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A MODEL FOR CONSIDERING THE 'TOTAL SAFETY' OF THE LIGHT PASSENGER VEHICLE FLEET

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A model for considering the 'total safety' of the light passenger vehicle fleet

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Abstract:
This report describes the results of research to develop and apply a comprehensive model to consider the influence of the mix of vehicle types on the total safety of the light passenger vehicle fleet in Australia. Key inputs to the model are estimates of the crashworthiness and aggressivity of light passenger vehicles in the key crash types representing the majority of crashes in which these vehicles are involved. They include crashes between two light vehicles, single vehicle crashes, crashes with heavy vehicles and crashes with unprotected road users such as pedestrians and bicyclists. The model combines these key crashworthiness inputs with measures of crash exposure of each vehicle class in the fleet mix to estimate the average injury outcome in all crashes involving the light vehicle fleet. By varying the key parameters of the model, it was possible to examine the effects on the average safety of the light vehicle fleet resulting from changes to the mix of types of vehicles in the fleet.

Application of the model was demonstrated through a number of scenarios varying the mix of vehicles in the fleet by broad market group classification. Scenarios considered include natural changes in market group mix of the fleet in recent times and projected over the next 10 years, elimination of various market groups from the fleet, homogeneous fleets composed of a single market group, and fleets composed of only vehicles with the best possible safety performance in each market group. Results of applying the model to the various scenarios considered point to how the vehicle fleet mix might best be manipulated in the future to optimise safety outcomes. Safety outcomes resulting from recent current and projected future trends in vehicle fleet mix were also able to be quantified.

Key Words:
Vehicle Fleet, Injury, Collision, Passenger Car Unit, Statistics, Vehicle Occupant, Crashworthiness, Aggressivity

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PREFACE

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EXECUTIVE SUMMARY

Sales trends in new vehicles in Australia over the past ten years have seen a polarisation of the vehicle fleet into large and small vehicles, with sales in the medium segment showing a rapid decline. Over the same period, sales of four-wheel drive vehicles have increased greatly. One of the key questions resulting from the observed changes in the distribution of new vehicle sales between market groups concerns the impact these changes may have had on safety.

The aim of this study was to build a model to estimate the influence of cross sectional changes in the composition of the light passenger vehicle fleet in terms of its mix by market segment on injury outcome in crashes involving the light vehicle fleet. The model built had to reflect not only injury outcomes within the light passenger vehicle but also amongst other road users involved in the crash. It also had to be proportionately representative of the major crash types involving light passenger vehicles. These major crash types are crashes between light passenger vehicles, single light passenger vehicle crashes, crashes between a light passenger vehicle and an unprotected road user such as a pedestrian or bicyclist and crashes between a light passenger vehicle and a heavy vehicle including trucks and buses.

Upon development of the model, a further aim of the research was to apply the model to consider the safety implications of various changes in the composition of the light passenger vehicle fleet in terms of mix of vehicles by market group. Analysis has focused on vehicles classified into 8 market groups representing the light passenger vehicle fleet. They are large, medium and small passenger cars, sports cars, luxury vehicles, 4 Wheel Drives, passenger vans and light commercial vehicles.

Two key data inputs were required for the model. First, the crashworthiness or aggressivity of each vehicle market group in each of the four major collision types was required. The input crashworthiness and aggressivity measures were estimated by Newstead et al (2004) and are summarised as follows.

- The crashworthiness of light passenger vehicles in collisions with other light passenger vehicles by market group as a function of the colliding passenger vehicle market group.
- The crashworthiness of light passenger vehicles in crashes with heavy vehicles by market group as a function of the class of heavy vehicle in the crash (bus, rigid truck or articulated truck).
- The crashworthiness of light passenger vehicles in single vehicle crashes by market group.
- The aggressivity of light passenger vehicles towards unprotected road users (pedestrians, bicyclists, motorcyclists) by market group.

In the above, crashworthiness is defined as the risk of death or serious injury to the driver of the light passenger vehicle given involvement in a crash where at least one vehicle is towed from the scene or someone is injured. Aggressivity towards unprotected users is the risk of death or serious injury to the unprotected road user in the crash given they were injured. Drivers of heavy vehicles in crashes with light vehicles and drivers of light vehicles in collisions with unprotected road users are typically uninjured so their injury outcome was not considered.

The second data input required is the proportionate involvement of each vehicle market group within a given crash type and the proportionate contribution of each crash type to the total crash population.

The output of the model is the Total Safety Index (TSI) which measures the average risk of death or serious injury amongst drivers or unprotected road users in crashes involving light passenger vehicles. By varying the key parameters of the model, it was possible to examine the effects on the average safety of the Australian light vehicle fleet resulting from changes to the mix of types of vehicles in the fleet. Application of the model was demonstrated through a number of scenarios varying the mix of vehicles in the fleet by broad market group classification. Scenarios considered include natural changes in market group mix of the fleet in recent times and projected over the next 10 years, elimination of various market groups from the fleet, homogeneous fleets composed of a single market group, and fleets composed of only vehicles with the best possible safety performance in each market group.

Historical and likely future changes in the Australian light vehicle fleet mix were found to have had little influence on the TSI. During the period from 1990 to 2000 the TSI fell by around 1% as a result of changes in the mix of the vehicle fleet, a marginal improvement in average injury outcome. However, it is estimated that over the following ten-year period the TSI will remain largely uninfluenced by vehicle fleet mix change. This result suggests that any goals for improvements in the safety of the passenger fleet aimed for in the future will have to come entirely from general improvements in crashworthiness and aggressivity of new vehicles entering the Australian fleet unless the mix can be changed from that predicted.

Of the homogeneous fleet scenarios, the largest increase in the TSI, indicating worsening injury outcome, occurred when passenger vans were the only passenger vehicle in use. In contrast, the situation in which only either large or luxury vehicles were available would generate the greatest improvement in overall fleet safety use. This result suggests that large vehicles provide the optimum balance of safety between crashworthiness and aggressivity in the mix of the four major crash types represented in the Australian crash population. The results show that the maximum gain that could be achieved through fleet mix changes is around a 10% improvement in the TSI whilst the potential loss could be up to 25%.

The scenarios considered in which a single vehicle market group was removed and replaced by either a proportionate mix of the remaining market groups, or one particular market group, provided information on the relative contribution of individual market groups to current safety levels. The contribution of both small and 4WD vehicles is of particular interest given the increasing trend towards the purchase of vehicles from these two market groups in Australia. The removal of either of these groups from the vehicle fleet and their replacement by a proportionate mix of the remaining market groups is estimated to improve overall fleet safety in comparison to the current situation. However, removal of small cars was estimated to produce much greater gains than removal of 4WD vehicles. Scenarios where single market groups were replaced with other market groups similar in functionality generally resulted in smaller safety losses or gains as measured by the TSI.

Of the scenarios considered, the safest vehicle in market group scenario led to the greatest improvement in the TSI. If each vehicle had a crashworthiness and aggressivity rating equivalent to the currently available best vehicle in its market group, total safety could be improved by up to 26% from the current level. This suggests that the promotion of safety as a key determinant of vehicle choice and subsequent changes in buyer behaviour could lead to the most significant improvements in total fleet safety. The TSI could be improved by up to 40% from the current situation if all vehicles incorporated design aspects that produce the best currently available crashworthiness and aggressivity (not necessarily in the same vehicle) within a market group. These improvements are based on currently available designs and safety features. Further regulation of vehicle safety standards and increased emphasis on safe choices in vehicle purchase through mechanisms like consumer information programs can help the vehicle fleet move towards these targets.

1. HISTORICAL DATA TRENDS AND PROJECT AIMS

1.1 Trends in the Mix of the Australian Light Vehicle Fleet

Sales trends in new vehicles in Australia over the past ten years have seen a polarisation of the vehicle fleet into large and small vehicles, with sales in the medium segment showing a rapid decline. These trends are reflected in the VFACTS new vehicle sales figures published monthly by the Federal Chamber of Automotive Industries. Over the same period, sales of four-wheel drive vehicles have increased greatly. These changes in new vehicle sales are reflected in the market group composition of vehicles crashing.

Records from the crashworthiness data file of Newstead et al (2003), consisting of drivers in reported crashes in NSW and Victoria during 1987 to 2000 and Queensland and Western Australia during 1991 to 2000 and driving vehicles of known market group, have been used to examine the market group composition of vehicles crashing. Analysis focused on composition by market group, year of manufacture and year of crash to assess any trends in the market group composition of the fleet. The frequency and percentage of vehicles involved in crashes by market group and year of manufacture are shown in Appendix 1 and graphed in Figure 1. The frequency and percentage of vehicles involved in crashes by market group and year of crash are also shown in Appendix 1 and graphed in Figure 2.

Figure 1. *Crash population composition by vehicle market group and year of manufacture.*

