by demerit point level of offence

Model 4 consists of the variables in the base model as well as the set of variables representing the demerit point levels of offences. Each of the five 'demerit level' variables were statistically significant in predicting a driver's future crash-involvement. However, the estimated odds of crash-involvement relative to the reference group of drivers, did not increase monotonically with increasing 'weighting' of offences as deemed by the number of demerit points given to an offence. For instance, the demerit level of offence category with the largest odds ratio was a 'four' demerit level of offence (odds ratio of 1.48, relative to the reference group of drivers) and not a 'six' demerit level of offence (odds ratio of 1.25). This may reflect the relatively rare nature of six point offences, which may in turn have affected the reliability of the estimate.

All demerit point level variables had odds ratios above unity and positive estimated coefficients, hence the estimated probability of 1993-1994 crash-involvement increased with increasing number of offences by demerit level incurred during 1991-1992.

Offences which incurred four demerit points (ie. those in which the speed limit was exceeded by at least 30 km/h but less than 45 km/h) were significantly different from all other demerit point level categories with the exception of offences which incurred six demerit points (ie. those in which the speed limit was exceeded by 45 km/h or more). In terms of crash-involvement, drivers in the reference group who had incurred a 'four demerit points' offence during 1991-1992 had a probability of being involved in a 1993-1994 crash of 0.0215, whereas those with a 'one', 'two' or 'three' demerit points offences had significantly lower probabilities of 0.0183, 0.0178, and 0.0193, respectively.

Prior offences which incurred *three* demerit points (includes offences in which the speed limit was exceeded by more than 15 km/h but less than 30 km/h and offences in which a traffic control signal was disobeyed) resulted in a significantly larger chance of future crash-involvement than did prior offences which incurred *one* demerit point (includes headlight offences and offences in which the speed limit was exceeded by 15 km/h or less).

However, offences which incurred the maximum number of demerit points (ie. those in which the speed limit was exceeded by 45 km/h or more) were not significantly different from any other 'demerit level of offence' category.

For model 4 (base model plus total offences by demerit point level of offence accrued by the driver in 1991-1992), the groups with the highest estimated probability of being

represented in 1993-1994 crashes were young drivers; male drivers; drivers endorsed with a truck licence; Melbourne residents; drivers with casualty crash-involvements and serious injuries during 1991-1992; drivers who had incurred licence convictions during 1991-1992; and drivers with 'four demerit points', 'three demerit points', 'one demerit point', 'six demerit points', and/or 'two demerit points' offences (in that order) during 1991-1992.

Highest Risk Groups

Some of the driver groups with the highest risk of casualty crash involvement during 1993-1994 predicted from Model 4 included:

- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992, who had incurred *one conviction* and *one offence* in ***each demerit level*** category during 1991-1992. The estimated probability of crash-involvement for this group was *31.9%*, with a corresponding odds ratio of *31.5* relative to the reference group of drivers.
- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred *one conviction* and *one 'four demerit points' offence* (exceeding speed limit by at least 30 km/h but less than 45 km/h) during 1991-1992. The estimated probability of crash-involvement for this group was *15.7%*, with a corresponding odds ratio of *12.5* relative to the reference group of drivers.
- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred *one conviction* and *one 'three demerit points' offence* (a list of these offences is given in section 3.3.11) during 1991-1992. The estimated probability of crash-involvement for this group was *14.3%*, with a corresponding odds ratio of *11.2* relative to the reference group of drivers.

4.4.5 Total Demerit Points Model

The final offence variable added to the base model was the total number of demerit points accrued by a driver during 1991-1992. Addition of this variable produced Model 5.

The forward selection procedure used to select important variables in the fitted model, found that all variables included in Model 5 were statistically significant in predicting a driver's casualty crash involvement during 1993-1994. Model 5 was superior to the base model with high statistical significance ($p < 0.0001$). The reduction in deviance (ie. 1,602.61) was tested as chi-square on 1 degree of freedom. Hence inclusion of a driver's accrued demerit points during 1991-1992 adds to the prediction of his or her casualty crash-involvement two years later.

For this model a goodness-of-fit ratio of 2.4350 was produced. In comparison with Model 2 (the total offences model), the goodness-of-fit ratio was almost the same at 2.4336, hence Model 2 gives a similar fit to Model 5.

Table 4.6 gives the results obtained from fitting the multivariate model containing the total demerit points accrued by a driver during 1991-1992. For this model, the odds ratios and estimated coefficients presented in Table 4.6 are referenced to male car drivers aged 20-21 years, residing in Melbourne, who did not have any casualty crash or serious injury involvement during 1991-1992 nor any convictions or demerit points during 1991-1992.

Table 4.6: Coefficient Estimates, Odds Ratios and 95% Confidence Limits for each Predictor in the “Total Demerit Points” Model (Model 5)

| Predictor | Predictor Levels | Coefficient Estimate, B_i^* | Standard Error | p-value | odds ratio* | 95% confidence interval for odds |
|--------------------------------------|--------------------|-------------------------------|----------------|---------|-------------|----------------------------------|
| Constant term | | -4.1841 | 0.0231 | 0.0001 | | |
| No. of crashes in 1991-1992 | None (reference) | 0 | 0 | | 1.00 | |
| | One | 0.5583 | 0.0508 | 0.0001 | 1.75 | 1.58 - 1.93 |
| | > One | 1.2540 | 0.2237 | 0.0001 | 3.50 | 2.26 - 5.43 |
| Age of Driver (yrs) | 20-21 (reference) | 0 | 0 | | 1.00 | |
| | 22-25 | -0.2890 | 0.0266 | 0.0001 | 0.75 | 0.71 - 0.79 |
| | 26-29 | -0.5520 | 0.0279 | 0.0001 | 0.58 | 0.55 - 0.61 |
| | 30-39 | -0.7572 | 0.0250 | 0.0001 | 0.47 | 0.45 - 0.49 |
| | 40-49 | -0.8802 | 0.0264 | 0.0001 | 0.42 | 0.39 - 0.44 |
| | 50-59 | -1.0014 | 0.0303 | 0.0001 | 0.37 | 0.35 - 0.39 |
| | 60+ | -1.3558 | 0.0315 | 0.0001 | 0.26 | 0.24 - 0.27 |
| Serious Injuries in 1991-1992 | None (reference) | 0 | 0 | | 1.00 | |
| | ≥ One | 0.2732 | 0.1135 | 0.0161 | 1.31 | 1.05 - 1.64 |
| Residential Location | Metro. (reference) | 0 | 0 | | 1.00 | |
| | Rural | -0.2000 | 0.0156 | 0.0001 | 0.82 | 0.79 - 0.84 |
| | Non-Victoria | -0.3279 | 0.0692 | 0.0001 | 0.72 | 0.63 - 0.83 |
| Sex of Driver | Male (reference) | 0 | 0 | | 1.00 | |
| | Female | -0.1227 | 0.0147 | 0.0001 | 0.89 | 0.86 - 0.91 |
| | Unknown | -0.2997 | 1.0022 | 0.7649 | 0.74 | 0.10 - 5.28 |
| Licence Endorsement | Car (reference) | 0 | 0 | | 1.00 | |
| | Truck | 0.3294 | 0.0199 | 0.0001 | 1.39 | 1.34 - 1.45 |
| | Motorcycle | -0.0364 | 0.0264 | 0.1677 | 0.96 | 0.92 - 1.02 |
| Convictions incurred in 1991-1992 | | 0.2280 | 0.0368 | 0.0001 | 1.26 | 1.17 - 1.35 |
| Demerit Points incurred in 1991-1992 | | 0.1058 | 0.0024 | 0.0001 | 1.112 | 1.106 - 1.117 |

*Coefficient estimates and odds are relative to the reference group of male car drivers aged 20-21 resident in Melbourne, who were not involved in a crash or were not seriously injured in 1991-1992, and who did not incur any demerit points or any licence convictions in 1991-1992.

For this reference group of drivers the probability of a being crash-involved during 1993-1994 was estimated to be:

$$\begin{aligned} & Prob(\text{crash in 1993-1994/reference group}) \\ &= 1/[1+e^{-(4.1841)}] \\ &= 0.0150. \end{aligned}$$

Thus, for Model 5, a male car driver, residing in Melbourne, with no prior crash-involvement, serious injuries, convictions or demerit points during 1991-1992 had a 1.5% chance of being involved in a casualty crash during 1993-1994.

To decide which model was preferable between Model 2 and Model 5, odds ratios for the median number of total offences and median number of total demerit points accrued during 1991-1992 were determined. The median was used because of the skewed nature of the offence and demerit points data. The median number of *demerit points* accrued by a driver was two, resulting in an odds ratio (relative to the reference group of drivers) of 1.24. However, the median number of *offences* accrued by a driver (ie. one offence) resulted in a slightly larger odds ratio of 1.29. Thus, the total offences model (Model 2) may be somewhat preferable to the total demerit points model (Model 5). Nevertheless, neither Model 2 nor Model 5 are as good as Model 3 or Model 4 which were significantly superior to both the total offence and total demerit points models.

Total Number of Demerit Points accrued during 1991-1992

The variable added to the base model to produce Model 5 was the total number of demerit points accrued by a driver during 1991-1992. This variable was statistically significant in predicting a driver's future crash-involvement ($p=0.0001$).