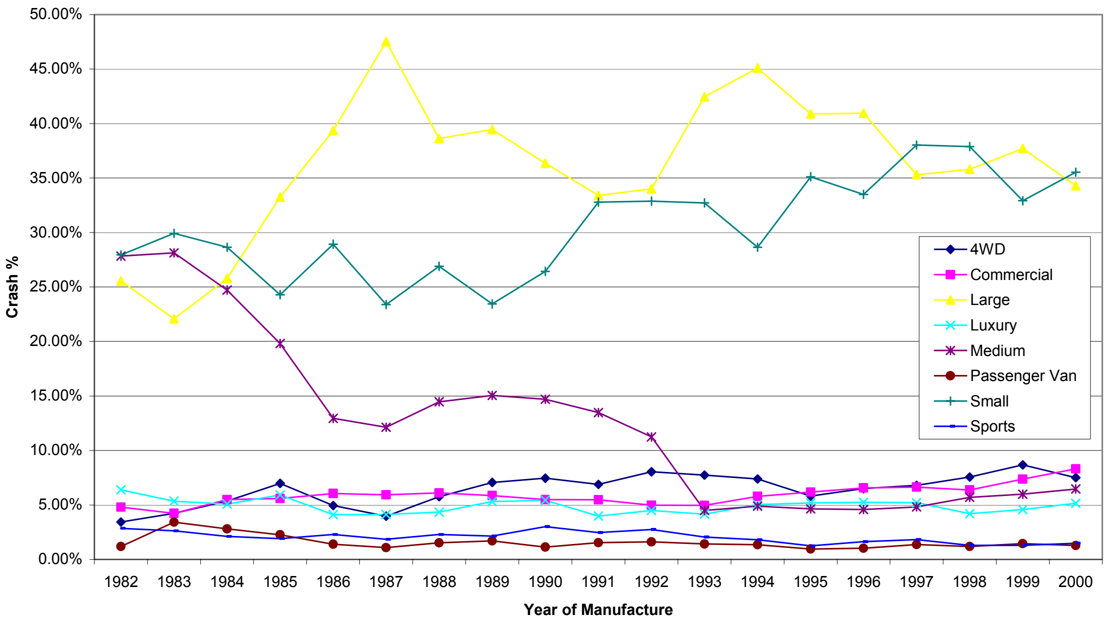

Figure 2. *Crash population composition by market group and year of crash.*

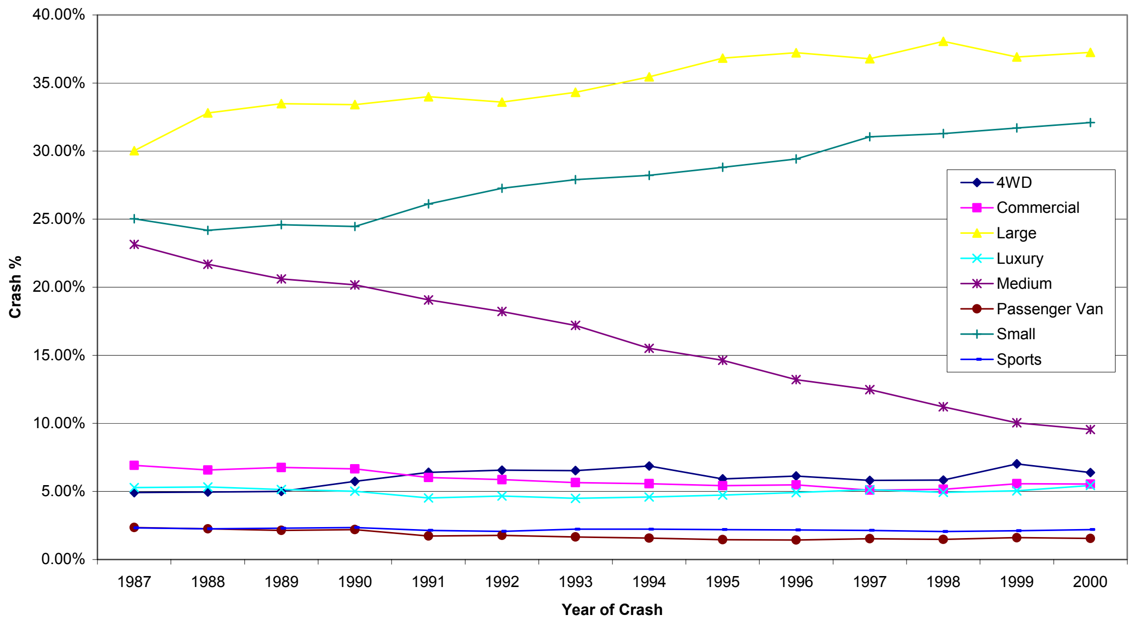

Figure 1 shows an increasing crash involvement for the years of manufacture 1982 to 2000 over the crash period 1987 to 2000 for the small and large market groups and declining involvement for the medium market group. Figure 2 shows clear evidence of trends in composition of market groups across crash years. In particular the percentage of crashes involving medium vehicles declined rapidly over the period 1987 to 2000 and small and large vehicle market groups increased markedly. The Four Wheel Drive (4WD) market group has shown a small increase over the period 1989 to 2000 although still represents a much smaller proportion of the crash population than small or large cars. This is despite the reported large increases in sales of 4WD vehicles.

1.2 Project Motivation, Aims and Scope

One of the key questions resulting from the observed changes in the distribution of new vehicle sales between market groups concerns the impact these changes may have had on safety. For example, much attention has been given to the likely effects of the growth in the 4WD sector given the high risk of injury these vehicles pose to other road users with which they collide (Hollowell and Gabler, 1996; McLean, 1996; Cameron, Attwell and Glase, 2000; Cameron, Newstead and Le, 1998). Newstead and Cameron (2001) also express concern over the polarisation of the fleet into large and small cars contributing to the observed trend towards poorer small car occupant protection performance during the 1990s.

The broad primary aim of this study was to build a model to estimate the influence of cross sectional changes in the composition of the light passenger vehicle fleet in terms of its mix by market segment on total safety of the light vehicle fleet. For the purpose of the study, safety refers to secondary safety or injury outcome in the event of a crash. Primary safety, or crash risk, was not the focus of the analysis. More specifically, the secondary safety measure considered was the risk of death or serious injury given involvement in a crash where at least one vehicle was towed from the scene or a person was injured. This is the secondary safety measure used in the vehicle crashworthiness and aggressivity ratings of Newstead et al (2003) and Cameron, Newstead and Le (1989).

In order for the model to comprehensively represent secondary safety outcomes associated with crashes involving light passenger vehicles, it had to reflect not only injury outcomes within the light passenger vehicle but also amongst other road users involved in the crash. It also had to be proportionately representative of the major crash types involving light passenger vehicles. Newstead et al (2004) has identified these major crash types as crashes between light passenger vehicles, single light passenger vehicle crashes, crashes between a light passenger vehicle and an unprotected road user such as a pedestrian or bicyclist and crashes between a light passenger vehicle and a heavy vehicle including trucks and buses.

The study did not aim to model total road trauma associated with changes in the light vehicle fleet size but rather only the average injury outcome assuming a fixed fleet size. Furthermore, the research did not aim to consider crashes where a light passenger vehicle was not involved. The model developed has been termed a model for the 'total safety' of the light vehicle fleet to reflect its encompassment of all injury outcomes in crashes across all crash types.

Upon development of the model for estimating the total safety of the light passenger fleet, the secondary aim of the research was to apply this model to consider the safety implications of various changes in the composition of the light passenger vehicle fleet in terms of mix of vehicles by market group. Historical and likely future changes have been considered, as well as some extreme change scenarios, to attempt to quantify the maximum influence light vehicle fleet mix can have on safety outcomes.

2. INPUT DATA

2.1 Definitions of Vehicle Market Groups

The introductory material presented above discusses the light passenger vehicle fleet classified into 8 market groups. Based on the vehicle make and model details, vehicles were assigned to one of 8 market group categories as follows:

- Passenger cars and station wagons:
  - Large (>1400kg tare mass)
  - Medium (1200-1400kg tare mass)
  - Small (<1200kg tare mass)
  - Sports (coupe or convertible body style)
  - Luxury (highly specified vehicle)
- Four-wheel drive vehicles (off-road vehicles with raised ride height)
- Passenger vans (single box body style vehicle with seating capacity > 5 people)
- Commercial vehicles (ultilities and vans less than 3000 kg GVM)

The market group categories listed are generally consistent with those used by the Federal Chamber of Automotive Industries (FCAI) in reporting vehicle sales, although some categories used by the FCAI have been combined here to ensure sufficient numbers of vehicles for analysis. For example, the FCAI small and light vehicle categories have been combined to give the ‘small’ category used here.

2.2 Vehicle Safety Inputs

There are two key data inputs required for the model of total safety of the light passenger vehicle fleet. First, the crashworthiness of each vehicle market group as a function of the collision partner in all major collision types is required along with the average serious injury risk (aggressivity) to unprotected road users as a function of colliding vehicle market group. The collision types considered in this study are vehicle-to-vehicle collisions, single vehicle collisions, collisions between passenger vehicles and heavy vehicles and collisions between passenger vehicles and unprotected road users. Real crash data sources from four Australian states have been used to estimate these measures across the eight market groups defined. The method and results of the estimation are described in detail in Newstead et al (2004).

The second data input required is the proportionate involvement of each vehicle market group within a given crash type and the proportionate contribution of each crash type to the total crash population. That is, for example, the proportion of all crashes between two passenger vehicles involving medium cars colliding with large cars and the proportion of all crashes that involved only two passenger vehicles. The first of these data requirements is met from the data used to estimate the crashworthiness and aggressivity ratings by market group in Newstead et al (2004). It provides the number of crash involvements for each crash configuration such as medium cars colliding with large cars. The contribution of each crash type to total crashes was extracted from NSW Police reported crash data for the period 1991 to 1998. It is assumed that the NSW data is representative of the national crash situation and has the advantage of including both injury and non-injury crashes.

The crashworthiness and aggressivity of each vehicle market group in each of the four major crash types considered are summarised in the following sections. Confidence limits on each of the estimates are given in Newstead et al (2004) but are not shown here as they are not important to the key concepts in developing the total safety model. The proportionate mixes of vehicles by market group within each crash type are also summarised. The names of the vehicle market groups have been abbreviated in the following material. The abbreviation key is given in Table 1.

Table 1: *Vehicle Market Group Name Abbreviations*

4WD	C	L	LX	M	PV	S	SP
4-wheel drive	Commercial	Large	Luxury	Medium	Passenger Van	Small	Sports

2.2.1 Passenger Vehicle-to-Passenger Vehicle Crashes

Crashworthiness estimates by vehicle market group of light passenger vehicles in collisions with other light passenger vehicles as a function of the market group of the colliding vehicle have been estimated by Newstead et al (2004). They are summarised in Table 2. The first vehicle market group code appearing in the crash configuration variable refers to the focus vehicle. That is, the vehicle for which the driver injury outcome is being rated. The second market group code refers to the market group of the collision partner vehicle. For example, “4WD-C” refers to a collision in which a commercial vehicle collides with a 4WD and the injury outcome of the 4WD driver is being assessed.

The crashworthiness (CWR) value in Table 2 is the risk of death or serious injury to the driver of the focus vehicle given involvement in a crash where at least one vehicle is towed from the scene or a person is injured. The number involved gives the number of vehicles of the focus vehicle market group involved in crashes from which the crashworthiness rating was derived. The total of the number involved column gives the total number of vehicles involved in this crash type. It might be expected that the number of crashes of a particular vehicle combination would be the same regardless of which vehicle market group was the focus (i.e. the number of L-SP crashes would be the same as the number of SP-L crashes). Whilst in practice this would be the case, it is not reflected in the table because some of the critical information, such as driver injury outcome or other factors necessary in calculating the rating may be missing for the driver of the partner vehicle when they are all known for the driver of the focus vehicle. In general, the discrepancies are not too large and will make little practical difference to the application of the model.

Table 2: *Crashworthiness by Market Group and Proportionate Exposure in Crashes between Two Passenger Vehicles*

Crash Configuration	Number Involved	CWR	Involved/ Total Involved
4WD-4WD	1110	2.31%	0.44%
4WD-C	755	1.56%	0.30%
4WD-L	4776	1.37%	1.88%
4WD-LX	644	1.54%	0.25%
4WD-M	1729	1.28%	0.68%
4WD-PV	191	2.55%	0.08%
4WD-S	4276	0.84%	1.69%
C-4WD	775	3.43%	0.31%
C-C	828	3.01%	0.33%
C-L	4684	2.15%	1.85%
C-LX	633	3.73%	0.25%
C-M	1857	1.66%	0.73%
C-PV	231	3.00%	0.09%
C-S	3935	1.29%	1.55%
C-SP	258	2.68%	0.10%
L-4WD	5000	2.92%	1.97%
L-C	4795	2.52%	1.89%
L-L	31694	2.16%	12.50%
L-LX	4505	1.77%	1.78%
L-M	12795	1.79%	5.05%
L-PV	1409	1.90%	0.56%
L-S	26509	1.60%	10.45%
L-SP	1938	1.69%	0.76%
LX-4WD	671	2.25%	0.26%
LX-C	644	2.59%	0.25%
LX-L	4491	1.83%	1.77%
LX-LX	801	1.66%	0.32%
LX-M	1826	1.32%	0.72%
LX-PV	226	1.50%	0.09%
LX-S	4194	0.96%	1.65%
LX-SP	341	1.65%	0.13%

Crash Configuration	Number Involved	CWR	Involved/ Total Involved
M-4WD	1792	3.63%	0.71%
M-C	1928	3.00%	0.76%
M-L	12890	2.70%	5.08%
M-LX	1846	2.11%	0.73%
M-M	5731	1.96%	2.26%
M-PV	662	2.53%	0.26%
M-S	10641	1.75%	4.20%
M-SP	817	3.06%	0.32%
PV-4WD	196	3.84%	0.08%
PV-C	225	3.37%	0.09%
PV-L	1387	2.77%	0.55%
PV-LX	230	4.14%	0.09%
PV-M	648	1.97%	0.26%
PV-S	1363	1.53%	0.54%
S-4WD	4660	3.72%	1.84%
S-C	4104	3.22%	1.62%
S-L	27311	3.19%	10.77%
S-LX	4303	2.90%	1.70%
S-M	10858	2.66%	4.28%
S-S	24594	2.06%	9.70%
S-SP	1818	2.83%	0.72%
SP-4WD	261	3.92%	0.10%
SP-C	279	3.70%	0.11%
SP-L	1980	2.49%	0.78%
SP-LX	343	2.71%	0.14%
SP-M	824	2.84%	0.32%
SP-S	1787	1.54%	0.70%
SP-SP	160	1.82%	0.06%
SP-V	1401	3.77%	0.55%
Totals	**253560**		**100.00%**
Weighted Average Crashworthiness		**2.24%**	

The final column in Table 2 is the proportion of the total number of vehicles involved in this crash type represented by the focus vehicle market group in collisions with the nominated partner vehicle market group. These are used as weighting factors to estimate the average crashworthiness of light passenger vehicles when involved in collisions with other light passenger vehicles. For the data presented, the weighted average is 2.24% or 2.24 deaths or serious injuries for every 100 drivers involved in crashes between two light vehicles. The concept of the weighted average is important when considering how the total safety model is constructed as described later.

2.2.2 Passenger Vehicle to Heavy Vehicle Crashes

Crashworthiness estimates by vehicle market group of light passenger vehicles in collisions with heavy vehicles have also been estimated by Newstead et al (2004). The crashworthiness ratings for each market group are a function of the type of heavy vehicle in the collision and are summarised in Table 3. The heavy vehicles have been broken down into three classes. They are articulated trucks (Artic), rigid trucks (Rigid) and buses of any size (Bus). The notation in Table 3 is similar to that in Table 2 with the passenger vehicle market group code followed by the heavy vehicle class code. For example, "4WD-Artic" refers to a collision in which a 4WD vehicle collides with an articulated truck. The injury outcome of the passenger vehicle driver is being assessed. Typically the driver of the heavy vehicle is uninjured in crashes with a light passenger vehicle.

The crashworthiness (CWR) value in Table 3 is the risk of death or serious injury to the driver of the passenger vehicle given involvement in a crash where at least one vehicle is towed from the scene or a person is injured (typically the passenger vehicle is towed or its driver injured). The number involved gives the number of passenger vehicles involved in crashes from which the crashworthiness rating was derived. The total of the number involved column gives the total number of vehicles involved in this crash type.

As for Table 3, the final column in Table 3 is the proportion of the total number of passenger vehicles involved in this crash type represented by the passenger vehicle to heavy vehicle collision combination. These are used as weighting factors to estimate the average crashworthiness of light passenger vehicles when involved in collisions with heavy vehicles. For the data presented, the weighted average is 4.71% or 4.71 deaths or serious injuries for every 100 drivers involved.

Table 3: *Light Passenger Vehicle Crashworthiness by Market Group and Proportionate Exposure in Crashes with a Heavy Vehicle*

Vehicle Class and Heavy Vehicle Collision Partner	Involved	CWR	Involved / Total Involved
4WD-Artic	296	9.20%	0.54%
4WD-Rigid	6540	2.59%	11.95%
4WD-Bus	231	3.43%	0.42%
C-Artic	359	8.39%	0.66%
C-Rigid	7377	4.03%	13.48%
C-Bus	412	4.25%	0.75%
L-Artic	2081	7.13%	3.80%
L-Rigid	10813	4.23%	19.76%
L-Bus	1627	4.56%	2.97%
LX-Artic	312	8.01%	0.57%
LX-Rigid	1620	2.86%	2.96%
LX-Bus	243	2.30%	0.44%
M-Artic	849	9.02%	1.55%
M-Rigid	4985	5.16%	9.11%
M-Bus	648	4.51%	1.18%
PV-Artic	75	13.83%	0.14%
PV-Rigid	2605	4.19%	4.76%
PV-Bus	372	5.27%	0.68%
S-Artic	1738	8.09%	3.18%
S-Rigid	9232	5.52%	16.87%
S-Bus	1375	5.06%	2.51%
SP-Artic	143	7.85%	0.26%
SP-Rigid	676	4.68%	1.24%
SP-Bus	102	3.70%	0.19%
Totals	**54711**		**100.00%**
Weighted Average Crashworthiness		**4.71%**	

NB: Artic refers to an articulated truck
Rigid refers to a rigid truck
Bus refers to a bus of any size.

2.2.3 Single Vehicle Crashes

Table 4 summarises the estimated crashworthiness by market group of light passenger vehicles in single vehicle crashes calculated by Newstead et al (2004). The format of the information is the same as for the two previously presented crash types. The weighted average crashworthiness of passenger vehicles in single vehicle crashes is 11.22% or 11.22 deaths or serious injuries for every 100 drivers involved.

Table 4: *Light Passenger Vehicle Crashworthiness by Market Group and Proportionate Exposure in Single Vehicle Crashes*

Vehicle Class	Involved	CWR	Involved / Total Involved
4WD	8466	14.19%	9.03%
C	6044	12.44%	6.45%
L	38784	10.06%	41.37%
LX	3025	10.17%	3.23%
M	11687	11.42%	12.47%
PV	1572	13.21%	1.68%
S	23402	11.65%	24.96%
SP	768	10.95%	0.82%
Totals	**93748**		**100.00%**
Weighted Average Crashworthiness		**11.22%**	

2.2.4 Unprotected Road Users

The final crash type considered by Newstead et al (2004) was crashes between light passenger vehicles and unprotected road users such as pedestrians and bicyclists. The aggressivity rating (AGG in Table 5) estimates the probability of death or serious injury of the unprotected road user given involvement in the crash. The driver of the passenger vehicle is typically uninjured in this type of crash so the focus on the injury outcome of the unprotected road user reflects the total injury outcome from the crash. The aggressivity ratings are summarised in Table 5 by vehicle market group along with the proportional exposure of each market group in this crash type. The weighted average aggressivity across all market groups is 33.62% or 33.62 deaths or serious injuries per 100 involved unprotected road users.

Table 5: *Aggressivity of Light Passenger Vehicles towards Unprotected Road Users by Market Group and Proportionate Exposure*

Vehicle Class	Involved	AGG	Involved / Total Involved
4WD	2748	38.67%	3.49%
C	2736	36.94%	3.48%
L	30775	32.25%	39.14%
LX	2764	34.96%	3.51%
M	17674	33.21%	22.48%
PV	2162	36.43%	2.75%
S	19385	34.48%	24.65%
SP	394	34.15%	0.50%
Totals	**78638**		**100.00%**
Weighted Average Crashworthiness		**33.62%**	

2.2.5 Crash Type Representation

The final data required as input into the total safety model was the relative proportion of the total crash population represented by each of the four major crash types for which crashworthiness or aggressivity ratings are summarised above. Table 6 gives these proportions which were derived from NSW crash data.

Table 6: *Light Passenger Vehicle Crashworthiness by Market Group and Proportionate Exposure in Crashes with a Heavy Vehicle*

Crash Type	Crash Weight
Single vehicle (sv)	28.93%
Passenger vehicle-to-vehicle (pp)	45.33%
Passenger vehicle to heavy vehicle (ph)	16.00%
Passenger vehicle to unprotected road user (ur)	9.74%
Total	**100%**

3. METHODOLOGY

3.1 The Total Safety Model

The total safety model used to calculate total fleet safety for a given vehicle fleet mix was defined as a two-step process. The first step estimates the average injury outcome in each of the four crash types considered for the given mix of vehicles in the fleet by market group. The second stage combined the average injury outcomes in each of the four crash types assigning proportionate weighting to each crash type using the weights in Table 6. Formal details of each step are as follows.

3.1.1 Average Injury Outcome by Crash Type

Vehicle to Vehicle Crashes

The average crashworthiness of light passenger vehicles in crashes with other light passenger vehicles is calculated using Equation 1.

$$CWR_{PP} = \sum_i \sum_j \left(w(pp)_{ij} \times cwr(pp)_{ij} \right) \ldots \text{Equation 1}$$

In Equation 1,

i	is the index of the focus vehicle market group (4WD, L, M, etc)
j	is the index of the colliding vehicle market group (4WD, L, M, etc)
$w(pp)_{ij}$	is the proportion of all light passenger vehicle to light passenger vehicle crashes involving market group i colliding with market group j.
$cwr(pp)_{ij}$	is the crashworthiness of a vehicle from market group i when colliding with vehicle market group j.

Table 2 illustrates the quantities used in Equation 1. The crashworthiness components by market group and vehicle partner, $cwr(pp)_{ij}$, are given in column 3 of Table 2. The weighting factors, $w(pp)_{ij}$, derived from the actual crash population are in the final column of Table 2.

Passenger Vehicle to Heavy Vehicle Crashes

The average crashworthiness of light passenger vehicles in crashes with heavy vehicles is calculated using Equation 2.

$$CWR_{PH} = \sum_i \sum_k \left(w(ph)_{ik} \times cwr(ph)_{ik} \right) \ldots \text{Equation 2}$$

In Equation 2,

i	is the index of the focus vehicle market group (4WD, L, M, etc)
k	is the index of the colliding heavy vehicle class (Artic, Rigid, Bus)
$w(ph)_{ik}$	is the proportion of all light passenger vehicle to heavy vehicle crashes involving market group *i* colliding with heavy vehicle class *j*.
$cwr(ph)_{ik}$	is the crashworthiness of a vehicle from market group *i* when colliding with heavy vehicle class *j*.