For the reference group of drivers incurring *one* demerit point during 1991-1992 increased the probability of 1993-1994 crash involvement from 1.50% to 1.67%. Because of the positive coefficient of the estimate, this probability further increased with increasing number of demerit points accrued by the driver as did the corresponding odds ratio. This can be seen in the following table:

Table 4.7 *Number of demerit points accrued during 1991-1992 and corresponding probability of crash involvement and odds of crash occurrence during 1993-1994**

| Demerit Points | 1 | 2 | 3 | 4 | 5 | 6 | 10 | 12 | 20 | 30 | 64 |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Probability | 0.0167 | 0.0185 | 0.0205 | 0.0227 | 0.0252 | 0.0279 | 0.0420 | 0.0514 | 0.1122 | 0.2670 | 0.9300 |
| Odds | 1.11 | 1.24 | 1.37 | 1.53 | 1.70 | 1.89 | 2.88 | 3.56 | 8.30 | 23.90 | 872.36 |

*Probability and odds are referenced relative to male car drivers aged 20-21, resident in Melbourne, with no crash or serious injury involvement during 1991-1992, and no licence convictions.

For this model (base model plus total demerit points accrued during 1991-1992) the driver groups most represented in 1993-1994 casualty crashes were young drivers; male drivers; drivers endorsed with a truck licence; Melbourne residents; drivers with casualty crash involvements and serious injuries during 1991-1992; drivers who had incurred licence convictions during 1991-1992 and drivers with accrued demerit points during 1991-1992.

Highest Risk Groups

For model 5, some of the driver groups with the highest risk of casualty crash involvement during 1993-1994 included:

- Male drivers, *aged 20-21*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992, who had incurred *one conviction* and *one demerit point* during 1991-1992. The estimated probability of crash-involvement for this group was *12%*, with a corresponding odds ratio of *8.9* relative to the reference group of drivers.
- Male drivers, *aged 22-25*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred *one conviction* and *one demerit point* during 1991-1992. The estimated probability of crash-involvement for this group was *9.3%*, with a corresponding odds ratio of *6.7* relative to the reference group of drivers.

Both these high risk groups had higher probabilities of crash-involvements during 1993-1994 the more demerit points and/or convictions that were incurred during 1991-1992. For example:

- Male drivers, *aged 20-21*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992, and who had incurred *two convictions* and *six demerit points* during 1991-1992 had an estimated probability of crash-involvement of *22.5%*. The corresponding odds ratio was *19.1*.
- Male drivers, *aged 22-25*, resident in Melbourne, endorsed to drive a ‘truck’ type, who were involved in more than one casualty crash during 1991-1992, who were seriously injured in a crash in 1991-1992 and who had incurred *two convictions* and *six demerit points* during 1991-1992 had an estimated probability of crash-involvement of *17.9%*. The corresponding odds ratio was *14.3*.

4.4.6 Which is the “best” model?

The two models which included the sets of variables that produced weightings of the offence categories that reflected their relative importance in predicting drivers’ crash involvements during 1993-1994 (ie. Model 3, the “category of offence” model, and Model 4, the “demerit point level of offence” model) were the best fitting of the five models.

The “demerit point level of offence” model (Model 4) was slightly better fitting and more economical than the “category of offence” model (Model 3), although there was little difference between the two models in terms of predicting a driver’s future casualty crash involvement.

For both these “best” models, the next section will examine the predictive ability of Models 3 and 4 when prior crash and serious injury involvements are ignored. Given the delays in obtaining crash data for each driver in Victoria, knowledge of the importance of this factor in predicting subsequent crash involvements would be useful additional information.

4.4.7 Models without Prior Crash Involvements

The best models were the “demerit point level of offence” model (Model 4) and the “category of offence” model (Model 5). Both these models were fitted again without the driver’s casualty crash and serious injury involvements during 1991-1992.

Demerit Point Level of Offence Model without Prior Crashes

Model 6 consisted of the set of variables containing the demerit point level of offences and the variables in the base model except for the prior crashes and serious injuries. All variables included in Model 6 were statistically significant in predicting a driver’s casualty crash involvement during 1993-1994.

This model was significantly superior to the base model ($p < 0.0001$). The reduction in deviance (ie. 1,609.7) was tested as chi-square with 2 degrees of freedom. However Model 4, the “demerit point level of offence” model *with* prior crashes/serious injuries included, was significantly superior to Model 6 ($p < 0.0001$). The reduction in deviance between Models 4 and 6 (ie. 174.74) was tested as chi-square on 3 degrees of freedom. Hence, omitting a driver’s prior casualty crash and serious injury involvements leads to a less informative model in terms of prediction of a driver’s future crash involvement.

Table 4.8 presents the results obtained from fitting the “demerit point level of offence” model without prior crashes or serious injuries. For this model, the odds ratios and estimated coefficients are referenced to male car drivers, aged 20-21 years, residing in Melbourne who did not have any licence convictions or demerit points during 1991-1992.

For this reference group of drivers the probability of casualty crash involvement during 1993-1994 was estimated to be:

$$\begin{aligned} & \text{Prob}(\text{crash in 1993-1994/reference group}) \\ &= 1/[1+e^{-(4.1939)}] \\ &= 0.0149. \end{aligned}$$

In other words, as estimated from Model 6, a male car driver, aged 20-21, residing in Melbourne with no convictions or demerit points during 1991-1992 had a 1.49% chance of being casualty crash involved during 1993-1994.

Table 4.8: Coefficient Estimates, Odds Ratios and 95% Confidence Limits for each Predictor in the “Demerit Point Level of Offence” Model without prior Crash and serious injury involvements (Model 6)

| Predictor | Predictor Levels | Coefficient Estimate, B_i^* | Standard Error | p-value | odds ratio* | 95% confidence interval for odds |
|---|--------------------|-------------------------------|----------------|---------|-------------|----------------------------------|
| Constant term | | -4.1939 | 0.0232 | 0.0001 | | |
| Age of Driver (yrs) | 20-21 (reference) | 0 | 0 | | 1.00 | |
| | 22-25 | -0.2932 | 0.0267 | 0.0001 | 0.75 | 0.71 - 0.79 |
| | 26-29 | -0.5642 | 0.0280 | 0.0001 | 0.57 | 0.54 - 0.60 |
| | 30-39 | -0.7724 | 0.0251 | 0.0001 | 0.46 | 0.44 - 0.49 |
| | 40-49 | -0.9015 | 0.0265 | 0.0001 | 0.41 | 0.39 - 0.43 |
| | 50-59 | -1.0215 | 0.0303 | 0.0001 | 0.36 | 0.34 - 0.38 |
| | 60+ | -1.3635 | 0.0315 | 0.0001 | 0.26 | 0.24 - 0.27 |
| Residential Location | Metro. (reference) | 0 | 0 | | 1.00 | |
| | Rural | -0.1918 | 0.0156 | 0.0001 | 0.83 | 0.80 - 0.85 |
| | Non-Victoria | -0.3002 | 0.0692 | 0.0001 | 0.74 | 0.65 - 0.85 |
| Sex of Driver | Male (reference) | 0 | 0 | | 1.00 | |
| | Female | -0.1244 | 0.0147 | 0.0001 | 0.88 | 0.86 - 0.91 |
| | Unknown | -0.3613 | 1.0023 | 0.7185 | 0.70 | 0.10 - 4.97 |
| Licence Endorsement | Car (reference) | 0 | 0 | | 1.00 | |
| | Truck | 0.3342 | 0.0199 | 0.0001 | 1.40 | 1.34 - 1.45 |
| | Motorcycle | -0.0285 | 0.0264 | 0.2802 | 0.97 | 0.92 - 1.02 |
| Convictions incurred in 1991-1992 | | 0.2986 | 0.0392 | 0.0001 | 1.35 | 1.25 - 1.46 |
| One Demerit Point Offence in 1991-1992 | | 0.2276 | 0.0094 | 0.0001 | 1.26 | 1.23 - 1.28 |
| Two Demerit Points Offence in 1991-1992 | | 0.2030 | 0.0399 | 0.0001 | 1.23 | 1.13 - 1.33 |
| Three Demerit Points Offence in 1991-1992 | | 0.2876 | 0.0093 | 0.0001 | 1.33 | 1.31 - 1.36 |
| Four Demerit Points Offence in 1991-1992 | | 0.3985 | 0.0466 | 0.0001 | 1.49 | 1.36 - 1.63 |
| Six Demerit Points Offence in 1991-1992 | | 0.2215 | 0.0926 | 0.0168 | 1.25 | 1.04 - 1.50 |

*Coefficient estimates and odds are relative to the reference group of male car drivers aged 20-21 resident in Melbourne, who did not incur any demerit points or any convictions in 1991-1992.

For the variables fitted in Model 6 the following trends were found:

- Young drivers, aged 20-21, were significantly more likely to be crash-involved during 1993-1994 than older drivers, with the probability of crash involvement decreasing with increasing driver age;
- Melbourne residents were significantly over-represented in 1993-1994 crashes when compared to rural or non-Victorian residents;
- Female drivers were significantly under-represented in 1993-1994 crashes when compared to males (odds ratio of 0.88);
- Drivers endorsed with a truck licence were significantly over-represented in crashes when compared to car drivers (odds ratio of 1.40) and motorcycle riders (odds ratio of 1.44). There were no statistically significant differences between car drivers and motorcycle riders, however ($p=0.2802$);
- Drivers who had incurred at least one conviction during 1991-1992 were significantly more likely to be in a casualty crash during 1993-1994 than drivers with no convictions;
- All five demerit point level of offence variables had odds ratios above unity and positive statistically significant coefficients, hence the probability of 1993-1994

crash involvement increased with increasing number of offences by demerit level accrued by the driver during 1991-1992

- Offences which incurred four demerit points (ie. those in which the speed limit was exceeded by at least 30 km/h) had the largest odds ratio out of all demerit levels of offence (odds ratio of 1.49 relative to the reference group of drivers). This was also true for Model 4, the model with the prior crash involvements.

In general for Model 6 (“demerit point level of offence” model without prior crash and serious injury involvements), the groups most represented in 1993-1994 crashes were young drivers; male drivers; drivers endorsed with a truck licence; Melbourne residents; drivers who had incurred licence convictions during 1991-1992, and drivers with ‘four demerit point’ and/or ‘three demerit points’ and/or ‘one demerit point’ and/or ‘six demerit points’ and/or ‘two demerit points’ offences during 1991-1992.