Table 3 illustrates the quantities used in Equation 2. The crashworthiness components by market group and heavy vehicle partner, $cwr(ph)_{ik}$, are given in column 3 of Table 3. The weighting factors, $w(ph)_{ik}$, derived from the actual crash population are in the final column of Table 3.

Single Vehicle Crashes

The average crashworthiness of light passenger vehicles in single vehicle crashes is calculated using Equation 3.

$$CWR_{SV} = \sum_i \left(w(sv)_i \times cwr(sv)_i \right) \ldots \text{Equation 3}$$

In Equation 3,

i	is the index of the focus vehicle market group (4WD, L, M, etc)
$w(sv)_i$	is the proportion of all light passenger vehicle single vehicle crashes involving market group *i*.
$cwr(sv)_i$	is the crashworthiness of a vehicle from market group *i* when in a single vehicle crash.

Table 4 illustrates the quantities used in Equation 3. The crashworthiness components by market group, $cwr(sv)_i$, are given in column 3 of Table 4, while the weighting factors, $w(sv)_i$, derived from the actual crash population are in the final column of Table 4.

Crashes with Unprotected Road Users

The final component index is the average aggressivity of light passenger vehicles towards unprotected road users and is calculated using Equation 4. The component index is denoted CWR_{UR} for convenience in formulating the total safety index.

$$CWR_{UR} = \sum_i \left(w(ur)_i \times agg(ur)_i \right) \ldots \text{Equation 4}$$

In Equation 4,

i	is the index of the focus vehicle market group (4WD, L, M, etc)
$w(ur)_i$	is the proportion of all unprotected road user crashes involving light passenger vehicle market group i.
$agg(ur)_i$	is the aggressivity of a vehicle from market group i towards unprotected road users.

Table 5 illustrates the quantities in Equation 4 with the aggressivity components by market group, $agg(ur)_i$, given in column 3 and the weighting factors, $w(ur)_i$, from the crash population in the final column.

3.1.2 The Total Safety Index

The final total safety index is simply a weighted average of the estimates of average crashworthiness or aggressivity for each crash type. The weights used to form the final index are the proportionate occurrence of each crash type given in Table 6. Equation 5 gives the formal definition of the final index.

$$TSI = \sum_{c} \left(w(tsi)_c \times CWR_c \right) \ldots \text{Equation 5}$$

In Equation 5,

c	is the crash type index (light passenger vehicle to light passenger vehicle - pp, light passenger vehicle to heavy vehicle - ph, single light passenger vehicle - sv or light passenger vehicle to unprotected road user - ur)
$w(tsi)$	is the proportion of crashes of type c from Table 6
CWR_C	is the weighted average crashworthiness or aggressivity for crash type c.

3.2 The Base Scenario

For the purposes of comparing the effect on the total safety index (TSI) from making changes in the fleet composition, it was necessary to calculate a baseline level of the TSI from a baseline set of input conditions. Although the choice of baseline scenario is somewhat arbitrary, an appropriate choice was considered to be the conditions represented in the current crash population shown in Tables 2 to 6. It should be noted that the conditions represented in Tables 2 to 6 represent the average for NSW over the period 1991 to 1998 which are considered to be representative of the national average over this period.

The computation of the baseline TSI from the information in Tables 2 to 6 is detailed in Table 7. It shows the average crashworthiness or aggressivity for each of the four major crash types calculated from Equations 1 to 4 along with the weights for each crash type from Table 6 used in calculating the TSI using Equation 5.

The baseline TSI given in Table 7 is 8.29%. This index value is a measure of the average risk of death or serious injury to drivers of light passenger vehicle or unprotected road users involved in crashes with light passenger vehicles given involvement in a crash where at least one vehicle is towed from the scene or someone is injured.

Table 7: *Baseline Total Safety Index and its Components*

Crash Type	Crash Weight $w(tsi)_c$	Component Index CWR_c
Vehicle to Vehicle (pp)	45.33%	2.24%
Vehicle to Heavy Vehicle (ph)	16.00%	4.71%
Single Vehicle (sv)	28.93%	11.22%
Unprotected Road Users (ur)	9.74%	33.62%
Baseline TSI		**8.29%**

3.3 Change Scenario Consideration

After defining the total safety of the fleet as measured by the TSI, the primary aim of the study was to then identify how changes in the mix of vehicles in the fleet by market group affect the TSI. This is readily achieved using the defined model through altering the weights associated with each market group in the component index measures of average crashworthiness or aggressivity given by Equations 1 to 4 ($w(pp)_{ij}$, $w(ph)_{ik}$, $w(sv)_i$, and $w(ur)_i$). The only restriction on altering the weights is that they add to unity for each component index.

The effects of crashworthiness changes on the TSI were investigated in a similar way by altering the crashworthiness estimates by vehicle market group and collision partner, where appropriate, in each of the component index measures. A limited number of change scenarios of this nature have been considered in this study. The final change scenario set it was possible to consider was altering the balance between the various crash types by altering the weights ($w(tsi)_c$) in Equation 5. Only one scenario of this type has been considered in this study as they are generally of lesser interest given it is the focus of the study to examine the effects of changes in the mix of the light passenger vehicle fleet and not the crash type distribution. Changes in crash type mix are generally affected by road safety campaigns that do not specifically focus on vehicles. To a large extent also, the crash type mix reflects the features of the jurisdiction being studied and features such as the level of urbanisation and investment in road infrastructure.

Each of the scenario changes considered in this study only alters one of the crash weights, crashworthiness or crash type distributions at a time. In theory, it is possible to alter all the dimensions simultaneously but doing so would make it difficult to assess the relative effects of each dimension.

4. RESULTS: APPLICATION OF THE TSI MODEL

A number of scenarios for possible changes to the vehicle fleet mix have been considered in this study. The scenarios considered are both realistic, based on historical trends in new vehicle sales and expectations for future trends, and on hypothetical extreme situations. The purpose in examining the hypothetical extreme situations was to measure the effects of individual vehicle market groups on total safety as well as to determine the maximum effects changes in fleet composition can have on the total safety index (TSI).

4.1 Historical Effects and Effects of Likely Future Trends

4.1.1 Effects on the Entire Fleet

The first scenario considers the impact on the total safety index of historical changes in the vehicle fleet mix since 1990 and the impact of the most likely projected changes in the vehicle fleet mix until 2010. The models used to project vehicle fleet mix beyond existing data are described in detail in Oxley et al, (2003). Changes in the proportion of vehicles in each market group both historically and predicted by Oxley et al (2003) have been translated into changes in the weighting factors in the crash type component index measures ($w(pp)_{ij}$, $w(ph)_{ik}$, $w(sv)_i$, and $w(ur)_i$). The resulting estimates of the total safety index are shown in Table 8 below along with the crash type component index measures from which each is derived. The crash component weights used to compute the TSI are those given in Table 6. The baseline comparison TSI has not been included in Table 8 as this analysis is only concerned with relative changes over time and comparison with the specific baseline is not particularly relevant.

Table 8: *Total Safety Index Based On Past and Predicted Future Fleet Mix.*

Crash Type	1990 Fleet Safety	1995 Fleet Safety	2000 Fleet Safety	2010 Fleet Safety
Vehicle to Vehicle	2.23	2.21	2.22	2.21
Vehicle to Heavy Vehicle	4.48	4.54	4.67	5.00
Single Vehicle	11.32	11.12	11.05	11.04
Unprotected Road Users	35.33	35.29	35.00	34.65
TSI	**8.44**	**8.38**	**8.36**	**8.37**

The above estimates represent changes in total vehicle fleet safety that have been influenced only by changes in vehicle fleet mix by market group. They do not reflect general improvements in vehicle safety over time, such as those brought about by inclusion of more standard safety features in cars, for example airbags. Further, they do not reflect changes in buyer selection of more or less safe cars over time, a factor that has been argued by Newstead and Cameron (2001) to have lead to reduced levels of safety in Australian small cars over the 1990s.

Despite what appear to have been major shifts in the composition of the Australian vehicle fleet over the last 10 years, Table 8 shows that this has had little impact on the total safety of the vehicle fleet. The estimates of the total safety index for each of the years under examination indicate that average fleet safety has actually improved slightly in the last 10 years due to market group composition changes. It also indicates that the total safety index will remain fairly steady due to this influence based on the most likely scenario of change until 2010. Examining the breakdown of trends by major crash type showed little historical or projected change in each. Whilst crashes with heavy vehicles are projected to reduce the total safety of the fleet, this is offset by slight improvement in single vehicle and unprotected road user crashes.

4.1.2 Effects on Individual Market Groups

A further historical based scenario set considers the effect of the change in vehicle fleet composition on the crashworthiness of each vehicle market group. That is, the analysis examines whether changes in the vehicle fleet have influenced the crashworthiness of individual vehicle market groups. Table 9 and Figure 3 below show estimated crashworthiness at three time points to illustrate the change in crashworthiness over time for each market group resulting from fleet mix changes over the period. The analysis identifies the effect of changes in vehicle fleet mix on individual crash types for each market group (i.e. vehicle-to-vehicle, vehicle-to-heavy vehicle, single vehicle and unprotected road user crashes). The changes for each crash type are then combined using the weightings in Table 6 to produce a total measure of effect for each market group. As such, they represent a further interpretation of the material used to obtain the TSI estimates in Table 8. It should be noted that the estimates in Table 9 are the average risk of serious injury or death to the driver of the light passenger vehicle given involvement in one of the four major crash types considered. The estimates are relatively low because the risk of death or serious injury to the light passenger vehicle driver is essentially zero in a collision with an unprotected road user.

Table 9: *Change in Average Crashworthiness of Individual Market Groups from 1990 to 2000.*

Market Group	1990	1995	2000	Improvement or Worsening 1990-2000
4WD	1.56%	1.33%	1.22%	✓
C	3.62%	3.52%	3.23%	✓
L	3.22%	3.38%	3.58%	X
LX	1.43%	1.42%	1.50%	X
M	2.85%	2.66%	2.47%	✓
PV	2.06%	1.96%	1.96%	✓
S	3.32%	3.48%	3.78%	X
SP	2.09%	2.06%	2.02%	✓

✓ Improvement in death or serious injury rate
X Worsening of death or serious injury rate

Figure 3: *Change in Average Crashworthiness of Individual Market Groups Associated with Fleet Mix Change from 1990 To 2000.*

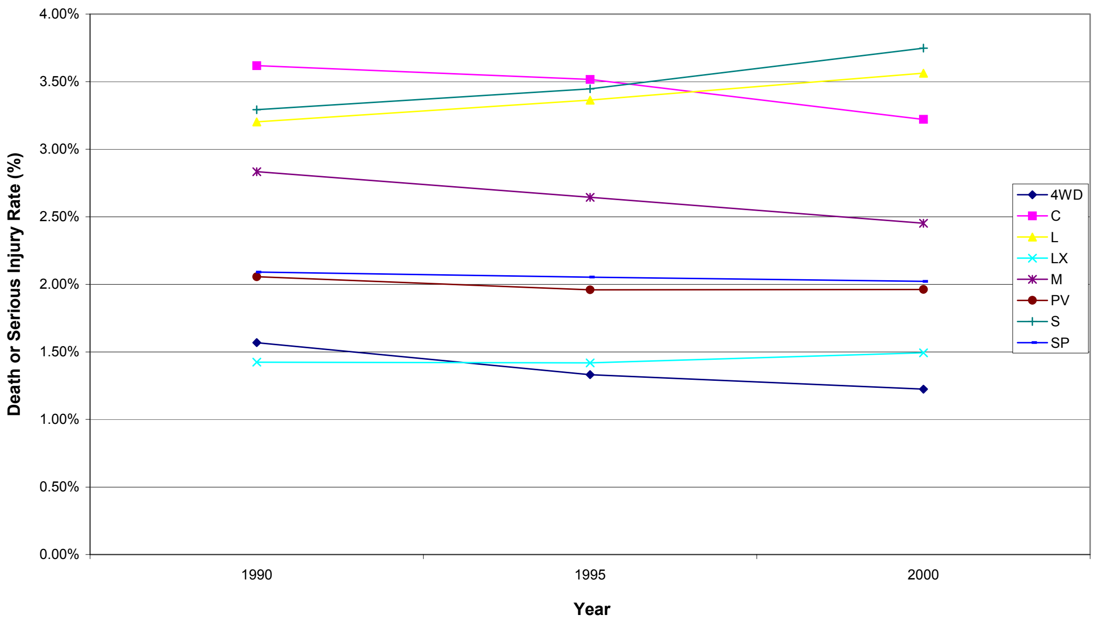

Figure 3 demonstrates that there has not been a consistent trend in the death or serious injury rate across all market groups. Commercial, medium and 4WD vehicles showed the greatest improvement in crashworthiness related to fleet mix changes over the ten-year period 1990 to 2000 whereas the average injury outcome to drivers of small, large and luxury cars has worsened.

4.2 Extreme Scenarios

4.2.1 Homogeneous Fleet

The scenarios presented below consider the case in which the passenger vehicle fleet is homogenised to only one vehicle market group. For example, passenger cars are restricted to being medium sized vehicles only. These fleet scenarios are the most extreme to be considered and are not likely to ever become a reality given the need for people to purchase different vehicle types to serve specific purposes. However, these scenarios define the boundaries of safety change that could be achieved through modification of the fleet composition in terms of market groups.

Under this scenario, all crash types involve only one market group. This is reflected in the calculation of the total safety index by setting the weights in the component crash indexes to zero for all but the single market group of focus. The remaining non zero weights are scaled to sum to unity for each crash type. The resulting TSI estimates are detailed in Table 10 for a homogeneous vehicle fleet of each market group in turn. The component index measures for each crash type are also given in Table 10. The component crash types have been combined to form the TSI using the weights in Table 6.

Table 10: *Total Safety Index Values base on Various Homogeneous Fleet Scenarios.*

Crash Type	Baseline	4WD Vehicles Only	Commercial Vehicles Only	Large Vehicles Only	Luxury Vehicles Only	Medium Vehicles Only	Pass. Vans Only	Small Vehicles Only	Sports Vehicles Only
Vehicle-to-Vehicle	2.24	2.31	3.01	2.16	1.66	1.96	4.96	2.06	1.82
Vehicle-to-Heavy Vehicle	4.70	3.25	4.50	4.55	3.30	5.50	5.20	5.75	4.60
Single Vehicle	11.22	14.19	12.44	10.06	10.17	11.42	13.21	11.65	10.95
Unprotected Road Users	33.62	38.67	36.94	32.25	34.96	33.21	36.43	34.48	34.15
TSI	**8.29**	**9.44**	**9.28**	**7.76**	**7.63**	**8.31**	**10.45**	**8.58**	**8.06**

The results in Table 10 indicate that, if the fleet comprised only luxury vehicles, the TSI would fall to 7.63, an improvement of around 9% on the baseline standard. A vehicle fleet comprising only large vehicles improves the TSI to 7.76, or about 7% in comparison to the baseline estimate. In contrast, a vehicle fleet comprised solely of passenger vans, 4WDs or commercial vehicles would see the overall TSI become worse by 25%, 13% and 11% respectively in comparison to the baseline standard. Caution should be exercised in interpreting the scenario for passenger vans only in the fleet as the estimate of average crashworthiness in vehicle to vehicle crashes is based on relatively few crashes.

4.2.2 Removal of a Single Market Group

In order to examine the relative effect of each market group on the total safety of the current vehicle fleet, the scenarios presented below remove a single market group from the fleet. The crashes that would be expected to involve this market group are then transferred to other market groups in one of two ways. Under the first method, a proportionately representative mix of vehicles from the remaining market groups replaced the eliminated market group. In terms of the market group weights in Equations 1 to 4, this corresponds to setting the weights for the eliminated market group to zero and then rescaling the remaining weights to sum to unity. Table 11 shows the TSI values calculated for these scenarios along with the crash component indices. The crash component weights of Table 6 have again been used.

Table 11: *Total Safety Index Resulting From Removal of a Single Market Group and Replacement with a Proportionate Mix of the Remaining Market Groups.*

Crash Type	Baseline	4WD Vehicles Removed	Commercial Vehicles Removed	Large Vehicles Removed	Luxury Vehicles Removed	Medium Vehicles Removed	PV Vehicles Removed	Small Vehicles Removed	Sports Vehicles Removed
Vehicle to Vehicle	2.24	2.23	2.22	2.21	2.27	2.24	2.23	2.22	2.22
Vehicle to Heavy Vehicle	4.70	4.98	4.79	3.46	4.76	4.59	5.05	3.85	5.24
Single Vehicle	11.22	10.92	11.13	12.03	11.25	11.19	12.56	9.49	12.71
Unprotected Road Users	33.62	33.44	33.50	34.51	33.57	33.74	33.54	33.34	33.62
TSI	**8.29**	**8.22**	**8.26**	**8.40**	**8.32**	**8.27**	**8.72**	**7.62**	**8.80**

Table 11 demonstrates that the removal of small vehicles from the vehicle fleet would result in the largest expected improvement (reduction) in the TSI compared to the base scenario. The estimated improvement is about 8%. This suggests that the presence of small cars in the vehicle fleet reduces the overall safety of the fleet. In contrast, the removal of sports cars from the vehicle fleet increases the TSI by the greatest amount, although the increase (representing a decrease in overall safety) is only 6%. Examination of the component crash indices shows this is a result of poorer average injury outcomes in crashes with heavy vehicle and in single vehicle crashes. The complete removal of passenger vans from the vehicle fleet also worsens the TSI, again through worsening single vehicle and heavy vehicle crash outcomes. The maximum variation in the TSI from the baseline standard is an 8% improvement through the removal of small cars.

An alternative means of redistributing expected crashes involving the removed market group is to transfer them to a single specified market group. This is achieved in calculating the TSI by transferring the weights in Equations 1 to 4 associated with the removed market group to the market group by which they are being replaced, maintaining collision partner where appropriate.

Five scenarios of this type have been considered for the reasons described below. Table 12 gives the resulting TSI estimates for each scenario along with component crash indices. As before, the weights in Table 12 have been used to combine the crash component indices to form the TSI.

- ***4WDs replaced by large cars***: given the high aggressivity associated with 4WD vehicles, it is interesting to consider what would happen to the TSI if 4WDs were removed from it. Large cars were chosen as the replacement vehicle as they would be, in practice, the most likely class to replace 4WD vehicles for reasons of functionality.

- ***4WDs replaced by passenger vans***: passenger vans are an alternative to large cars as the replacement vehicle for 4WDs. Passenger vans are often able to carry more occupants than large cars and may therefore be chosen in preference to them as replacement vehicles for 4WDs.

- ***Large cars replaced by 4WDs***: this scenario is considered because of the increasing trend towards the purchase of 4WDs instead of large cars. This scenario considers the effect on overall fleet crashworthiness if this trend were to continue to the extreme.

- ***Small cars replaced by medium cars***: small cars have the worst average crashworthiness ratings in many crash types with the scenario considered above showing the greatest improvement in the TSI through removing small cars from the fleet. Consequently, it would be expected that the overall crashworthiness of the fleet would improve if medium cars were purchased in favour of small cars. For reasons of cost and preference for more compact size, it is considered that medium cars would be the most likely alternative to small cars.

- ***Medium cars replaced by small cars***: this scenario is considered in view of the increasing trend towards the purchase of small cars and away from the purchase of medium cars. This scenario considers the effect on overall fleet crashworthiness if this trend were to continue to the extreme.

Table 12: *Total Safety Index Resulting from the Removal of a Single Market Group and Replacement with Alternative Market Groups*.

Crash Type	Baseline	4WD→Large	4WD→PV	Large→4WD	Small→Medium	Medium→Small
Vehicle to Vehicle	2.24	2.23	2.24	2.29	2.20	2.24
Vehicle to Heavy Vehicle	4.70	4.90	4.93	4.43	4.66	4.73
Single Vehicle	11.22	10.84	11.13	12.92	11.16	11.25
Unprotected Road Users	33.62	33.40	33.54	36.14	33.31	33.91
TSI	**8.29**	8.19	8.29	9.01	8.22	8.33

The removal of all large cars and the replacement of them with 4WDs is estimated to produce the greatest increase in the TSI (reduction in overall safety) of all the scenarios presented in Table 12. This result is not unexpected given the poorer safety performance of 4WDs in single vehicle crashes and in protecting unprotected road users compared to large cars. The relative increase in the TSI compared to the baseline for this scenario is 8.7%. Also consistent with the relative safety performance of these two market groups is the result that the replacement of all 4WDs with large cars creates the greatest improvement in the TSI of when compared to the other scenarios considered. However, the improvement is only in the order of 2%. Replacement of small cars with medium cars is estimated to improve average fleet safety by a similar amount. This is apparently due to the improved crashworthiness of medium cars in comparison to small cars. Compared with the other scenarios considered in previous sections, the replacement of single market groups with other single market groups produces a smaller maximum improvement in safety of 2% by replacing the 4WD class with large vehicles.