Some of the driver groups with the highest estimated risk of casualty crash involvement during 1993-1994 as predicted by Model 6 included:

- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a ‘truck’ type, who had incurred *one conviction* and *one offence* in ***each demerit level*** category during 1991-1992. The estimated probability of crash-involvement for this group was 9.8%, with a corresponding odds ratio of 7.2 relative to the reference group of drivers. It is worth noting that for the same group of drivers in the model which included prior crash and serious injury involvements (Model 4), the corresponding probability was 31.9%.
- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a ‘truck’ type, who had incurred *one conviction* and *one ‘four demerit points’ offence* (exceeding speed limit by at least 30 km/h but less than 45 km/h) during 1991-1992. The estimated probability of crash-involvement for this group was 4.1%, with a corresponding odds ratio of 2.8 relative to the reference group of drivers. For Model 4, the corresponding probability was 15.7% and corresponding odds ratio was estimated to be 12.5.
- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a ‘truck’ type, who had incurred *one conviction* and *one ‘three demerit points’ offence* (a list of these offences is given in section 3.3.11) during 1991-1992. The estimated probability of crash-involvement for this group was 3.7% , with a corresponding odds ratio of 2.5 relative to the reference group of drivers.

Category of Offence Model without Prior Crashes

Model 7 is comprised of the set of variables that made up Model 3 (the “category of offence” model) with the exception of a driver’s casualty crash and serious injury involvement during 1991-1992. All variables fitted in Model 7 were statistically significant in predicting a driver’s casualty crash involvement during 1993-1994.

When comparing this model with Model 3 (which included prior crash and serious injury involvements), it was found that Model 7 was significantly inferior to Model 3 ($p < 0.0001$). The reduction in deviance (ie. 175.03) was tested as chi-square with 3 degrees of freedom. Hence, as was found for Model 6, omission of a driver’s prior

crash and serious injury involvements leads to a less informative model in terms of prediction of his or her future crash involvement.

Table 4.9 gives the results obtained from fitting the category of offence model without prior crashes or serious injuries. For this model, the odds ratios and estimated coefficients are referenced to male car drivers, aged 20-21 years, residing in Melbourne who did not have any convictions or offences during 1991-1992.

Table 4.9: Coefficient Estimates, Odds Ratios and 95% Confidence Limits for each Predictor in the “Category of Offence” Model without prior Crash or Serious Injury involvements (Model 7)

| Predictor | Predictor Levels | Coefficient Estimate, B_i^* | Standard Error | p-value | odds ratio* | 95% confidence interval for odds |
|-----------------------------------|--------------------|-------------------------------|----------------|---------|-------------|----------------------------------|
| Constant term | | -4.1969 | 0.0233 | 0.0001 | | |
| Age of Driver (yrs) | 20-21 (reference) | 0 | 0 | | 1.00 | |
| | 22-25 | -0.2865 | 0.0267 | 0.0001 | 0.75 | 0.71 - 0.79 |
| | 26-29 | -0.5590 | 0.0280 | 0.0001 | 0.57 | 0.54 - 0.60 |
| | 30-39 | -0.7682 | 0.0252 | 0.0001 | 0.46 | 0.44 - 0.49 |
| | 40-49 | -0.8989 | 0.0265 | 0.0001 | 0.41 | 0.39 - 0.43 |
| | 50-59 | -1.0196 | 0.0303 | 0.0001 | 0.36 | 0.34 - 0.38 |
| | 60+ | -1.3615 | 0.0316 | 0.0001 | 0.26 | 0.24 - 0.27 |
| Residential Location | Metro. (reference) | 0 | 0 | | 1.00 | |
| | Rural | -0.1917 | 0.0156 | 0.0001 | 0.83 | 0.80 - 0.85 |
| | Non-Victoria | -0.2995 | 0.0692 | 0.0001 | 0.74 | 0.65 - 0.85 |
| Sex of Driver | Male (reference) | 0 | 0 | | 1.00 | |
| | Female | -0.1264 | 0.0147 | 0.0001 | 0.88 | 0.86 - 0.91 |
| | Unknown | -0.3710 | 1.0023 | 0.7113 | 0.69 | 0.10 - 4.92 |
| Licence Endorsement | Car (reference) | 0 | 0 | | 1.00 | |
| | Truck | 0.3354 | 0.0199 | 0.0001 | 1.40 | 1.35 - 1.45 |
| | Motorcycle | -0.0281 | 0.0264 | 0.2876 | 0.97 | 0.92 - 1.02 |
| Convictions incurred in 1991-1992 | | 0.3004 | 0.0393 | 0.0001 | 1.35 | 1.25 - 1.46 |
| Exceed Speed Limit <30km/h | Offence Type 1 | 0.2405 | 0.007 | 0.0001 | 1.27 | 1.25 - 1.29 |
| Exceed Speed Limit \geq 30 km/h | Offence Type 2 | 0.3819 | 0.0439 | 0.0001 | 1.47 | 1.34 - 1.60 |
| Stop/Give Way Offences | Offence Type 3 | 0.3258 | 0.0796 | 0.0001 | 1.39 | 1.19 - 1.62 |
| Unsafe Driving Action Offences | Offence Type 4 | 0.2521 | 0.0349 | 0.0001 | 1.29 | 1.20 - 1.38 |
| Headlight/Defect Notice Offences | Offence Type 5 | 0.4923 | 0.0765 | 0.0001 | 1.64 | 1.41 - 1.90 |
| Restraint/Helmet Offences | Offence Type 6 | 0.2994 | 0.0258 | 0.0001 | 1.35 | 1.28 - 1.42 |
| Disobey Traffic Signal or Sign | Offence Type 7 | 0.3097 | 0.0286 | 0.0001 | 1.36 | 1.29 - 1.44 |

*Coefficient estimates and odds are relative to the reference group of male car drivers, aged 20-21, resident in Melbourne, who did not incur any offences in any category or any convictions in 1991-1992.

For this reference group of drivers, the chance of being casualty crash-involved during 1993-1994 was estimated to be 1.48%.

For the same variables fitted in this model as were fitted in Model 6 above, similar trends were produced. For instance, the groups most represented in 1993-1994 crashes were young drivers; male drivers; drivers endorsed with a truck licence; Melbourne residents; drivers who had incurred licence convictions during 1991-1992, and drivers with Type 5 and/or Type 2 and/or Type 3 and/or Type 7 and/or Type 6 and/or Type 4 and/or Type 1 offences (in that order) during 1991-1992.

Some of the driver groups with the highest estimated risk of casualty crash involvement during 1993-1994, based on Model 7, included:

- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who had incurred *one conviction* and *one offence* of *each* type during 1991-1992. The estimated probability of crash involvement for this group was 22.1% with a corresponding odds ratio of 18.9 relative to the reference group (when prior crashes and serious injuries were included this proportion was 53.4%).
- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who had incurred *one conviction* and *one offence* of *Type 5* (headlight/defect notice) during 1991-1992. The estimated probability of crash involvement for this group was 4.4% with a corresponding odds ratio of 3.1 relative to the reference group (when prior crashes and serious injuries were included this proportion was 16.7%).
- Male drivers, aged 20-21, resident in Melbourne, endorsed to drive a 'truck' type, who had incurred *one conviction* and *one offence* of *Type 2* (offences in which the speed limit was exceeded by ≥ 30 km/h) during 1991-1992. The estimated probability of crash-involvement for this group was 4% , with a corresponding odds ratio of 2.8 relative to the reference group of drivers.

Overall, inclusion of a driver's prior casualty crash and serious injury involvements leads to better predictive ability of a multivariate model in predicting a driver's subsequent crash involvements. This is true whether the set of variables included in the multivariate model are the demerit point level of offence variables or the category of offence variables. Thus, although delays occur in obtaining crash data for each driver in Victoria, the ability of the models to predict subsequent crash involvements would be enhanced if such data could be included.

5. EFFICIENCY OF PREDICTION MODELS

The efficiency of the developed models was measured in the following two ways:

1. In terms of their ability to discriminate between crash-involved and not crash-involved drivers;
2. In terms of their ability to correctly (or incorrectly) classify drivers according to their subsequent crash involvement.

5.1 METHODOLOGY

Since the drivers who were not crash-involved during 1991-1994 represent a one-fiftieth sample of all non-involved drivers, they were given a weight of 50 to give an estimated population of 3,127,316 driver licence records. This total does not add to the total population of drivers used in the univariate analysis in Chapter 3 because of the exclusion of some drivers in the multivariate modelling due to the criteria given in section 4.2. For each of the following prediction models (derived by multivariate analysis in Chapter 4), the 3,127,316 drivers were sorted according to their predicted probability of being crash-involved during 1993-1994:

- i. Base Model (Model 1)
- ii. Category of Offence Model (Model 3)
- iii. Demerit Point Level of Offence Model (Model 4)
- iv. Demerit Point Level of Offence Model without Prior Crashes/Serious Injuries (Model 6)

The drivers with the largest predicted probabilities are the “highest scoring” drivers or those with the highest “accident potential”.

Method 1:

For each of the four models, the highest scoring drivers (highest “accident” potential) were defined by thresholds representing the top 1%, the next 2%, the next 3%, the next 4%, the next 10% and the next 30% in the data file of drivers. Together these thresholds cover the top 50% of drivers with the highest accident potential according to each model. The proportion of drivers who were crash-involved during 1993-1994 and who also exceeded each threshold were compared with the proportion of all drivers in the estimated population who were crash-involved during 1993-1994. The ratio of the proportion of crash-involved drivers exceeding the threshold to the proportion of all crash-involved drivers represents an estimate of the *relative risk* of crash-involvement, as follows:

$$\text{Relative Risk} = \frac{\text{(proportion of crash-involved drivers during 1993-1994 exceeding threshold)}}{\text{(proportion of all crash involved drivers during 1993-1994)}}$$

This method therefore measures efficiency in terms of the crash-involvement rate of drivers within each threshold to the rate for all crash-involved drivers during 1993-1994.

Method 2:

For each of the four models, the top 500, the top 1,000, the top 3,000, the top 6,000, the top 10,000, the top 20,000 and the top 100,000 drivers were examined according to their accident involvements. For each of these groups of “top” drivers, efficiency was measured in terms of

- the proportion of “correct positives” (drivers with high scores who were subsequently involved in crashes), and
- the proportion of “false positives” (drivers with high scores who were not subsequently crash-involved).

Efficiency was also measured by the proportion of drivers scoring below the 50% threshold (as defined above for Method 1) who were subsequently involved in crashes (“false negatives”).

Method 2, therefore, correctly (or incorrectly) classifies drivers according to their subsequent crash involvement.

5.2 RELATIVE RISK RESULTS

5.2.1 Base Model (Model 1)

The model used to predict a driver’s casualty crash-involvement during 1993-1994 given knowledge of his or her age, sex, licence endorsement, residential location, and casualty crash and serious injury involvements during 1991-1992 produced the relative risk estimates given in Table 5.1 for the drivers in each threshold. The corresponding actual risks (%) of casualty crash involvement are also given in Table 5.1.

Table 5.1: Actual Risk and Relative Risk of Crash-Involvement of the Top 50% of drivers predicted from the Base Model

| 1993-1994 crash involvement | Thresholds* representing the highest scoring drivers | | | | | | |
|-----------------------------------|--|-------------|-------------|-------------|-------------|-------------|-----------|
| | top 1% | next 2% | next 3% | next 4% | next 10% | next 30% | total |
| yes | 945 | 1,053 | 1,331 | 1,750 | 3,699 | 7,820 | 23,650 |
| no | 38,111 | 56,270 | 85,949 | 130,843 | 328,703 | 1,030,554 | 3,103,666 |
| total | 39,056 | 57,323 | 87,280 | 132,593 | 332,402 | 1,038,374 | 3,127,316 |
| Risk of crash- involvement | 2.42% | 1.84% | 1.52% | 1.32% | 1.11% | 0.75% | 0.76% |
| Relative Risk | 3.20 | 2.43 | 2.02 | 1.75 | 1.47 | 1.00 | 1 |

* Because of the presence of tied observations at a particular threshold, these “top” percentages are approximately equal to the appropriate level.

The highest scoring 1% of drivers had a risk of crash-involvement during 1993-1994 of 3.2 relative to all crash-involved drivers in the estimated licence population. Hence, even without any offence or demerit points data in the predicted model, the relative risk of crash-involvement of the highest scoring 1% of drivers was over three times that of all drivers. For the same model, the next 2% of highest scoring drivers had a relative risk of 2.43 of 1993-1994 crash-involvement relative to all licensed drivers. The relative risk remained above unity for the 20% of drivers with the highest accident potential.

5.2.2 Category of Offence Model (Model 3)

Adding the driver's prior offences in seven categories to the base model produced one of the best models used to predict a driver's subsequent crash-involvement. The relative risks and actual risks of crash-involvement estimated from the "category of offence" model are presented in Table 5.2 for the highest scoring 50% of drivers.

Each group in the highest scoring 50% of drivers had a relative risk above unity, with the highest scoring 1% drivers, having a risk of crash-involvement during 1993-1994 almost 4.4 times that of all the crashed drivers in the database. Further, each group of "top" drivers (as estimated by the "category of offence" model) had a greater relative risk than the corresponding high risk group as predicted from the Base model.

Table 5.2: Actual Risk and Relative Risk of Crash-Involvement of the Top 50% of drivers predicted from the "Category of Offence" Model

| 1993-1994 crash involvement | Thresholds* representing the highest scoring drivers | | | | | | |
|-----------------------------------|--|-------------|-------------|-------------|-------------|-------------|-----------|
| | top 1% | next 2% | next 3% | next 4% | next 10% | next 30% | total |
| yes | 1,044 | 1,265 | 1,595 | 1,662 | 3,581 | 7,280 | 23,650 |
| no | 30,373 | 60,137 | 98,144 | 122,355 | 316,272 | 924,359 | 3,103,666 |
| total | 31,417 | 61,402 | 99,739 | 124,017 | 319,853 | 931,639 | 3,127,316 |
| Risk of crash- involvement | 3.32% | 2.06% | 1.60% | 1.34% | 1.12% | 0.78% | 0.76% |
| Relative Risk | 4.39 | 2.72 | 2.11 | 1.77 | 1.48 | 1.03 | 1 |

* Because of the presence of tied observations at a particular threshold, these "top" percentages are approximately equal to the appropriate level.

5.2.3 Demerit Point Level of Offence Model (Model 4)

Adding the offence data to the base model in "demerit point level" categories rather than categories of offences produced similar relative risk estimates of casualty crash-involvement (Table 5.3). The top 1% of drivers with the highest accident potential (as estimated by the "demerit point level of offence" model), had a relative risk of crash-involvement in 1993-1994 of 4.37, as compared to all drivers in the database. The "category of offence" model produced a similar relative risk of 4.39 for this group of drivers.

Table 5.3: Actual Risk and Relative Risk of Crash-Involvement of the Top 50% of drivers predicted from the “Demerit Point Level of Offence” Model

| 1993-1994 crash involvement | Thresholds* representing the highest scoring drivers | | | | | | |
|-----------------------------------|--|-------------|-------------|-------------|-------------|-------------|-----------|
| | top 1% | next 2% | next 3% | next 4% | next 10% | next 30% | total |
| yes | 1,036 | 1,305 | 1,486 | 1,807 | 3,470 | 7,293 | 23,650 |
| no | 30,323 | 61,204 | 94,521 | 130,524 | 304,010 | 927,445 | 3,103,666 |
| total | 31,359 | 62,509 | 96,007 | 132,331 | 307,480 | 934,738 | 3,127,316 |
| Risk of crash- involvement | 3.30% | 2.09% | 1.55% | 1.37% | 1.13% | 0.78% | 0.76% |
| Relative Risk | 4.37 | 2.76 | 2.05 | 1.81 | 1.49 | 1.03 | 1 |

* Because of the presence of tied observations at a particular threshold, these “top” percentages are approximately equal to the appropriate level.

5.2.4 Demerit Point Level of Offence Model without Prior Crashes (Model 6)

Table 5.4 gives the relative risk and actual risk of crash-involvement of the drivers with the highest accident potential as estimated by the “demerit point level of offence” model but with the exclusion of the driver’s prior casualty crash and serious injury involvements. Comparing this table with Table 5.3, it can be seen that apart from the highest scoring 1% of drivers, there was little difference between the relative risk estimates at each threshold in the top 50% of drivers. The highest scoring 1% of drivers had a somewhat smaller relative risk of 1993-1994 crash-involvement as estimated by Model 6 (ie. 4.20) than the corresponding relative risks predicted from the “demerit point level of offence” model (ie. 4.37) or the “category of offence” model (ie. 4.39).

Table 5.4: Actual Risk and Relative Risk of Crash-Involvement of the Top 50% of drivers predicted from the “Demerit Point Level of Offence without Prior Crashes” Model

| 1993-1994 crash involvement | Thresholds* representing the highest scoring drivers | | | | | | |
|-----------------------------------|--|-------------|-------------|-------------|-------------|-------------|-----------|
| | top 1% | next 2% | next 3% | next 4% | next 10% | next 30% | total |
| yes | 998 | 1,351 | 1,365 | 1,754 | 3,480 | 7,394 | 23,650 |
| no | 30,402 | 62,801 | 87,751 | 127,144 | 302,033 | 932,887 | 3,103,666 |
| total | 31,400 | 64,152 | 89,116 | 128,898 | 305,513 | 940,281 | 3,127,316 |
| Risk of crash- involvement | 3.18% | 2.11% | 1.53% | 1.36% | 1.14% | 0.79% | 0.76% |
| Relative Risk | 4.20 | 2.78 | 2.03 | 1.80 | 1.51 | 1.04 | 1 |

* Because of the presence of tied observations at a particular threshold, these “top” percentages are approximately equal to the appropriate level.

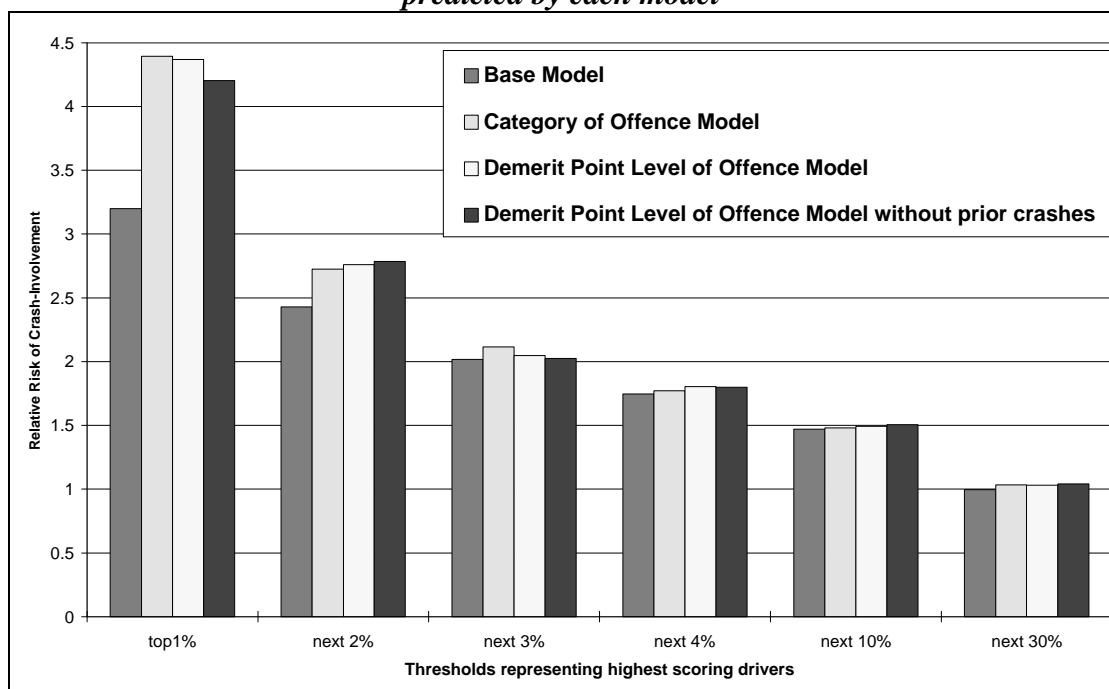
5.2.5 Comparison of Models

For each group of drivers in the top 50%, comparison between the four estimated models (ie. base model, category of offence model, demerit point level of offence model, and demerit point level of offence model without prior crashes) of the relative

risk of being crash-involved during 1993-1994 was made. Figure 5.1 depicts this comparison.