4.2.3 Safest Vehicle in Market Group

The scenarios analysed in sections 4.2.1 and 4.2.2 involving either a homogeneous fleet or the complete removal of market groups is unlikely to ever occur in reality. They are also based on keeping the mix of vehicles with respect to safety performance constant within each market. The following scenarios consider perhaps more realistic goals for fleet composition in which drivers use only the safest vehicle in the market group of their choice. Scenarios for defining the safest vehicle within each market group are examined in two ways.

Using the first method, the hypothetical best vehicle in each market group is defined by identifying individually the best crashworthiness and aggressivity ratings amongst all vehicles in a market group rated by Newstead et al (2003). These best ratings in each dimension need not be associated with the same vehicle in the class. Indeed, it is likely that the vehicle selected in each market group with the best crashworthiness rating will not be the same as that selected with best aggressivity rating. The crashworthiness and aggressivity estimates for each of the four crash types making up the TSI, given by Equations 1 to 4, are adjusted by the proportional difference between the average crashworthiness or aggressivity of the market group and the best performing vehicle in that market group according to Equations 6 to 9 respectively. Equations 1 to 5 are then applied using the adjusted measures to calculate the TSI.

$$cwr(pp)_{ADJij} = cwr(pp)_{ij}\left(\frac{cwr_{Besti}}{cwr_{Avgi}}\right)\times\left(\frac{agg_{Bestj}}{agg_{Avgj}}\right) \ldots\text{Equation 6}$$

$$cwr(hv)_{ADJik} = cwr(hv)_{ik}\left(\frac{cwr_{Besti}}{cwr_{Avgi}}\right) \ldots\text{Equation 7}$$

$$cwr(sv)_{ADJi} = cwr(sv)_{i}\left(\frac{cwr_{Besti}}{cwr_{Avgi}}\right) \ldots\text{Equation 8}$$

$$agg(ur)_{ADJi} = agg(ur)_{i}\left(\frac{agg_{Bestj}}{agg_{Avgj}}\right) \ldots\text{Equation 9}$$

In Equations 6 to 9,

ADJ	indicates the adjusted crashworthiness or aggressivity
cwr_{Besti}	is the best crashworthiness of vehicles in market group *i* of those rated by Newstead et al (2003).
cwr_{Avgi}	is the average crashworthiness of vehicles in market group *i* of those rated by Newstead et al (2003).
agg_{Besti}	is the lowest aggressivity of vehicles in market group *i* of those rated by Newstead et al (2003).
agg_{Avgi}	is the average aggressivity of vehicles in market group *i* of those rated by Newstead et al (2003).

It is noted that this scenario does not represent what is possible given vehicles necessarily currently available on the market. Rather it represents, hypothetically, what could be achieved if the design aspects to produce best possible crashworthiness and aggressivity within a market group were included in all vehicles in the market group.

In contrast, the second method adopted identifies the best vehicle in each market group based on the best combination of crashworthiness and aggressivity exhibited in the one vehicle. The measure of combined crashworthiness and aggressivity is given in Equation 10. It reflects the total injury outcome for a car assuming the crashworthiness and aggressivity measures are independent.

$$Cwr + Aggr - (Cwr*Aggr) \ldots\text{Equation 10}$$

The TSI for this scenario is calculated by substituting the crashworthiness and aggressivity for the vehicle in each market group assessed as best according to the measure of Equation 10 into Equations 6-9. For this scenario, cwr_{Besti} and agg_{Besti}, now come from the same vehicle. In contrast to the hypothetical scenario considered above, this scenario is based on vehicles that already exist in the fleet and it is certain the safety benefit of this scenario could be achieved in practice.

The resulting TSIs from the two best in market group scenarios are presented in Table 13 along with the component crash indices. The weights used to calculate the component crash indices and TSI in Equations 1-5 are the same as those used for the baseline scenario. Only the crashworthiness and aggressivity estimates were changed.

Table 13: *Total Safety Index Resulting From the Use of the Hypothetical and Existing Safest Vehicle in Each Market Group Only.*

Crash type	Baseline	Hypothetical Safest Vehicle	Existing Safest Vehicle
Vehicle to Vehicle	2.24	0.91	1.38
Vehicle to Heavy Vehicle	4.70	2.72	3.36
Single Vehicle	11.22	6.62	7.98
Unprotected Road Users	33.62	23.67	28.20
TSI	**8.29**	**5.07**	**6.22**

It is clear that significant improvements in total fleet safety could be achieved were all drivers to drive the safest (as measured by combined crashworthiness and aggressivity) currently available vehicle in the market group in which their current vehicle is classified. Further improvements would be generated if existing vehicles were modified to incorporate within a single vehicle design aspects that produce the best currently available crashworthiness and aggressivity in the market group.

If all vehicles in a market group performed as well as the current existing benchmark vehicle in the market group (Existing Safest Vehicle), an improvement of up to around 26% in the total fleet safety index would result. If each vehicle in each market group met the individual benchmarks for crashworthiness and aggressivity (Hypothetical Safest Vehicle), an improvement of up to 40% in the total fleet safety index would result.

One caveat on the scenarios presented here should be noted. Because the safety estimates of the benchmark vehicles have been taken from the bottom tail of a distribution that includes stochastic error, a phenomenon similar to regression-to-the-mean possibly exists in the estimated safety benefits. This means the true effects may be smaller than those estimated.

4.4 The Effects of Growth in Heavy Vehicle Travel

Although crashes between heavy vehicles and passenger vehicles do not represent a large part of the crash population, Australian Government projections indicate heavy vehicle travel will show significant growth relative to other forms of travel over the next decade or so. The final scenario set examines the effect of increasing the number of heavy vehicle crashes in the crash population by various amounts including 10 percent, 25 percent, 50 percent and 100 percent increases. This has been achieved through altering the relative crash weights in Table 6 used to compute the TSI to reflect the proportionate increase in heavy vehicle crashes.

Table 14: *Changes in the Total Safety Index Resulting From Changes in the Proportions of Heavy Vehicle Crashes.*

Crash Type	Baseline Crash Weight	Crash Weight HV up 10%	Crash Weight HV up 25%	Crash Weight HV up 50%	Crash Weight HV up 100%
Vehicle to Vehicle	45.33%	44.61%	43.58%	41.97%	39.08%
Vehicle to Heavy Vehicle	16.00%	17.32%	19.23%	22.22%	27.59%
Single Vehicle	28.93%	28.48%	27.82%	26.79%	24.94%
Unprotected Road Users	9.74%	9.59%	9.37%	9.02%	8.40%
TSI	**8.36%**	**8.30%**	**8.22%**	**8.09%**	**7.85%**

Table 14 shows that increasing the proportion of vehicle to heavy vehicle crashes results in notable reduction in the TSI. This is because by increasing the proportion of heavy vehicles in the fleet the relative weight of other crash types is reduced. In particular, the weighting of single vehicle crashes and crashes involving unprotected road users, both with higher rates of serious driver injuries per 100 crash involvements than vehicle to heavy vehicle crashes, is reduced. By increasing the weighting attached to a crash type with relatively lower driver injury risk and decreasing the weighting attached to crash types with higher injury risk, the estimate of overall light vehicle fleet safety reflected in the TSI is improved.

The scenarios considered here highlight the interpretation of the TSI as an average injury outcome resulting from crashes involving light passenger vehicles. To assess the full effects of increased heavy vehicle travel, it would be necessary to examine changes in total rather than average road trauma associated with the exposure increase. In the case of increased heavy vehicle travel, overall road trauma would be expected to increase as a result of increased exposure. Interpretation of the baseline scenario used for this study shows that for every additional 100 crashes involving heavy vehicles colliding with light passenger vehicles, 4.7 additional deaths or serious injuries would result amongst the light vehicle drivers. The absolute number of national deaths and serious injuries associated with each of the study scenarios could not be calculated, as the national crash population involving light and heavy vehicles colliding was not available. Furthermore, to measure the total road trauma burden of heavy vehicle exposure increases, crash types other than those considered in Table 4 in which heavy vehicles may be involved need to also be considered. These include single heavy vehicle crashes and heavy vehicle to pedestrian crashes. Further research is recommended to examine these points.

5. DISCUSSION

This study has demonstrated the development of a model to estimate the effects of fleet mix changes on the total average safety of the light passenger vehicle fleet. The study has defined total safety as the average risk of death or serious injury amongst drivers or unprotected road users in crashes involving light passenger vehicles. The key output from the model, the Total Safety Index (TSI) is a measure of this average risk. As well as considering the effects of fleet mix changes, the model also has the ability to consider the effect of changes in average crashworthiness within vehicle market groups or changes in the distribution of crashes between the four major crash types considered. Application of the model to a number of scenarios for changes in the composition of the light passenger fleet provides useful information on the effect of changes in the vehicle fleet mix on total fleet safety through the TSI. Changes have generally been compared to a baseline scenario which represents the current mix of the Australian light passenger fleet.

Of particular interest and relevance was to examine the effect on the TSI of actual changes in the vehicle fleet over the decade leading up to 2000 and changes in the vehicle fleet expected to occur over the following ten years. These scenarios demonstrate that there has not been and is unlikely to be significant improvements or deterioration in the TSI as a result of fleet mix changes. During the period from 1990 to 2000 the TSI fell by around 1% as a result of changes in the mix of the vehicle fleet, a marginal improvement in average injury outcome. However, it is estimated that over the following ten-year period the TSI will remain largely uninfluenced by vehicle fleet mix change.

This result suggests that any goals for improvements in the safety of the passenger fleet aimed for in the future will have to come entirely from general improvements in crashworthiness and aggressivity of new vehicles entering the Australian fleet. Such goals include the 10% reduction in fatalities related to vehicle improvements by 2010 in the Australian National Road Safety Strategy. What the TSI highlights is that these gains will have to come not only from improved occupant protection but also from improved protection of unprotected road users who typically have a serious injury risk much higher than vehicle occupants.

Whilst the safety effects of historical changes in fleet mix are relatively static for the fleet as a whole, analysis of safety trends within market groups related to fleet mix changes reveals an interesting trend. It shows that the distribution of risk between the market groups is changing. Whilst serious injury risk for drivers of 4WD, commercial vehicle and passenger vans is reducing as a result of fleet mix change, this is at the expense of increases in serious injury risk amongst drivers of large, luxury and small vehicles.

Because of the relative static nature of fleet mix safety effects in historical and likely future Australian fleet mix trends, it was also of interest to consider other scenarios that might lead to dramatic improvements of worsening of the TSI. The extreme fleet mix change scenarios considered were useful for determining boundaries on safety changes as measured by the TSI resulting from fleet mix changes. Whilst a number of the scenarios considered were not realistic and are unlikely to ever occur in practice, they provide the boundaries of effects within which more realistic changes will lie.