The relative risk of 1993-1994 crash involvement of the highest scoring 1% of drivers relative to all drivers in the database was greatest (and very similar) for the “category of offence” and “demerit point level of offence” models. These two models were considerably more efficient in predicting future crash-involvement than the base model for the top group of drivers with the highest accident potential. This was also true for the drivers in the next group of top percentages, however the differences in relative risk between the models diminished with decreasing accident potential of the drivers.

Figure 5.1: Relative Risk of Crash-Involvement of top 50% of drivers as predicted by each model



5.3 PROPORTION OF CORRECT POSITIVES

5.3.1 Base Model (Model 1)

For the base model of drivers, the proportion of drivers who were subsequently involved in crashes and those who were not subsequently involved in crashes during 1993-1994 in each threshold amongst the top 100,000 high risk drivers are given in Table 5.5.

Amongst the 500 highest scoring drivers, 7.28% were subsequently involved in crashes during 1993-1994. The corresponding crash-involvement proportion for all drivers in the database was 0.76%. Thus the proportion of correct positives amongst the 500 highest scoring drivers as estimated by the base model had almost a ten-fold improvement on all crashed drivers.

Table 5.5: Proportion of Correct Positives and False Positives Amongst Top 100,000 High Risk Drivers as Estimated from the Base Model

| Drivers in | Top 500 (536)* | Top 1,000 (1,014) | Top 3,000 (3,182) | Top 6,000 (5,870) | Top 10,000 (11,251) | Top 20,000 (21,167) | Top 100,000 (105,165) |
|-----------------------------------|-------------------|----------------------|----------------------|----------------------|------------------------|------------------------|--------------------------|
| Drivers with crashes in 1993-1994 | 39 | 57 | 115 | 187 | 340 | 599 | 2,134 |
| Correct Positives | 7.28% | 5.62% | 3.61% | 3.19% | 3.02% | 2.83% | 2.03% |
| False Positives | 92.72% | 94.38% | 96.39% | 96.81% | 96.98% | 97.17% | 97.97% |

* Because of the presence of ties, the figures in brackets refer to the actual number of drivers closest to each top threshold.

Efficiency was also measured in terms of the proportion of drivers scoring below the 50% threshold who were subsequently involved in crashes or “false negatives”. For the base model of drivers, this proportion of “false negatives” was 0.4896%. Thus fewer than 0.5% of drivers who scored below the 50% threshold were subsequently crash-involved, indicating a relatively small proportion of false negatives.

5.3.2 Category of Offence Model (Model 3)

Table 5.6 gives the proportion of correct positives and the proportion of false positives amongst the top 100,000 drivers with high accident scores as estimated by the “category of offence” model. For each group of top drivers the proportion of correct positives as estimated by the “category of offence” model was greater than the corresponding proportion as estimated by the base model. For instance, amongst the 500 highest scoring drivers, the proportion who were subsequently involved in 1993-1994 crashes was 12.4%. This is 16 times the proportion of all crash-involved drivers in the database.

For the “category of offence” model of drivers, the proportion of “false negatives” or the proportion of drivers scoring below the 50% threshold was 0.4632%. This proportion is somewhat smaller than the base model proportion, therefore this model identifies fewer false negatives than the base model.

Table 5.6: Proportion of Correct Positives and False Positives Amongst High Risk Drivers as Estimated from the Category of Offence Model

| Drivers in | Top 500 (500)* | Top 1,000 (1,023) | Top 3,000 (3,045) | Top 6,000 (6,000) | Top 10,000 (10,025) | Top 20,000 (20,208) | Top 100,000 (100,886) |
|-----------------------------------|-------------------|----------------------|----------------------|----------------------|------------------------|------------------------|--------------------------|
| Drivers with crashes in 1993-1994 | 62 | 105 | 188 | 301 | 457 | 753 | 2,449 |
| Correct Positives | 12.40% | 10.26% | 6.17% | 5.02% | 4.56% | 3.73% | 2.43% |
| False Positives | 87.60% | 89.74% | 93.83% | 94.98% | 95.44% | 96.27% | 97.57% |

* Because of the presence of ties, the figures in brackets refer to the actual number of drivers closest to each top threshold.

5.3.3 Demerit Point Level of Offence Model (Model 4)

The proportion of correct positives and the proportion of false positives amongst the top 100,000 drivers with the highest scores as predicted from the “demerit point level of offence” model are given in Table 5.7. The proportions amongst each group of high risk drivers are similar to the corresponding proportions as estimated by the “category of offence” model in Table 5.6. For both the “demerit point level of offence” and “category of offence” models, the proportion of drivers amongst the 500 highest scoring drivers who were crash-involved during 1993-1994 was the same at 12.4%. Amongst the 1,000 highest scoring drivers the “demerit point level of offence” model identified a greater proportion of crash-involved drivers (ie. 11.6%) than the “category of offence” model (ie. 10.3%). This was also true amongst the 3,000 highest scoring drivers.

Table 5.7: Proportion of Correct Positives and False Positives Amongst High Risk Drivers as Estimated from the Demerit Point Level of Offence Model

| Drivers in | Top 500 (501)* | Top 1,000 (1,000) | Top 3,000 (3,025) | Top 6,000 (6,014) | Top 10,000 (10,088) | Top 20,000 (20,091) | Top 100,000 (102,317) |
|--------------------------------------|----------------------|-------------------------|-------------------------|-------------------------|---------------------------|---------------------------|-----------------------------|
| Drivers with crashes in 1993-1994 | 62 | 116 | 196 | 285 | 446 | 762 | 2485 |
| Correct Positives | 12.38% | 11.60% | 6.48% | 4.74% | 4.42% | 3.79% | 2.43% |
| False Positives | 87.62% | 88.40% | 93.52% | 95.26% | 95.58% | 96.21% | 97.57% |

* Because of the presence of ties, the figures in brackets refer to the actual number of drivers closest to each top threshold.

For the “demerit point level of offence” model of drivers, the proportion of “false negatives” was *0.4641%*. This proportion was again smaller than the corresponding base model proportion, therefore the “demerit point level of offence” model identifies fewer false negatives than the base model, but it was almost identical to the corresponding proportion estimated from the “category of offence” model. Hence in terms of identifying high risk drivers subsequently involved in crashes, a driver’s offence data adds to a model’s prediction, however whether this offence data is categorised into demerit point levels of offences or categories of offences does not alter the efficiency of the model.

5.3.4 Demerit Point Level of Offence Model without Prior Crashes (Model 6)

Table 5.8 gives the proportion of drivers with high scores who were subsequently involved in casualty crashes during 1993-1994 and the proportion who were not crash-involved, as estimated from the “demerit point level of offence” model but with the exclusion of the driver’s prior crash and serious injury involvements. For each group of drivers in the top 100,000, this model was less efficient in identifying high risk drivers than the “demerit point level of offence” model. However the differences became less marked with an increasing number of drivers considered under each threshold. For instance, amongst the 500 highest scoring drivers the proportion of correct positives was 10.9% (the “demerit point level of offence” model estimated this proportion as 12.4%). But amongst the 20,000 highest scoring drivers there was little

difference between these two models in identifying crash-involved drivers (ie. the proportions of correct positives were respectively 3.79% and 3.66% for Model 4 and Model 6).

Table 5.8: Proportion of Correct Positives and False Positives Amongst High Risk Drivers as Estimated from the Demerit Point Level of Offence Model without Prior Crashes

| Drivers in | Top 500 (506)* | Top 1,000 (1,019) | Top 3,000 (3,016) | Top 6,000 (6,014) | Top 10,000 (10,043) | Top 20,000 (20,091) | Top 100,000 (100,069) |
|--------------------------------------|----------------------|-------------------------|-------------------------|-------------------------|---------------------------|---------------------------|-----------------------------|
| Drivers with crashes in 1993-1994 | 55 | 86 | 166 | 255 | 437 | 736 | 2,437 |
| Correct Positives | 10.87% | 8.44% | 5.50% | 4.24% | 4.35% | 3.66% | 2.44% |
| False Positives | 89.13% | 91.56% | 94.50% | 95.76% | 95.65% | 96.34% | 97.56% |

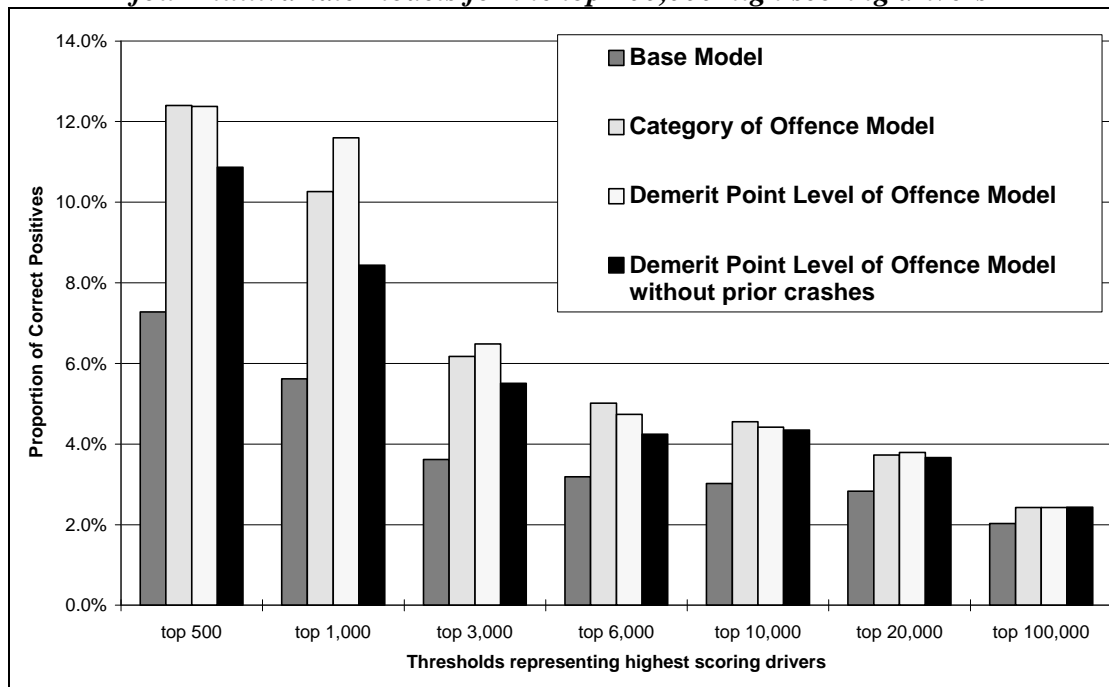
* Because of the presence of ties, the figures in brackets refer to the actual number of drivers closest to each top threshold.

For the “demerit point level of offence without prior crashes/serious injuries” model of drivers, this proportion of “false negatives” was 0.4661%. This proportion was somewhat smaller than the base model proportion, therefore this model identifies fewer false negatives than the base model, but was slightly larger than either the proportions estimated by the “category of offence” or “demerit point level of offence” models.

5.3.5 Comparison of Models

Figure 5.2 compares the proportion of correct positives as estimated from each of the four models for the 100,000 highest scoring drivers. For each group of top drivers, the base model was the least efficient in identifying drivers subsequently involved in crashes. Amongst the 500 highest scoring drivers, the “category of offence” and “demerit point level of offence” models were equally efficient in identifying the crash-involved drivers. But for the 1,000 and 3,000 highest scoring drivers the “demerit point level of offence” model was more efficient than the “category of offence” model.

Figure 5.2: Comparison of Proportions of Correct Positives as estimated by the four multivariate models for the top 100,000 high scoring drivers



5.4 CHARACTERISTICS OF TOP 501 DRIVERS

The characteristics of the top 501³ drivers with the largest probabilities of being crash-involved during 1993-1994 as predicted by the “demerit point level of offence” model are presented in this section. As shown in Table 5.7, 62 (or 12.4%) of these high scoring drivers were subsequently involved in at least one casualty crash during 1993-1994.

5.4.1 Age of Driver

The age distribution of the top 501 drivers is given in Table 5.9. The majority of the drivers (78%) were young drivers aged 20-25 years. On the other hand, there were no older drivers aged 60 years and above amongst the top 501 drivers.

³ Because of the presence of ties, the number of drivers closest to the top 500 scoring drivers was 501 for the “demerit point level of offence” model.

Table 5.9: Age Distribution of the Top 501 Drivers

| Age-Group | No. of Drivers | Percentage of Drivers | Cumulative Percentage |
|------------------|-----------------------|------------------------------|------------------------------|
| 20-21 | 185 | 36.9 | 36.9 |
| 22-25 | 208 | 41.5 | 78.4 |
| 26-29 | 33 | 6.6 | 85.0 |
| 30-39 | 18 | 3.6 | 88.6 |
| 40-49 | 55 | 11.0 | 99.6 |
| 50-59 | 2 | 0.4 | 100 |
| Total | 501 | 100 | |

5.4.2 Sex of Driver

Males were over-represented amongst the top 501 high scoring drivers. Eighty-seven percent (or 435) of the top 501 drivers were males. This gender trend corresponds with that found in the univariate and multivariate analyses.

5.4.3 Residential Location of Driver

Over 94% of the top 501 drivers were residents of Melbourne. The majority of the remaining drivers were from rural regions of Victoria (Table 5.10). These findings correspond with those found in the univariate and multivariate analyses.

Table 5.10: Residential Location of the Top 501 Drivers

| Location | No. of Drivers | Percentage of Drivers |
|-----------------|-----------------------|------------------------------|
| Melbourne | 472 | 94.2 |
| Rural Victoria | 28 | 5.6 |
| Non-Victoria | 1 | 0.2 |
| Total | 501 | 100 |

5.4.4 Licence Endorsement

Approximately two-thirds of the top 501 drivers had a car licence. However, a sizeable proportion (29%) were endorsed to drive some type of truck (Table 5.11).

Table 5.11: Licence Endorsement of the Top 501 Drivers

| Licence Type | No. of Drivers | Percentage of Drivers |
|---------------------|-----------------------|------------------------------|
| Car | 338 | 67.5 |
| Truck | 143 | 28.5 |
| Motorcycle | 20 | 4.0 |
| Total | 501 | 100 |

5.4.5 Crash and Serious Injury Involvements during 1991-1992

A considerable number of the top 501 scoring drivers (187 drivers or 37%) were involved in at least one casualty crash during 1991-1992. Furthermore, 13% of these drivers were seriously injured in a crash during the same time period.

5.4.6 Convictions during 1991-1992

Table 5.12 gives the number of licence convictions incurred during 1991-1992 by the top 501 scoring drivers. Fourteen percent of the drivers had incurred at least one conviction during 1991-1992.

Table 5.12: Convictions incurred by the Top 501 Drivers during 1991-1992

| No. of convictions | No. of Drivers | Percentage of Drivers |
|--------------------|----------------|-----------------------|
| 0 | 431 | 86.0 |
| 1 | 30 | 6.0 |
| 2 | 31 | 6.2 |
| 3 | 5 | 1.0 |
| 4 | 3 | 0.6 |
| 5 | 1 | 0.2 |
| Total | 501 | 100 |

5.4.7 Offences accrued during 1991-1992

Total Offences

Table 5.13 gives the total number of offences accrued by the top 501 scoring drivers during 1991-1992. Almost all the top 501 drivers had incurred at least two offences during 1991-1992. Furthermore, nearly one-quarter of the drivers had accrued 10 offences during 1991-1992, and almost 50% of the top 501 drivers had at least 10 offences for the same period.

Table 5.13: Total Offences accrued by the Top 501 Drivers during 1991-1992

| No. of offences in 1991-1992 | No. of drivers | Percentage of Drivers |
|------------------------------|----------------|-----------------------|
| 0 | 1 | 0.2 |
| 2 | 4 | 0.8 |
| 3 | 7 | 1.4 |
| 4 | 24 | 4.8 |
| 5 | 19 | 3.8 |
| 6 | 39 | 7.8 |
| 7 | 64 | 12.8 |
| 8 | 32 | 6.4 |
| 9 | 62 | 12.4 |
| 10 | 123 | 24.6 |
| 11 | 4 | 0.8 |
| 12 | 55 | 11.0 |
| 13 | 3 | 0.6 |
| 14 | 55 | 11.0 |
| 16 | 2 | 0.4 |
| 17 | 1 | 0.2 |
| 18 | 2 | 0.4 |
| 20 | 2 | 0.4 |
| 22 | 1 | 0.2 |
| 28 | 1 | 0.2 |
| Total | 501 | 100 |

Category of Offences

The appendix gives the number of offences in each category (section 3.3.1 gives the definitions) incurred by the top 501 drivers during 1991-1992. The main findings included:

- 36% of the top 501 drivers had incurred exactly *six* offences in which the speed limit was exceeded by under 30 km/h during 1991-1992, and a further 17% had incurred *more than six* of these offence types;
- 35% of the top 501 drivers had incurred *at least one* offence in which the speed limit was exceeded by at least 30 km/h during 1991-1992;
- less than 3% of the top 501 drivers had incurred *at least one stop/give way* offence during 1991-1992;
- 40% of the top 501 drivers had incurred *at least one unsafe action* offence during 1991-1992;
- 16% of the top 501 drivers had incurred *at least one headlight/defect notice* offence during 1991-1992;
- 45% of the top 501 drivers/riders had incurred *at least one restraint/helmet* offence during 1991-1992;
- 65% of the top 501 drivers had incurred *at least one signal offence* during 1991-1992.

Total Demerit Points

Table 5.14 gives the total number of demerit points accrued by the top 501 drivers during 1991-1992. Almost all the high scoring drivers had incurred at least four demerit points. Furthermore, 81% of the drivers had incurred at least 17 demerit points during 1991-1992.