Of interest in this context are the scenarios considering homogeneous fleets. The largest increase in the TSI, indicating worsening injury outcome, occurred when passenger vans were the only passenger vehicle in use (a TSI of 10.45 compared to the baseline TSI of 8.29). In contrast, the situation in which only luxury vehicles were available would generate the greatest improvement in overall fleet safety use, with a TSI of 7.63. The TSI for a fleet comprised only of large cars was close to the figure for luxury vehicles at 7.76. This result suggests that large vehicles provide the optimum balance of safety between crashworthiness and aggressivity in the mix of the four major crash types represented in the Australian crash population. Fortuitously, the large car sector is the most highly represented in the crash population, reflecting both high sales and high exposure in Australia. It is for this reason that the baseline TSI (8.29), which represents the current fleet situation, is much closer to the best that can be achieved with a homogenous fleet (7.63) than the worst that can be achieved (10.45). This means Australia potentially has far more to lose than to gain in vehicle safety outcomes in moving away from the current Australian fleet mix. The result shows that the maximum gain in safety that could be achieved through fleet mix changes is around a 10% improvement in the TSI whilst the potential loss could be up to 25%

The scenarios considered in which a single vehicle market group is removed and replaced by either a proportionate mix of the remaining market groups or one particular market group provide information on the relative contribution of individual market groups to current safety levels. The contribution of both small and 4WD vehicles is of particular interest given the increasing trend towards the purchase of vehicles from these two market groups. The removal of either of these groups from the vehicle fleet and their replacement by a proportionate mix of the remaining market groups is estimated to improve overall fleet safety in comparison to the current situation, although the improvements are much greater when removing small vehicles. This suggests that were it possible to halt the current trend towards the purchase of these vehicle types, and small vehicles in particular, incremental improvements in total fleet safety could be achieved. In practice, it is unlikely that a complete market group of vehicles would be removed and replaced by a proportionate mix of vehicles from the remaining market groups. The scenarios considering the replacement of small cars with medium cars and 4WDs with large cars or passenger vans are possibly more practical alternatives and would also result in improvements, albeit smaller, in overall fleet safety. Therefore, whilst it is unlikely that a whole market group would ever be eliminated, any decrease in the proportion of small cars and 4WDs and moves towards more medium, large and luxury cars would result in some improvement in the overall safety of the vehicle fleet.

The analysis also demonstrates that the removal of passenger vans and sports cars from the vehicle fleet would lead to reductions in overall safety of the vehicle fleet. It is not immediately clear why this is so. Neither of these vehicle market groups has a particularly strong crashworthiness rating on average. However, neither of these two vehicle market groups are very aggressive. It is possible that the relatively poor crashworthiness of these vehicle market groups is outweighed by the good aggressivity ratings of these market groups when considering the total safety of the market group and for this reason the removal of them would result in an overall worsening in total fleet safety. These results should be interpreted with care, particularly for passenger vans, as the average crashworthiness and aggressivity estimates are based on relatively few vehicle models rated by Newstead et al (2003).

A further scenario that results in a decline in total fleet safety involves the replacement of all large cars with 4WDs. This takes the current trend to increased purchase of 4WDs in preference to large cars to the extreme. If this were to happen in practice, there would be an increase in the TSI from 8.29 (base scenario) to 9.01. It is again noted that it is unlikely all large cars would ever be replaced by 4WDs. However, movements in that direction would result in reductions in overall fleet safety to a degree proportionate to the movement, but overall fleet safety would not fall further than estimated in the extreme case of complete replacement. It is interesting to note, however, that the large increases in 4WD sales in the late 1990s is not reflected in the same increase in their representation in the crash population (see Figures 1 and 2). This suggests that whilst sales have grown, either these types of vehicles are being driven particularly safely or their exposure has not increased proportionately. The latter is considered more likely. The lack of increase in 4WD crash representation also explains why this vehicle class has not had the expected effects on historical or predicted future trends.

The increases and decreases in overall fleet safety discussed above generally affect total fleet safety by less than one death or serious injury per 100 crash involvements. In reality any potential improvement in total fleet safety due to the changes identified are likely to be less profound as the changes in the fleet mix will not be as extreme or complete as in the scenarios considered. Of the scenarios considered, analysis demonstrates that adopting a best in market group approach would lead to the greatest improvement in the TSI. Currently, great variability exists in the crashworthiness and aggressivity estimates of vehicles within each of the market groups. If each vehicle had a crashworthiness and aggressivity rating equivalent to the currently available best vehicle in its market group, total safety could be improved by up to 26% from the current level. This improvement in TSI from 8.29 to 6.22 is in excess of two driver deaths or serious injuries per 100 crash involvements and suggests that the promotion of safety as a key determinant of vehicle choice and subsequent changes in buyer behaviour could lead to the most significant improvements in total fleet safety. The TSI could be further improved to as low as 5.07, or up to 40% from the current situation, if all vehicles incorporate design aspects that produce the best currently available crashworthiness and aggressivity within a market group. Further regulation of vehicle safety standards and increased emphasis on safe choices in vehicle purchase through mechanisms like consumer information programs can help the vehicle fleet move towards these targets.

As noted in the results, because the safety estimates of the benchmark vehicles have been taken from the top tail of a distribution that includes stochastic error, the best in fleet scenarios may be subject a phenomenon similar to regression-to-the-mean. Consequently, the real safety benefits for these scenarios may be smaller than that estimated although to what degree is unclear.

The analysis of predicted increases in the proportion of crashes with heavy vehicles amongst the light vehicle fleet provides a warning for the use of the TSI. It estimates that there would be an improvement in the TSI associated with increases in heavy vehicle travel and hence crashes. However, this analysis does not reflect that increases in exposure of these vehicles would increase total road trauma significantly. Increases in crash types such as heavy vehicles to unprotected road user crashes and single heavy vehicle crashes are also not considered in the analysis. Further work to examine changes in exposure is recommended to determine the changes in total road trauma associated with increasing numbers of heavy vehicles.

Whilst the total fleet safety model has been applied here to the Australian light passenger vehicle fleet, the general approach could also be used to investigate the effect of vehicle mix changes in other vehicle fleets. To do this, the model input measures would need to be re-calibrated to reflect the fleet being studied. Clearly, the proportion of each major crash type in which the light vehicle fleet was involved would need to reflect the fleet under study, as would the weights for the relative involvement of each vehicle class within each crash type. Less obviously, it would also be necessary to re-calibrate the estimates of crashworthiness and aggressivity by market group and major crash type to reflect the fleet being studied. The crashworthiness and aggressivity estimates used in this study reflect to a large degree the specific make-model mix and age of vehicles within each market group in the Australian fleet. The mixes found in other fleets would likely be very different, particularly in countries where the average vehicle size or age is significantly different. Furthermore, the relative injury outcome between the major crash types may be significantly different in other countries. For example, unprotected road user injury severity in crashes may be lower in countries with lower urban speed limits. Similarly, single vehicle crashes might be less severe in countries with higher levels of road infrastructure development. All these factors would need to be reflected in calibrating the approach for use in studying another fleet.

There is also no reason why the approach here could not be used to study fleet mix safety effects beyond the light passenger vehicle fleet. In theory, it could be extended to include all classes of vehicle within the fleet. Furthermore, it need not be constrained to looking at the fleet categorised only by market group. The approach could be used on fleets categorised by groupings of specific makes and models of vehicles although this would be far more onerous on the data to provide sufficient numbers of each make-model grouping to produce sensible results.

The research presented here demonstrates the development and application of the TSI through consideration only of the point estimates of the component crashworthiness and aggressivity estimates. An area of further development needed for the total safety model is to consider the statistical accuracy of the TSI estimates and the statistical significance of changes in the TSI across different scenarios. This would require more than simply translating the confidence limits on each of the crashworthiness and aggressivity estimates of which the TSI is comprised into confidence limits on the TSI in a linear fashion. The confidence limits for the TSI would also have to reflect the covariance between the component crashworthiness and aggressivity measures. However, these are generally not available since the crashworthiness and aggressivity estimates for different crash types are not obtained in an integrated model. It would be theoretically possible to estimate all the crashworthiness and aggressivity estimates in an integrated model although whether the approach would be effective in practice is difficult to determine. In practice, the statistical precision of the TSI may be best assessed through statistical re-sampling methods.

Despite the research here not considering the statistical precision of the TSI, it is still considered valuable in laying the groundwork for the research area by defining the TSI metric and demonstrating its application in a number of scenarios relevant to the Australian vehicle fleet.

Finally, this research has only looked at the effects of vehicle fleet mix on safety outcomes. There are a number of other aspects important to the community that are also affected by vehicle fleet mix, the principal amongst these being the environment. Clearly, optimising the fleet mix for a combination of safety and environmental benefits may produce a different optimum profile to the ones identified considering safety only. In order to simultaneously optimise safety and environmental effects, however, the two outcomes would have to be compared on a common basis, such as cost to the community. Regardless of the basis chosen, the model framework demonstrated in this research could be readily extended to consider vehicle fleet mix effects across a number of comparable outcome criteria simultaneously.

6 CONCLUSIONS

This study has demonstrated the development and application of a model to estimate the effects of fleet mix changes on the total average safety of the Australian light passenger vehicle fleet. Key inputs to the model are estimates of the crashworthiness and aggressivity of light passenger vehicles in the key crash types representing the majority of crashes in which these vehicles are involved. They are crashes between two light vehicles, single vehicle crashes, crashes with heavy vehicles and crashes with unprotected road users such as pedestrians and bicyclists. The model combines these key crashworthiness inputs with measures of crash exposure of each vehicle class in the fleet mix to estimate the average injury outcomes in all crashes involving the light vehicle fleet. The output of the model is the Total Safety Index (TSI) which measures the average risk of death or serious injury amongst drivers or unprotected road users in crashes involving light passenger vehicles.

By varying the key parameters of the model, it was possible to examine the effects on the average safety of the Australian light vehicle fleet resulting from changes to the mix of types of vehicles in the fleet. Application of the model was demonstrated through a number of scenarios varying the mix of vehicles in the fleet by broad market group classification. Scenarios considered include natural changes in market group mix of the fleet in recent times and projected over the next 10 years, elimination of various market groups from the fleet, homogeneous fleets composed of a single market group, and fleets composed of only vehicles with the best possible safety performance in each market group.

Historical and likely future changes in the Australian light vehicle fleet mix were found to have had little influence on the TSI. Of the homogeneous fleet scenarios, a fleet composed only of large or luxury vehicles led to the best overall safety whilst fleets composed only of 4WD and commercial vehicles or passenger vans led to the worst overall safety. Of the scenarios considering removal of a single market group from the fleet, removal of small cars from the fleet provided the largest gains. Removal of 4WD vehicles from the fleet only led to a very small improvement in the TSI whilst removal of large, luxury and sports vehicles from the fleet led to an increase in the TSI indicating a worsening of average safety.