Table 5.14: Total Demerit Points incurred by the Top 501 Drivers during 1991-1992

| No. of Demerit Points in 1991-1992 | No. of Drivers | Percentage of Drivers |
|------------------------------------|----------------|-----------------------|
| 0 | 1 | 0.2 |
| 4 | 2 | 0.4 |
| 6 | 4 | 0.8 |
| 7 | 2 | 0.4 |
| 8 | 7 | 1.4 |
| 9 | 5 | 1.0 |
| 10 | 5 | 1.0 |
| 11 | 2 | 0.4 |
| 12 | 18 | 3.6 |
| 13 | 8 | 1.6 |
| 14 | 14 | 2.8 |
| 15 | 10 | 2.0 |
| 16 | 15 | 3.0 |
| 17 | 7 | 1.4 |
| 18 | 61 | 12.2 |
| 19 | 4 | 0.8 |
| 20 | 17 | 3.4 |
| 21 | 6 | 1.2 |
| 22 | 59 | 11.8 |
| 23 | 3 | 0.6 |
| 24 | 7 | 1.4 |
| 25 | 52 | 10.4 |
| 26 | 55 | 11.0 |
| 27 | 53 | 10.6 |
| 28 | 6 | 1.2 |
| 29 | 1 | 0.2 |
| 30 | 8 | 1.6 |
| 31 | 1 | 0.2 |
| 32 | 53 | 10.6 |
| 33 | 1 | 0.2 |
| 36 | 2 | 0.4 |
| 37 | 1 | 0.2 |
| 38 | 2 | 0.4 |
| 40 | 1 | 0.2 |
| 42 | 1 | 0.2 |
| 46 | 1 | 0.2 |
| 50 | 2 | 0.4 |
| 51 | 1 | 0.2 |
| 63 | 1 | 0.2 |
| 64 | 2 | 0.4 |
| Total | 501 | 100 |

Demerit Point Levels of Offences

The number of offences categorised into demerit point levels of offences incurred by the top 501 drivers are given in the appendix. The main findings included:

- 85% of the top 501 drivers had accrued *at least one* offence in which *one demerit point* was incurred during 1991-1992 (eg. driving at night without headlights on; exceeding speed limit by 15 km/h or less; following too closely);
- 28% of the top 501 drivers had accrued *at least one* offence in which *two demerit points* were incurred during 1991-1992 (eg. improper overtaking; turning without signalling; turning improperly);
- 21% of the top 501 drivers had accrued exactly *four* offences in which *three demerit points* were incurred during 1991-1992 (eg. exceeding speed limit by more than 15 km/h but less than 30 km/h; disobeying traffic control signal; failing to give way), and a further 57% had accrued *more than four* of these offence types;
- 44% of the top 501 drivers had accrued *at least one* offence in which *four demerit points* were incurred during 1991-1992 (eg. exceeding the speed limit by at least 30 km/h but less than 45 km/h);
- 2% of the top 501 drivers had accrued *at least one* offence in which *six demerit points* were incurred during 1991-1992 (eg. exceeding the speed limit by 45 km/h or more).

6. SUMMARY

The Victorian Parliamentary Road Safety Committee recommended that an analysis be undertaken of the VicRoads driver and accident databases to determine the relationship between driver accident involvement, demerit points accrual and other relevant factors as a means of identifying groups that have a significantly higher than average accident potential. The Monash University Accident Research Centre (MUARC) was contracted by VicRoads to determine both the nature and strength of the relationship between prior offence history and subsequent road accident involvement of drivers in Victoria.

While the focus of the Parliamentary Committee's recommendation was on the relationship between demerit points and subsequent crashes, the study considered all available potential predictor variables such as the full range of offence information available, prior crash involvements, and driver characteristics such as age, sex, residential postcode and licence type.

The main objective of the study was to consider whether a driver's prior demerit points data (or their offence data used in other ways) could be used (in combination with other variables) to improve the prediction of the driver's subsequent crashes. To achieve this aim, multivariate statistical models were developed to represent drivers' crash involvements during 1993-1994 as a function of potential predictor variables measured during 1991-1992.

Prior to developing the multivariate models, a preliminary univariate examination of each potential predictor variable, in comparison with the subsequent accident involvements was undertaken.

6.1 MAIN FINDINGS OF UNIVARIATE ANALYSIS

It was estimated that 0.8% of drivers were involved in at least one casualty crash during 1993-1994.

The driver groups with the highest casualty crash-involvement rates in 1993-1994 were:

- males (0.89% crash-involvement rate);
- young drivers aged 18-25 (1.48%);
- Melbourne residents (0.84%);
- inexperienced drivers (0.9% for probationary and 3.58% for learner drivers, however, because of sampling problems with the data, these rates should be treated with caution);
- drivers endorsed to drive a multi-combination vehicle (1.73%) or a heavy combination vehicle (1.2%);
- drivers with traffic convictions during 1991-1992;

- drivers involved in at least one casualty crash during 1991-1992;
- drivers who were seriously injured in a casualty crash during 1991-1992.

In addition the proportion of drivers involved in at least one casualty crash during 1993-1994 generally increased with increasing number of offences or increasing number of demerit points accrued during 1991-1992.

6.2 MAIN FINDINGS OF MULTIVARIATE ANALYSIS

The initial multivariate model fitted was the *base* model (Model 1). This model included all available driver and licence variables (driver age, driver sex, driver location and endorsement of licence) as well as the driver's reported casualty crash and serious injury involvements, and total traffic convictions during 1991-1992.

To this model the driver's prior offence data (in various forms) was added with the aim of finding a model which best predicted the driver's crash involvements during 1993-1994. Addition of the offence data resulted in the estimation of the following four models:

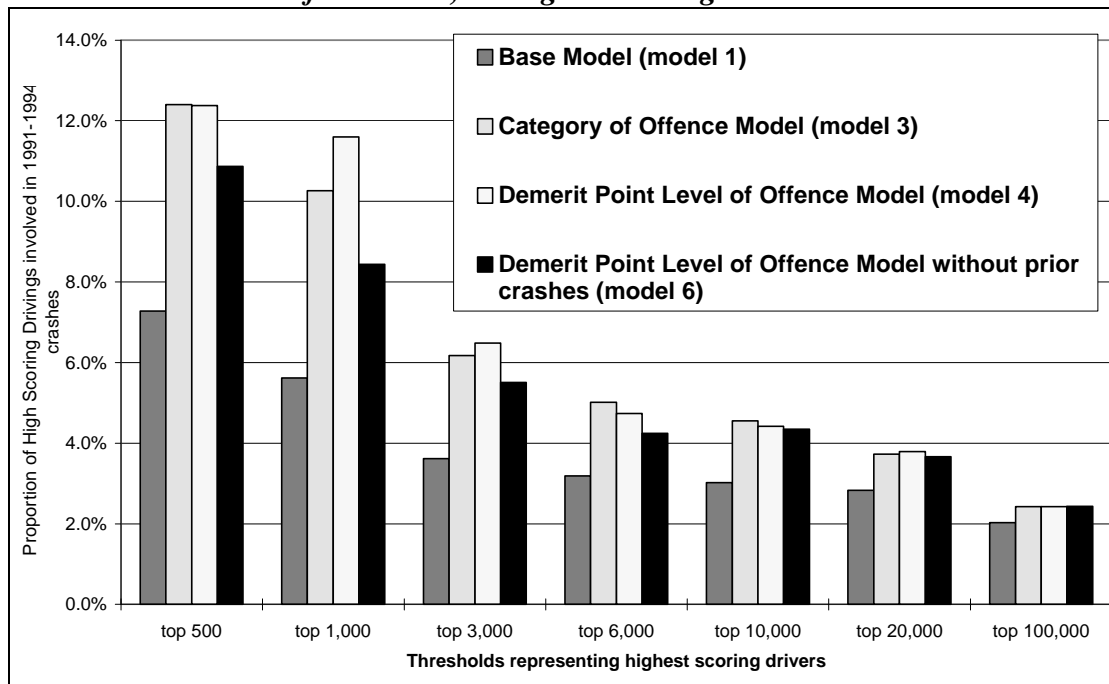
- *Model 2*: base model + total number of offences during 1991-1992;
- *Model 3*: base model + number of offences during 1991-1992 by category of offence;
- *Model 4*: base model + number of offences during 1991-1992 by demerit point level of offence;
- *Model 5*: base model + total number of demerit points incurred during 1991-1992.

The above four models were all superior to the base model with high statistical significance ($p < 0.0001$). Hence, addition of a driver's prior offence data (in some form) adds to the ability of a model in predicting subsequent casualty crash-involvements.

The two models which included offence categories that reflected their relative importance in predicting drivers' crash involvements during 1993-1994 (ie. Model 3, the "category of offence" model, and Model 4, the "demerit point level of offence" model) were the best fitting of the five models. Both these models were significantly superior to both the "total offences" and "total demerit points" models ($p < 0.0004$). Figure 6.1 compares the efficiency of these models in predicting subsequent casualty crash-involvements.

In addition to the above models, another model was fitted to the data in which the driver's prior casualty crash and serious injury involvements were omitted. This was found to be a less informative model in terms of predicting subsequent crash-involvements. This model is also shown in Figure 6.1. Thus, although delays occur in obtaining crash data for each driver in Victoria, the ability of the models to predict subsequent crash involvements would be enhanced if such data could be included.

Figure 6.1: Comparison of Proportions of Drivers with highest accident potential with subsequent crash-involvements as estimated by the four multivariate models for the 100,000 highest scoring drivers



For the best fitting model (ie. Model 4, the “demerit point level of offence” model), the groups with the highest estimated probability of being represented in 1993-1994 crashes were:

- young drivers;
- male drivers;
- drivers endorsed with a truck licence;
- Melbourne residents;
- drivers with casualty crash and serious injury involvements during 1991-1992;
- drivers who had incurred licence convictions during 1991-1992;
- drivers with ‘four demerit points’, ‘three demerit points’, ‘one demerit point’, ‘six demerit points’, and/or ‘two demerit points’ offences (in that order) during 1991-1992.

These findings generally coincide with those found in the univariate analysis.

6.3 EFFICIENCY OF THE MULTIVARIATE MODELS

The efficiency of the models was measured in terms of their ability to identify the drivers with the highest “accident potential”. Each model’s efficiency was compared by estimating the *relative risk* of casualty crash-involvement of the highest scoring drivers to that of all drivers in the database, and by estimating the proportion of “*correct positives*” (ie. drivers with high scores who were subsequently involved in crashes).

The risk of 1993-1994 crash involvement of the highest scoring 1% of drivers relative to all drivers in the database was greatest (and very similar) for the “category of offence” and “demerit point level of offence” models. For both these models, the highest scoring 1% of drivers had an estimated risk of crash-involvement 4.4 times that of all crashed drivers. These two models were considerably more efficient in predicting future crash-involvement than the base model, for which the corresponding relative risk estimate was 3.2. This was also true for the drivers in the next 2% ranked in order of crash potential, however the differences in relative risk between the models diminished with decreasing accident potential of the drivers.

As estimated by the base model, amongst the 500 highest scoring drivers (approximately 0.02% of the estimated driver population), 7.3% were subsequently involved in crashes during 1993-1994. The corresponding crash-involvement proportion for all drivers in the database was 0.76%. Thus even without any offence data in the predicted model, the proportion of correct positives amongst the 500 highest scoring drivers had almost a ten-fold improvement on all crashed drivers. However, for the top scoring drivers, the base model was less efficient in identifying drivers subsequently involved in crashes than the models containing prior offences in some form. Amongst the top 500 drivers, the “category of offence” and “demerit point level of offence” models were equally efficient in identifying the crash-involved drivers. For both these models, the proportion of drivers amongst the top 500 who were subsequently involved in 1993-1994 crashes was 12.4%, ie. considerably greater than the 7.3% crash-involvement rate for the top 500 drivers identified by the base model which did not use prior offence data. For the top 1,000 and top 3,000 drivers the “demerit point level of offence” model was more efficient than the “category of offence” model in being able to identify somewhat more crash-involved drivers.

Hence in terms of identifying high risk drivers subsequently involved in crashes, a driver’s offence data adds to a model’s efficiency, but whether this offence data is categorised into demerit point levels of offences or categories of offences does not alter the efficiency of the model substantially.

It should be noted, however, that there is considerable scope for further improvements in the models’ efficiencies, because of the presence of a relatively large proportion of “false positives” (ie. drivers with high scores who were not involved in crashes during the subsequent two years). Amongst the top 500 drivers, the proportion of “false positives” was 87.6% for both the “demerit point level of offence” and “category of offence” models.

7. CONCLUSION

This research on the relationship between demerit points accrual and subsequent crash-involvement has shown that inclusion of a driver's prior offences (whether as demerit point levels or categories of offence) in a multivariate model adds to the predictive ability of that model in identifying drivers with subsequent crash-involvements. The more efficient model uses a driver's prior offences classified into demerit point levels. Demerit points alone can be used to predict a driver's subsequent crash involvement, but an even better model can be produced by including prior casualty crash involvements as well.

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APPENDIX

OFFENCES INCURRED BY THE 501 HIGHEST SCORING DRIVERS BY:

- 1. DEMERIT POINT LEVEL OF OFFENCE**
- 2. CATEGORY OF OFFENCE**

**OFFENCES INCURRED BY THE 501 HIGHEST SCORING
DRIVERS BY DEMERIT POINT LEVEL OF OFFENCE**

| OFFENCES IN WHICH ONE DEMERIT POINT WAS INCURRED | | |
|---|-------------------------|-----------------------------|
| No. of ONE Demerit Point Offences | Number of Drivers | Percentage of Drivers |
| 0 | 76 | 15.2 |
| 1 | 73 | 14.6 |
| 2 | 197 | 39.3 |
| 3 | 64 | 12.8 |
| 4 | 22 | 4.4 |
| 5 | 2 | 0.4 |
| 6 | 60 | 12.0 |
| 7 | 1 | 0.2 |
| 8 | 3 | 0.6 |
| 10 | 2 | 0.4 |
| 12 | 1 | 0.2 |
| Total | 501 | 100 |

| OFFENCES IN WHICH TWO DEMERIT POINTS WERE INCURRED | | |
|---|-------------------------|-----------------------------|
| No. of TWO Demerit Points Offences | Number of Drivers | Percentage of Drivers |
| 0 | 362 | 72.3 |
| 1 | 21 | 4.2 |
| 2 | 64 | 12.8 |
| 4 | 4 | 0.8 |
| 5 | 50 | 10.0 |
| Total | 501 | 100 |

| OFFENCES IN WHICH THREE DEMERIT POINTS WERE INCURRED | | |
|---|-------------------------|-----------------------------|
| No. of THREE Demerit Points Offences | Number of Drivers | Percentage of Drivers |
| 0 | 12 | 2.4 |
| 1 | 4 | 0.8 |
| 2 | 25 | 5.0 |
| 3 | 72 | 14.4 |
| 4 | 103 | 20.6 |
| 5 | 59 | 11.8 |
| 6 | 37 | 7.4 |
| 7 | 60 | 12.0 |
| 8 | 62 | 12.4 |
| 9 | 54 | 10.8 |
| 10 | 5 | 1.0 |
| 11 | 1 | 0.2 |
| 12 | 3 | 0.6 |
| 13 | 2 | 0.4 |
| 16 | 1 | 0.2 |
| 18 | 1 | 0.2 |
| Total | 501 | 100 |

| OFFENCES IN WHICH FOUR DEMERIT POINTS WERE INCURRED | | |
|--|-------------------------|-----------------------------|
| No. of FOUR Demerit Points Offences | Number of Drivers | Percentage of Drivers |
| 0 | 282 | 56.3 |
| 1 | 181 | 36.1 |
| 2 | 32 | 6.4 |
| 3 | 2 | 0.4 |
| 4 | 3 | 0.6 |
| 6 | 1 | 0.2 |
| Total | 501 | 100 |

| OFFENCES IN WHICH SIX DEMERIT POINTS WERE INCURRED | | |
|---|-------------------------|-----------------------------|
| No. of SIX Demerit Points Offences | Number of Drivers | Percentage of Drivers |
| 0 | 493 | 98.4 |
| 1 | 4 | 0.8 |
| 2 | 4 | 0.8 |
| Total | 501 | 100 |

OFFENCES INCURRED BY THE 501 HIGHEST SCORING DRIVERS BY CATEGORY OF OFFENCE

| OFFENCES IN WHICH THE SPEED LIMIT WAS EXCEEDED BY LESS THAN 30 KM/H | | |
|--|----------------|-----------------------|
| No. of type 1 Offences | No. of drivers | Percentage of drivers |
| 0 | 17 | 3.4 |
| 1 | 4 | 0.8 |
| 2 | 33 | 6.6 |
| 3 | 69 | 13.8 |
| 4 | 48 | 9.6 |
| 5 | 62 | 12.4 |
| 6 | 181 | 36.1 |
| 7 | 5 | 1.0 |
| 8 | 59 | 11.8 |
| 9 | 4 | 0.8 |
| 10 | 9 | 1.8 |
| 11 | 2 | 0.4 |
| 12 | 4 | 0.8 |
| 14 | 3 | 0.6 |
| 20 | 1 | 0.2 |
| Total | 501 | 100 |

| OFFENCES IN WHICH THE SPEED LIMIT WAS EXCEEDED BY AT LEAST 30 KM/H | | |
|---|----------------|-----------------------|
| No. of type 2 Offences | No. of drivers | Percentage of drivers |
| 0 | 327 | 65.3 |
| 1 | 134 | 26.7 |
| 2 | 34 | 6.8 |
| 3 | 3 | 0.6 |
| 4 | 1 | 0.2 |
| 5 | 1 | 0.2 |
| 8 | 1 | 0.2 |
| Total | 501 | 100 |

| UNSAFE ACTION OFFENCES | | |
|-------------------------------|----------------|-----------------------|
| No. of type 4 Offences | No. of drivers | Percentage of drivers |
| 0 | 303 | 60.5 |
| 1 | 74 | 14.8 |
| 2 | 70 | 14.0 |
| 4 | 4 | 0.8 |
| 5 | 50 | 10.0 |
| Total | 501 | 100 |

| STOP/GIVE WAY OFFENCES | | |
|-------------------------------|----------------|-----------------------|
| No. of type 3 Offences | No. of drivers | Percentage of drivers |
| 0 | 489 | 97.6 |
| 1 | 6 | 1.2 |
| 2 | 6 | 1.2 |
| Total | 501 | 100 |

| RESTRAINT AND HELMET OFFENCES | | |
|--------------------------------------|----------------|-----------------------|
| No. of type 6 Offences | No. of drivers | Percentage of drivers |
| 0 | 274 | 54.7 |
| 1 | 24 | 4.8 |
| 2 | 86 | 17.2 |
| 3 | 55 | 11.0 |
| 4 | 59 | 11.8 |
| 5 | 1 | 0.2 |
| 6 | 1 | 0.2 |
| 8 | 1 | 0.2 |
| Total | 501 | 100 |

| HEADLIGHT AND DEFECT NOTICE OFFENCES | | |
|---|----------------|-----------------------|
| No. of type 5 Offences | No. of drivers | Percentage of drivers |
| 0 | 423 | 84.4 |
| 1 | 68 | 13.6 |
| 2 | 7 | 1.4 |
| 3 | 3 | 0.6 |
| Total | 501 | 100 |

| SIGNAL OFFENCES | | |
|------------------------|----------------|-----------------------|
| No. of type 7 Offences | No. of drivers | Percentage of drivers |
| 0 | 176 | 35.1 |
| 1 | 171 | 34.1 |
| 2 | 84 | 16.8 |
| 3 | 58 | 11.6 |
| 4 | 7 | 1.4 |
| 6 | 5 | 1.0 |
| Total | 501 | 100 |