Of the scenarios considered, the safest vehicle available in market group scenarios led to the greatest improvement in the TSI. If each vehicle had a crashworthiness and aggressivity rating equivalent to the currently available best vehicle in its market group, total safety could be improved by up to 26% from the current level. It suggests that the promotion of safety as a key determinant of vehicle choice and subsequent changes in buyer behaviour could lead to the most significant improvements in total fleet safety. The TSI could be improved by up to 40% from the current situation, if all vehicles incorporated design aspects that produce the best currently available crashworthiness and aggressivity within a market group. These improvements are based on currently available designs and safety features. Further regulation of vehicle safety standards and increased emphasis on safe choices in vehicle purchase through mechanisms like consumer information programs can help the vehicle fleet move towards these targets.

7. ASSUMPTIONS AND QUALIFICATIONS

The results and conclusions presented in this report are based on a number of assumptions and warrant a number of qualifications that the reader should note. These are as follows.

In relation to the crashworthiness and aggressivity ratings used in this report, it has been assumed that:

- TAC claims records and, Victorian, NSW, Western Australian and Queensland Police crash reports accurately recorded driver injury, hospitalisation and death.

- There was no bias in the merging of TAC claims and Victorian Police crash reports related to the model of car and factors affecting the severity of the crash.

- Crashed vehicle registration numbers were recorded accurately on Police crash reports and that they correctly identified the crashed vehicles in the Victorian, NSW and Queensland vehicle registers.

- The adjustments for driver sex, age, speed zone, the number of vehicles involved and the state and year in which the crash occurred removed the influences of the other main factors available in the data that affected crash severity and injury susceptibility.

- The form of the logistic models used to relate injury risk and injury severity with the available factors influencing these outcomes (including the car models) was correct.

- Information contained in the Police crash records allowed accurate matching of both vehicles involved in crashes between two passenger cars for the purpose of calculating aggressivity ratings.

The vehicle safety ratings used in this report also warrant the following qualifications:

- Only injury outcomes to drivers of light passenger vehicles have been considered. Passengers occupying the same model cars may have had different injury outcomes.

- Other factors not collected in the data (eg. crash speed) may differ between the models and may affect the results. However, earlier analysis has suggested that the different rating scores are predominantly due to vehicle factors alone (Cameron et al 1992).

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APPENDIX 1

MARKET GROUP COMPOSITION OF CRASHING VEHICLES BY YEAR OF MANUFACTURE AND YEAR OF CRASH

VICTORIAN AND NSW CRASHES DURING 1987-2000
WESTERN AUSTRALIA AND QUEENSLAND CRASHES DURING 1991-2000

VEHICLE CRASH COMPOSITION BY MARKET GROUP AND YEAR OF MANUFACTURE (UNSMOOTHED BY FREQUENCY AND PERCENTAGE)

Year of Manufacture	Market Group Frequency (%)								
	Four Wheel Drive	Commercial	Large	Luxury	Medium	Passenger Van	Small	Sport	Total
1982	2,289 (3.43)	3,203 (4.81)	17,029 (25.55)	4,265 (6.40)	18,556 (27.84)	791 (1.19)	18,629 (27.95)	1,895 (2.84)	66657
1983	2,543 (4.23)	2,540 (4.23)	13,272 (22.08	3,214 (5.35)	16,909 (28.13)	2,057 (3.42)	17,986 (29.93)	1,579 (2.63)	60100
1984	4,082 (5.37)	4,177 (5.49)	19,617 (25.80	3,865 (5.08)	18,793 (24.72)	2,127 (2.80)	21,777 (28.64)	1,597 (2.10)	76035
1985	5,506 (6.98)	4,413 (5.60)	26,223 (33.25	4,664 (5.91)	15,619 (19.80)	1,787 (2.27)	19,154 (24.29)	1,504 (1.91)	78870
1986	3,440 (4.94)	4,212 (6.05)	27,402 (39.36	2,856 (4.10)	9,015 (12.95)	970 (1.39)	20,143 (28.93)	1,588 (2.28)	69626
1987	2,306 (3.97)	3,451 (5.94)	27,615 (47.52	2,401 (4.13)	7,051 (12.13)	631 (1.09)	13,593 (23.39)	1,069 (1.84)	58117
1988	4,174 (5.76)	4,426 (6.10)	28,010 (38.63	3,139 (4.33)	10,494 (14.47)	1,107 (1.53)	19,501 (26.90)	1,654 (2.28)	72505
1989	5,711 (7.06)	4,737 (5.85)	31,917 (39.44	4,301 (5.32)	12,175 (15.05)	1,378 (1.70)	18,965 (23.44)	1,734 (2.14)	80918
1990	5,318 (7.46)	3,918 (5.50)	25,906 (36.35	3,869 (5.43)	10,472 (14.69)	803 (1.13)	18,836 (26.43)	2,147 (3.01)	71269
1991	4,054 (6.88)	3,227 (5.48)	19,678 (33.40	2,345 (3.98)	7,941 (13.48)	906 (1.54)	19,312 (32.78)	1,447 (2.46)	58910
1992	4,781 (8.05)	2,954 (4.97)	20,210 (34.01	2,669 (4.49)	6,684 (11.25)	962 (1.62)	19,538 (32.88)	1,626 (2.74)	59424
1993	4,443 (7.74)	2,852 (4.97)	24,385 (42.46	2,388 (4.16)	2,582 (4.50)	815 (1.42)	18,794 (32.72)	1,177 (2.05)	57436
1994	4,159 (7.39)	3,264 (5.80)	25,387 (45.10	2,831 (5.03)	2,754 (4.89)	754 (1.34)	16,125 (28.64)	1,021 (1.81)	56295
1995	2,909 (5.81)	3,091 (6.17)	20,473 (40.89	2,599 (5.19)	2,325 (4.64)	477 (0.95)	17,581 (35.11)	618 (1.23)	50073
1996	2,612 (6.49)	2,639 (6.56)	16,476 (40.96	2,108 (5.24)	1,847 (4.59)	415 (1.03)	13,477 (33.50)	655 (1.63)	40229
1997	2,377 (6.81)	2,321 (6.65)	12,328 (35.31	1,817 (5.20)	1,680 (4.81)	479 (1.37)	13,277 (38.02)	638 (1.83)	34917
1998	2,197 (7.55)	1,853 (6.37)	10,413 (35.81	1,220 (4.20)	1,659 (5.70)	345 (1.19)	11,020 (37.89)	375 (1.29)	29082
1999	1,316 (8.68)	1,117 (7.37)	5,716 (37.71	695 (4.59)	908 (5.99)	219 (1.44)	4,990 (32.92)	197 (1.30)	15158
2000	348 (7.50)	385 (8.30)	1,591 (34.29	239 (5.15)	300 (6.47)	59 (1.27)	1,649 (35.54)	69 (1.49)	4640
Total	64,565 (6.21)	58,780 (5.65)	373,648 (35.92	51,485 (4.95)	147,764 (14.20)	17,082 (1.64)	304,347 (29.26)	22,590 (2.17)	1040261

VEHICLE CRASH COMPOSITION BY MARKET GROUP AND YEAR OF CRASH (SMOOTHED BY FREQUENCY AND PERCENTAGE)

Year of Crash	Market Group Frequency (%)								
	Four Wheel Drive	Commercial	Large	Luxury	Medium	Passenger Van	Small	Sport	Total
1987	1,483 (4.92)	2,085 (6.91)	9,059 (30.03)	1,594 (5.28)	6,982 (23.15)	710 (2.35)	7,549 (25.03)	700 (2.32)	30,162
1988	1,484 (4.96)	1,964 (6.57)	9,811 (32.80)	1,591 (5.32)	6,487 (21.69)	672 (2.25)	7,231 (24.17)	673 (2.25)	29,913
1989	1,673 (5.00)	2,260 (6.75)	11,206 (33.48)	1,720 (5.14)	6,899 (20.61)	716 (2.14)	8,230 (24.59)	768 (2.29)	33,472
1990	2,054 (5.73)	2,387 (6.66)	11,970 (33.42)	1,796 (5.01)	7,223 (20.16)	787 (2.20)	8,761 (24.46)	844 (2.36)	35,822
1991	3,444 (6.40)	3,242 (6.02)	18,308 (34.00)	2,432 (4.52)	10,268 (19.07)	933 (1.73)	14,065 (26.12)	1,154 (2.14)	53,846
1992	3,921 (6.56)	3,507 (5.86)	20,097 (33.60)	2,787 (4.66)	10,891 (18.21)	1,060 (1.77)	16,303 (27.26)	1,241 (2.08)	59,807
1993	4,442 (6.53)	3,846 (5.66)	23,329 (34.32)	3,055 (4.49)	11,688 (17.20)	1,131 (1.66)	18,968 (27.91)	1,514 (2.23)	67,973
1994	5,306 (6.87)	4,293 (5.56)	27,372 (35.45)	3,544 (4.59)	11,976 (15.51)	1,213 (1.57)	21,790 (28.22)	1,720 (2.23)	77,214
1995	5,146 (5.92)	4,707 (5.42)	31,993 (36.83)	4,105 (4.73)	12,711 (14.63)	1,270 (1.46)	25,021 (28.80)	1,912 (2.20)	86,865
1996	6,100 (6.14)	5,450 (5.48)	37,005 (37.22)	4,883 (4.91)	13,143 (13.22)	1,428 (1.44)	29,251 (29.42)	2,154 (2.17)	99,414
1997	5,135 (5.81)	4,507 (5.10)	32,520 (36.78)	4,537 (5.13)	11,031 (12.48)	1,347 (1.52)	27,456 (31.05)	1,888 (2.14)	88,421
1998	6,189 (5.83)	5,467 (5.15)	40,413 (38.06)	5,232 (4.93)	11,912 (11.22)	1,564 (1.47)	33,218 (31.29)	2,176 (2.05)	106,171
1999	9,459 (7.03)	7,498 (5.57)	49,659 (36.91)	6,778 (5.04)	13,505 (10.04)	2,149 (1.60)	42,639 (31.69)	2,848 (2.12)	134,535
2000	8,729 (6.39)	7,567 (5.54)	50,906 (37.25)	7,431 (5.44)	13,048 (9.55)	2,102 (1.54)	43,865 (32.10)	2,998 (2.19)	136,646
Total	64,565 (6.21)	58,780 (5.65)	373,648 (35.92)	51,485 (4.95)	147,764 (14.20)	17,082 (1.64)	304,347 (29.26)	22,590 (2.17)	1,040,261